Carbon and Water Dynamics in Modern and Ancient Plants and Soils

by

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DEDICATION

To Dr. Alvin Stein, PhD of Brooklyn, NY (November 24, 1925 – December 20, 2014).

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ABSTRACT

During modern times of unprecedented climate change, historical and geological records of past climate allow us to understand and project ancient patterns in the carbon and water cycle. Plants and soils are excellent records for climate because of the direct interaction between the terrestrial biosphere and the atmosphere and their preservation potential. Organic carbon isotope records in plants and soils have been linked to several environmental, evolutionary, and edaphic drivers, in addition to being used to measure ecosystem stress. Most of the works use organic carbon isotope values in ancient plant fossils with unconstrained and uncertain environments or in modern plant growth experiments with highly controlled environments that are not directly comparable to the natural world. The period of Industrialization provides a natural experiment with measurable, but not lab-controlled climate change, ideal for investigating the relationship between climate variability (particularly the carbon and water cycles) and C isotope values.

This dissertation includes several high-resolution spatiotemporal studies of several plant species through the pre-Industrial era. In **Chapter II,** leaf carbon isotope values from a single Great Lakes region species are compared to environmental variables involved in the water and carbon cycles (e.g. atmospheric CO_2 concentration and isotopic signature, temperature, precipitation, etc.) over the span of 200 years. Leaf isotope biogeochemistry of this species is unresponsive to every environmental variable except the isotopic composition of atmospheric CO_2. **Chapter III** expands on results from previous experiments, and investigates the

relationship between the carbon dioxide of the atmosphere and plant carbon isotope geochemistry with eight Northern Hemisphere focal species. These specimens are complemented by C_3 plant isotope analyses of aggregated from literature. Results from this work demonstrate that plants do not change biochemically as expected in response to CO_2 rise.

In **Chapter IV,** findings from previous chapters are re-examined from the context of aboveground carbon integrator: soils. The role of weathering in the development of soils provides incentive for investigating soils as potential water cycle records. As in **Chapter III,** this study includes soils collected across a climosequence, supplemented by aggregated carbon isotope values from prior publications. This work also tests the relationship between soil carbon isotopes and precipitation in ancient soils (paleosols). In both modern and ancient studies, carbon isotope values of soil correlate to precipitation.

Chapter V integrates the results and conclusions from early dissertation chapters with pre-established geochemical and physiognomic proxies to provide a comprehensive analysis of early Eocene hothouse sediments. Depositional basins from the Eocene are well-studied and contain opportunities for multi-proxy-based environmental reconstruction. Using organic and inorganic tools to constrain provenance, parent material, and other features of the depositional environment, an early Eocene fluvial-lacustrine subtropical forest deposit shows constant sedimentological and hydrological inputs and consistent climate during a time of expected cooling and tectonic activity.

In summary, this dissertation contains case studies relating soils and plants to the carbon and water cycle in modern, historical and deep time and demonstrates the recording power of the terrestrial biosphere. These findings can be used to contextualize and guide applications of organic isotope biogeochemistry in paleoclimate reconstructions. Related to modern climate

problems, results from this dissertation provide integral information about plants and soils as carbon and water distributors and mitigators of anthropogenic climate change.

CHAPTER I
Introduction

As Earth's climate changes due to anthropogenic forcing, it is imperative that we understand how terrestrial ecosystems respond such that we learn what changes to expect and how to mitigate these changes, as well as considering potential terrestrial carbon sinks (Cao & Woodward 1998). We look to ancient environmental records to elucidate what might happen in light of future climate change on individual species, and on regional and ecosystem scales. In particular, it is crucial that we understand how anthropogenic climate change will perturb the carbon and water cycle, as these cycles are vital for life on Earth. Examples of tools used to reconstruct paleoclimate include: microfossil records preserved in marine sediments (Hendy & Kennett 2000; Tipple et al. 2010), leaf fossil morphological traits (e.g. McElwain 1998; Peppe et al. 2011; Teodoridis et al. 2011; Peppe et al. 2018), the chemistry of leaf waxes (Tierney et al. 2017), paleosol elemental and isotopic geochemistry (e.g. carbonate paleobarometer; Chemical Index of Alteration; Paleosol Weathering Index; Cerling et al. 1991; Sheldon et al. 2002; Gallagher & Sheldon 2013), chemical sediments from lakes and caves (Scholz et al. 2007; Hopley et al. 2007; Conroy et al. 2008), and climate models (Zhu et al. 2019).

Land ecosystems provide a unique mechanism to reconstruct atmospheric events and parameters such as precipitation, concentration of carbon dioxide (CO_2), and changes in CO_2 fluxes due to the direct interaction between plants and the atmosphere (Cao & Woodward 1998; Stein et al. 2019). Furthermore, plants play irreplaceable roles in carbon and water cycles, acting as "giant straws" that funnel vast quantities of water from the ground via transpiration (Berner 1992; Pennisi 2008). In some ecosystems, this effect is greater than others (e.g. rainforest; Schlesinger & Jasechko 2014). Likewise, plants are important in the storage of carbon through photosynthesis (Bolin 1970) both in plant tissues (Hessen et al. 2004) and in soils (Ojima et al.

1993; Jobbágy & Jackson 2000). Due to the instrumental role that plants and soils have in these major global biogeochemical cycles, they are both (a) important to understand and protect, and (b) excellent potential records for perturbations within the carbon and water cycles (Sterling 2005). Carbon isotope values as recorded in plant tissues ($\delta^{13}C_{leaf}$) are relatively stable through time and can be excellent records for changes in the carbon and water cycles, as these values have been linked to environmental, edaphic, and phylogenetic factors (Sheldon et al. 2020). Carbon isotope values in soils ($\delta^{13}C_{SOM}$), originating from senescent plant material and soil microbial contributions (Wynn 2007), provide potential insight into environmental drivers on ecosystems. Soil carbon isotopes have additional fractionation processes complicating these signals, including microbial reduction and respiration and the formation of carbonates (Cruz-Martínez et al. 2012).

1.1 The mechanism of carbon isotope fractionation in terrestrial ecosystems: Incorporation of CO_2 into plants

The mechanism driving plant production of organic compounds from CO_2, and the role that this process plays in carbon isotope discrimination, has been well-constrained, and largely attributed to biochemical and physical factors (O'Leary 1981; Farquhar et al. 1989). The majority of carbon isotope discrimination in plants occurs due to the ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBisCO) enzyme's selective preference for ^{12}C. Diffusion, the second largest driving factor of fractionation, occurs as CO_2 gas encounters the leaf surface; CO_2 gas enters through the stomata (leaf pores; Fig. 1.1; O'Leary 1981). The different average velocities of ^{12}C (faster) and ^{13}C (slower) result in a carbon isotope fractionation of $\simeq$ 4.4‰ favoring entry of ^{12}C at 1.0044 times the rate of ^{13}C (Farquhar et al. 1989). Both biochemical reactions (e.g. RuBisCO) and physical fractionations related to plant morphology (e.g. diffusion) are sensitive to climate (O'Leary 1981; Farquhar et al. 1989; Arens et al. 2000). To facilitate photosynthesis, stomata must be open to let in CO_2. The stomatal aperture (diameter open) is important in this process, and when stomata are closed, photosynthesis stops. Due to the regulatory function stomata play in the inlet of CO_2 and outlet of leaf water (via transpiration), water availability and CO_2 availability play a large role in stomatal behavior (Haworth et al. 2011), which subsequently regulates isotopic fractionation via diffusion.

Stomatal parameters can be related to size (ultimately, the volume of gas that can be retained within the cell), including pore length, guard cell length, guard cell width, guard cell shape and the shape and/or presence of subsidiary cells (Franks et al. 2014; McElwain & Steinthorsdottir 2017); these are all taxonomically dependent parameters. Stomatal density is also very important in regulating atmosphere-biosphere interaction: this is a measure of the number of stomata per area, or can be measured as stomatal index (the number of stomata per total number of cells, Equation 1.1; Royer 2001).

$$Stomatal\ Index = \frac{\#\ stomata}{\#\ epidermal\ cells + \#stomata} \quad \text{(Eq. 1.1)}$$

Textbox 1.1: How to interpret isotope values

Alpha (**α**), or a fractionation factor, is one way to look at the fractionation of isotopes due to certain processes, and relates the absolute ratio of one isotope to the other. For example, the α value of RuBisCO is 1.030 (see text), which means that for each single ^{13}C atom that is fixed by RuBisCO, 1.030 ^{12}Cs are fixed. Delta notation (**δ**) helps us to measure and visualize the differences caused by isotope effects in more digestible numbers. δ relates the carbon isotope ratio of a substance as compared to a standard. Of note: δ is reported as units per one thousand (‰) (compared to percent (%) that is measured units per one hundred) (Eq. A).

$$\delta^{13}C = \left(\frac{\left(\frac{^{13}C}{^{12}C}\right)_{sample}}{\left(\frac{^{13}C}{^{12}C}\right)_{standard}} - 1 \right) * 1000 \text{ (Eq. A)}$$

The standard used in this case is typically the Pee Dee Belemnite (PDB), a Cretaceous marine belemnite from the Pee Dee Formation in South Carolina, USA (Craig 1957). The PDB has an anomalously high ratio of ^{13}C to ^{12}C: 0.0112372, and was established as the $\delta^{13}C = 0$ value. Thus, any substance with a higher ^{13}C:^{12}C ratio than the PDB >0, while any substance with a lower ^{13}C:^{12}C ratio than the PDB is negative. 98% of all carbon on Earth is the more abundant and lighter ^{12}C, while 1% is ^{13}C, so most substances have a negative $\delta^{13}C$ value as compared to the PDB.

The absolute isotopic composition of a sample (α) is not easy to measure exactly due to tiny masses so this allows us to rely on tools like a mass spectrometer or cavity ring-down spectroscope to calculate instead the deviation from the standard (Farquhar et al. 1989).

Once CO_2 is inside the leaf surface, RuBisCO fixes the CO_2 contained within the leaf (e.g. Lorimer et al. 1976; Andersson & Backlund 2008). This process includes multiple steps — enolisation, carboxylation, hydration and protonation — before resulting in an unstable and ephemeral six-carbon chain that becomes two 3-phosphoglycerate molecules that make glucose (Andersson & Backlund 2008). RuBisCO's fixation alone has an isotope effect of 1.030, or ≃ 30‰ of additional fractionation, however, when including the effects of internal partial pressure of CO_2 within the leaf, this ends up resulting in a net isotope effect of 1.027 or ≃ 27‰ (Farquhar et al. 1989). Other isotope effects of steps in photosynthesis include boundary layer diffusion, diffusion of dissolved CO_2 in water, in C_4 plants: fixation by PEP carboxylase, and the poorly constrained process of photorespiration (Farquhar et al. 1989; Schubert & Jahren 2018). Most workers that focus on C_3 plants specifically address the roles of

diffusion through the stomatal pore and fixation of gaseous CO_2 by RuBisCO in isotopic fractionation (disregarding the less impactful steps; Farquhar et al. 1989; Schubert & Jahren 2018).

$$\Delta_{leaf}\ (‰) = a + (b - a)(\frac{C_i}{C_a}) \qquad \text{(Eq. 1.2)}$$

Combined, these effects are summarized in Equation 1.2, where Δ_{leaf} denotes total carbon isotope discrimination of C_3 plants, "a" denotes fractionation due to diffusion of carbon in air (4.4‰), "b" denotes fractionation due to the process of carboxylation (mostly by RuBisCO (27‰), and "C_i/C_a" represents the relationship between internal leaf carbon dioxide (C_i) to atmospheric carbon dioxide (C_a), sometimes used to represent water use efficiency (Ponton et al. 2006). Equation 1.3 shows the relationship between Δ_{leaf} values and atmospheric source carbon isotope measurements (carbon isotope value of the atmosphere: $\delta^{13}C_{atm}$, and carbon isotope value of leaves: $\delta^{13}C_{leaf}$).

$$\Delta_{leaf}\ (‰) = \frac{\delta^{13}C_{atm} - \delta^{13}C_{leaf}}{1 + (\frac{\delta^{13}C_{leaf}}{1000})} \qquad \text{(Eq. 1.3)}$$

RuBisCO's enzymatic activity is very slow, with a catalytic rate of 0.03–0.60 s^{-1} fixed each second per molecule of RuBisCO (Bar-On & Milo 2019). The rate of this activity is sensitive to temperature, to light, and to CO_2 (Crafts-Brandner & Salvucci 2000; Warren & Adams 2001; Bowes 1991), which introduces additional sensitivity of plants to environmental drivers in the context of their role in the carbon cycle.

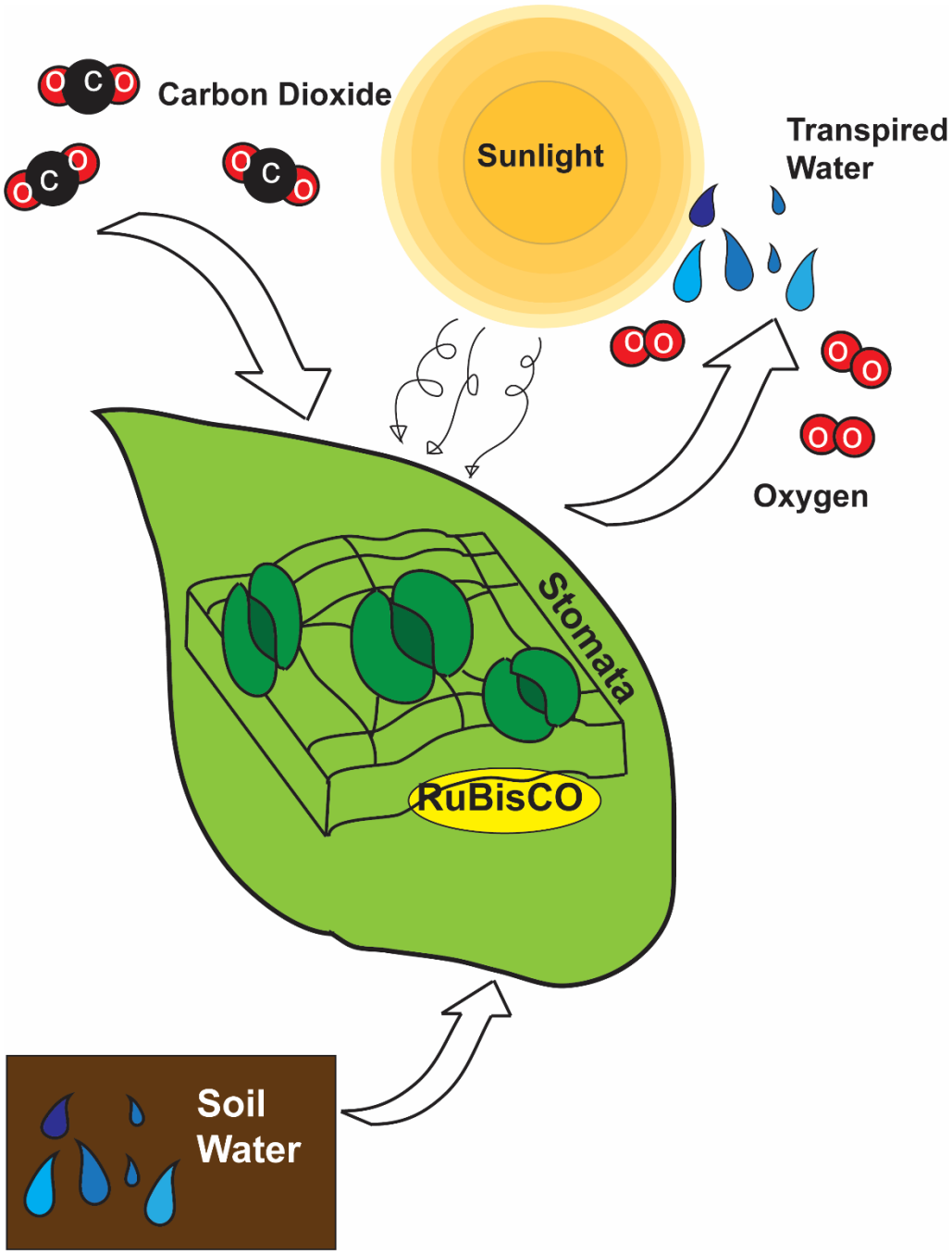

Figure 1.1 Diagram of a stoma on a leaf surface related to the role it plays in the carbon and water cycle.

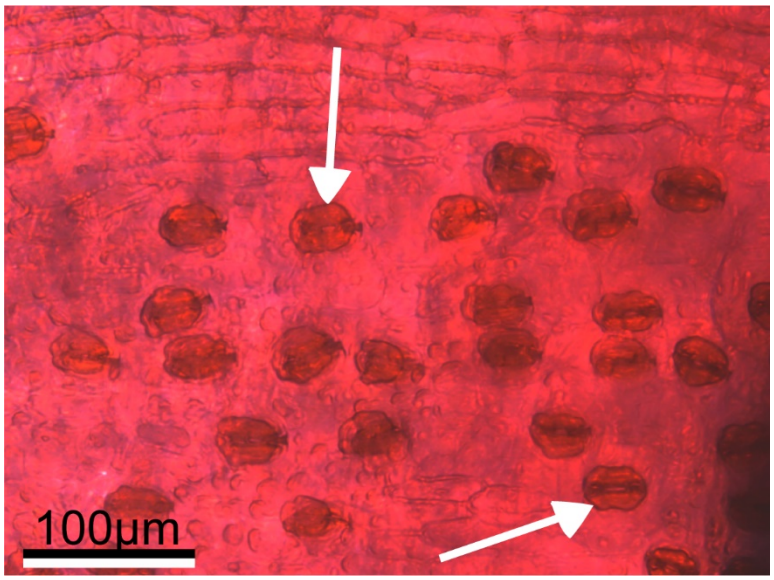

Figure 1.2 Cleared and stained stomata on a *Thuja occidentalis* leaf surface, with arrows pointing to individual stomata.

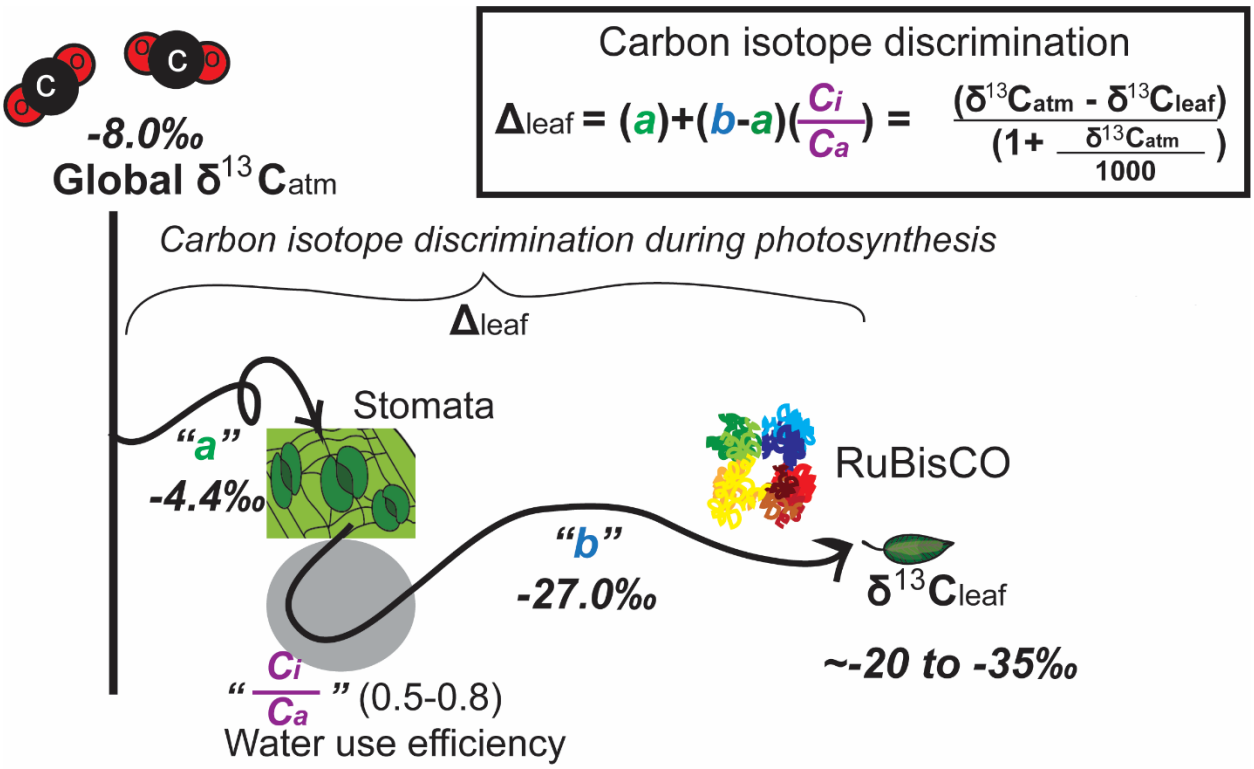

Figure 1.3 Diagram of carbon isotope discrimination during C_3 photosynthesis. The grey "Ci/Ca" region demonstrates the complexity of the isotopic fractionation by RuBisCO, which is controlled partially by internal and atmospheric CO_2 concentration.

1.2 The effects of climate on carbon isotope discrimination

1.2.1 CO_2

The concentration of CO_2 in the atmosphere influences stomatal distribution, shape, and size (Franks et al. 2014). As atmospheric [CO_2] increases, stomata have increased access to CO_2. [CO_2] has not been seen to have any impacts on the rate of RuBisCO activity (Campbell et al. 1988). Previous studies have examined the relationship between [CO_2] and quantity of stomata, and have determined there is an inverse relationship between [CO_2] and number of stomata (Woodward 1987; Körner 1988; Woodward & Bazzaz 1988; Apel 1989; Vatén & Bergmann 2012). While this relationship is generally seen in most plants, it does not hold up for every single species. For example, in a study plants growing next to a naturally occurring CO_2 vent in Pisa, Italy of Mediterranean shrub species (*Juniperus communis,* common juniper; Cupressaceae; *Myrtus communis,* common myrtle; Myrtaceae*, Erica arborea,* tree heather; Ericaceae), *Juniperus communis* had no change in the number of stomata, while the other two did (Tognetti et al. 2000).

Given the established connections between carbon isotope fractionation (via diffusion) and stomata, workers have looked to examine the relationship between elevated CO_2 and carbon isotope values of plant tissues. Previous workers have tested this relationship in plants grown in growth chambers (Schubert & Jahren 2012; Lomax et al. 2019), in free air concentration enrichment experiments (FACE) in modern ecosystems (Norby & Zak 2011); and in plants preserved in the fossil record (Cui & Schubert 2017; Schlanser et al. 2020). Scientists conducting growth chamber experiments with elevated CO_2 on *Arabidopsis thaliana* and *Raphanus sativus* found a strong logarithmic relationship between CO_2 and Δ_{leaf}, and have extrapolated this to use Δ_{leaf} values as a paleobarometer. These findings suggest that plants adapt to enhanced CO_2 rapidly (within a single generation), and Δ_{leaf} values increase; authors proposed that Δ_{leaf} values therefore can be used to reflect CO_2 in the fossil record (Schubert & Jahren 2012). Complementary responses of rapid responses including increased photosynthesis and productivity with enhanced CO_2 in FACE experiments demonstrated a theoretical increase in carbon sequestration in plant products that corresponds with increased carbon isotope discrimination (Long et al. 2004; Ainsworth & Long 2004; Leakey et al. 2009). However, responses are nuanced: alternate studies also using growth chambers found increase in Δ_{leaf} was

viable when water was plentiful but was ultimately limited by when plants were experiencing water stress (Lomax et al. 2019). Longer term, effects of elevated CO_2 on plant productivity diminished over time (Nowak et al. 2004; Norby & Zak 2011). Furthermore, microfossil record compound-specific findings indicate that in fact, over a range of 200–900 ppm CO_2, after controlling for precipitation (see section 1.2.3), Δ_{leaf} response to CO_2 is small and *negative* (Schlanser et al. 2020). The relationship between plant productivity (as represented in carbon isotope space by increased discrimination — Δ_{leaf} — and/or depleted $\delta^{13}C_{leaf}$ values) and enhanced CO_2, while controversial, has predictive value for expectations and mitigation strategies as we face imminent anthropogenic climate change, and this relationship is examined in depth in **Chapters II** and **III**.

1.2.2 $\delta^{13}C_{atm}$

The isotopic value of the atmosphere ($\delta^{13}C_{atm}$) plays a direct role in controlling the isotopic values of plants ($\delta^{13}C_{leaf}$). As the carbon source for photosynthesis, changes in the atmosphere should cause a shift in carbon isotope values in plants (Fig. 1.3). In a meta-analysis by Arens et al. (2000), $\delta^{13}C_{leaf}$ values of a series of 519 land plants were compared to $\delta^{13}C_{atm}$ values. From those results, it was clear that there was a relationship between $\delta^{13}C_{leaf}$ and $\delta^{13}C_{atm}$ values (Equation 1.4; $R^2 = 0.34$, $p < 0.001$), albeit one with somewhat modest predictive value.

$$\delta^{13}C_{leaf} = (1.10 * \delta^{13}C_{atm}) - 18.67 \qquad \text{(Equation 1.4)}$$

If changes in $\delta^{13}C_{leaf}$ reflect changes in $\delta^{13}C_{atm}$ values exactly, this implies that $\delta^{13}C_{leaf}$ cannot be used to reconstruct other climate variables and that Δ_{leaf} remains relatively constant regardless of interfering climate variables. This also implies that $\delta^{13}C_{leaf}$ and be used as a proxy to understand changes in sources of CO_2 to the atmosphere (e.g. methane-derived or fossil-fuel combusted CO_2 is isotopically depleted at ~-60 and ~-25‰ respectively, while mantle derived CO_2 has an average $\delta^{13}C$ composition of -5.5‰; Figure 1.4). This potential proxy is tested in historical analyses in **Chapter II** of this dissertation**.**

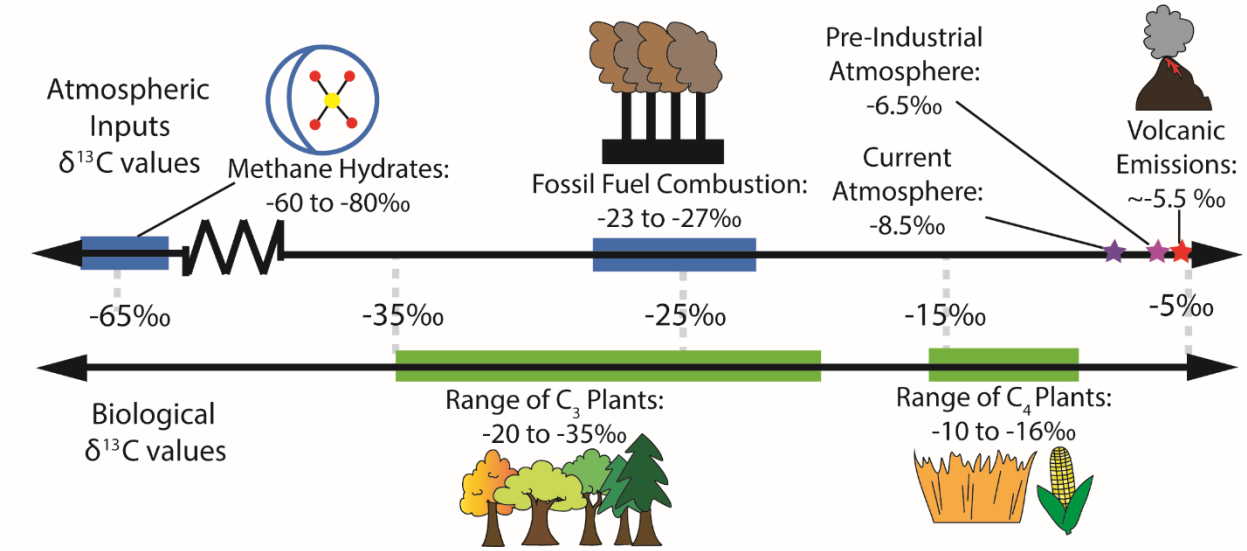

Figure 1.4 Isotopic compositions ($\delta^{13}C$) of natural sources and sinks of atmospheric CO_2.

1.2.3 Mean annual precipitation and water availability

Carbon isotope values in plants have been linked to precipitation. Like CO_2, this relationship is related to stomata's role in regulating transpiration. Increased water availability means that stomata can stay open without risk of desiccation, which should result in maximized carbon isotope discrimination (favoring ^{12}C; Ehleringer 1993). Thus, increased water availability (e.g. higher mean annual precipitation rates, and/or higher growing season precipitation) for plants should result in increased carbon isotope discrimination (depleted $\delta^{13}C$ values, increased Δ_{leaf} values).

This hypothesized relationship has been empirically tested in several studies (Stewart et al. 1995; Schulze et al. 1996), including a meta-analysis that compared Δ_{leaf} values of a wide spread of C_3 plants and precipitation (Diefendorf et al. 2010). In this empirical study, there was a significant ($p < 0.001$) logarithmic relationship between carbon isotope discrimination (Δ_{leaf}) and mean annual precipitation (MAP) across a wide range of precipitation regimes (Figure 1.5; Equation 1.5; Diefendorf et al. 2010; Kohn 2010). These results affirm the hypothesis that water stress results in less carbon isotope discrimination, related to minimizing transpiration through the stomata.

$$\Delta_{leaf}(‰) = 5.54(\pm 0.22) * \log(MAP) + 4.07(\pm 0.70) \quad \text{(Equation 1.5)}$$

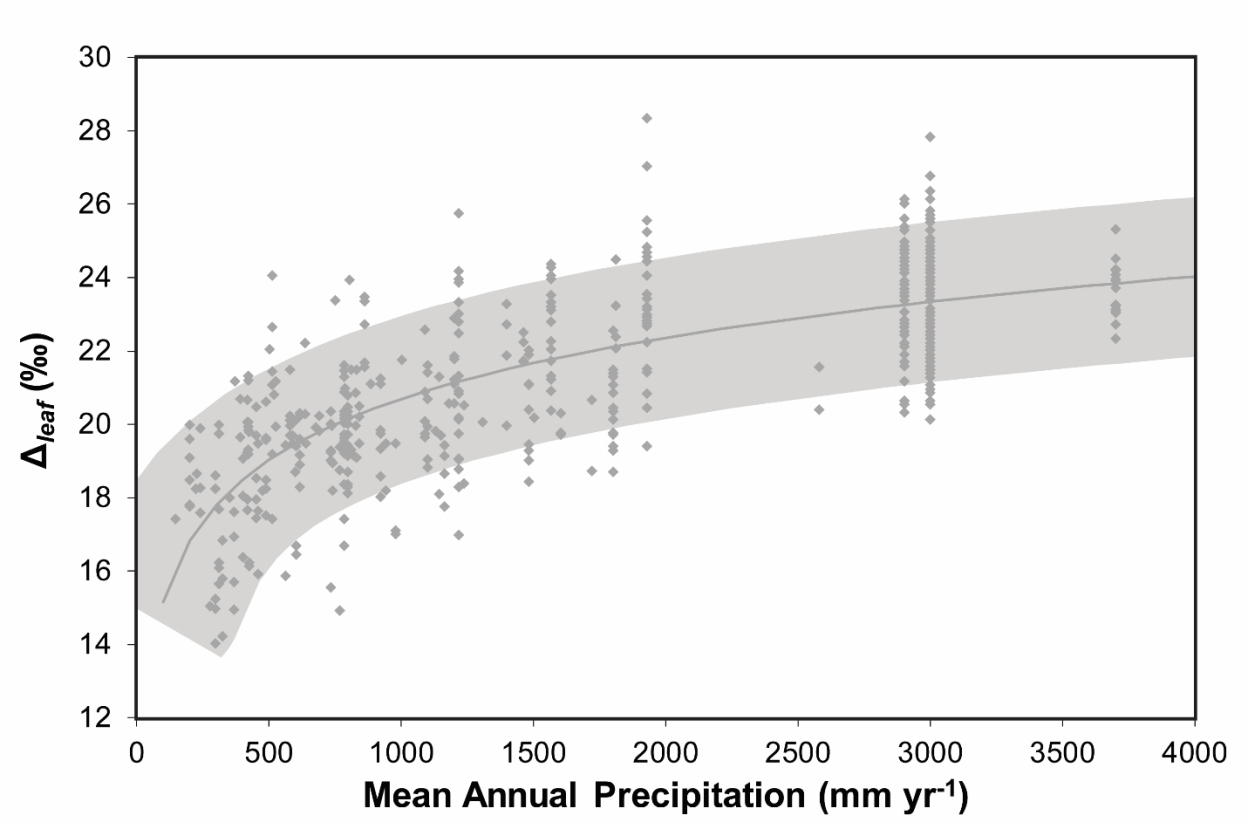

Figure 1.5 Relationship between Δ_{leaf} values (‰) and mean annual precipitation (mm yr^{-1}). Adapted after Diefendorf et al.'s (2010) meta-analysis findings. Everything within the grey box is within the standard deviation around the equation.

Relative humidity (RH) and vapor pressure deficit (VPD), both measurements representing moisture in ecosystems, have also been tested as drivers of stomatal response and subsequent fluctuations in carbon isotope discrimination (Schulze & Kuppers 1979; Hall et al. 1994). However, results have been mixed: *Lycopersicon esculentum* (tomato), *Glycine max* (soybeans), *Tagetes erecta* (marigold), and *Triticum aestivum* (wheat) were grown at controlled RH; higher humidity scenarios (RH of 75%) resulted in depletion of $\delta^{13}C_{leaf}$ values by up to -3‰ compared to low humidity counterparts (RH of 30%; Madhaven et al. 1991). Likewise, when VPD was controlled in a series of *Triticum aestivum* (winter wheat) growth experiments, VPD played a significant role, attributed to stomatal closure in high VPD conditions (Condon et al. 1992). However, when VPD was compared to carbon isotope values of *Larrea tridentate*

(creosote bush) in growth chamber experiments, VPD was not shown to affect Δ_{leaf} values (Sharifi & Rundel 1993).

1.2.4 Temperature

Activity of the RuBisCO enzyme is temperature-dependent, so natural changes in temperature are thought to affect photosynthesis, and as a proxy, $\delta^{13}C_{leaf}$ values (Arens et al. 2000). To one extreme, high air temperatures result in higher evapotranspiration rates and a decrease in RuBisCO activation (Gates 1968; Crafts-Brandner & Salvucci 2000); which have similar effects on isotope discrimination as low water availability (O'Leary 1981). On the other end, low temperatures result in depleted $\delta^{13}C_{leaf}$ values by up to -3‰ in some plants (Tieszen 1991; Körner et al. 1991) and no change in others (Gebrekirstos et al. 2009). It is worth noting that for studies that found increased discrimination with temperature, temperature was not de-convolved from latitude and altitude, so these factors should be considered as related to this climate driver (Körner et al. 1991). Furthermore, Helliker and Richter (2008) found that during the growing season, leaves maintained internal temperatures ideal for photosynthesis 21.4 ± 2.2 °C independent of external temperatures (Helliker & Richter 2008). In other words, although temperature could drive the efficiency of the enzyme RuBisCO as well as transpiration rates, in practice plants have adapted to self-regulate leaf temperatures.

1.2.5 Light and height

Light level and plant height, two local factors that are linked by growth form, are both considered potential drivers of $\delta^{13}C_{leaf}$ variability (Arens et al. 2000). These are linked because leaves higher in the canopy typically receive more ambient sunlight, while lower canopy leaves are shaded, with only intermittent irradiance (Xiao et al. 2013). Increased sunlight, an important catalyst for photosynthesis, increases opportunity for leaves to conduct photosynthesis (Knapp & Smith 1990), thus sun versus shade conditions (including as related to height) link to plants' rates of photosynthesis. Like temperature, increased sunlight results in higher rates of evapotranspiration (as well as higher temperatures), so sun leaves typically are drier and more water stressed (Uhl & Walther 2000). Due to this water stress, sun leaves are expected to be enriched in ^{13}C compared to shade leaves (Tu et al. 2004). Heterogeneity in light availability and

associated microenvironments dependent on leaf placement on the tree is a small-scale demonstration of the importance of environmental drivers on photosynthesis and carbon isotope discrimination. Furthermore, leaves growing very close to the forest floor can have isotopic values shifted by the addition of isotopically depleted soil-respired CO_2 (Brooks et al. 1997), emphasizing the importance of carbon availability in plant carbon isotope discrimination; this issue is addressed in **Chapter III**. However, when this expectation is tested rigorously by comparing sun and shade leaves of a single species, the differences are not statistically difference (0.33‰; $p > 0.200$; Xiao et al. 2013). Therefore, though sun vs shade is an important microcosm of the importance of the water and carbon cycle in carbon isotope records and controlling plant productivity, the bias this plays when looking at environmental factors on carbon isotope ecology of leaves in modern, historical and fossil records is negligible.

1.2.6 Evolutionary lineage and history

Other potential drivers of carbon isotope discrimination differences among plants includes evolution (Rundel et al. 1999). In particular, different plant functional types and crown versus stem group lineages may have developed different carbon isotope discrimination strategies; on a broad scale, this can be seen when comparing plants using C_3, C_4 and CAM photosynthetic pathways (Tipple & Pagani 2007; Sage 2008). All of the work contained in this thesis considers the importance of evolution and of making general versus species-specific assumptions.

Textbox 1.2: Three photosynthetic pathways

C_3 plants (e.g. trees, soybeans, wheat, rice, 85% plant species) use primarily the RuBisCO enzyme to assimilate CO_2, first to 3-phosphoglycerate, a 3-carbon atom product. The majority of plant species on Earth use C_3 photosynthesis. *This dissertation focuses solely on C_3 plants, but will refer to other photosynthetic mechanisms at times.*

C_4 plants (e.g. corn, maize, sugarcane) use first an additional enzyme to assimilate CO_2, first to a 4 carbon organic acid (oxaloacetate). This step exists so that plants minimize **photorespiration** (when RuBisCO acts on oxygen, rather than CO_2), by separating initial CO_2 fixation and RuBisCO's fixation to 3-carbon products during the Calvin Cycle.

CAM plants (e.g. cacti) minimize photorespiration and save water by separating nighttime fixation with daytime Calvin Cycle.

1.3 Carbon isotope records in sediments

The translation of carbon and organic matter from plants to sediments occurs during senescence and deposition of plant matter. In modern studies and the fossil record, organic carbon in sediments has been derived from plant fossils (to reconstruct $\delta^{13}C_{atm}$ and CO_2; Arens et al. 2000; Cui & Schubert 2016) and leaf waxes (to reconstruct paleoecology; Tierney et al. 2011, Wu et al. 2017; Bhattacharya et al. 2018), while carbonates in sediments have been used from pedogenic carbonates and plant and animal fossils (to reconstruct CO_2; Cerling et al. 1991; Cerling 1992; and to reconstruct paleodiets; Koch 1998). In addition to the factors controlling carbon isotope discrimination in plants, the use of organic matter in sediments introduces additional factors, such as microbial metabolism and diagenetic alteration (^{13}C; Wynn 2007; Fig. 1.6a). Heterotrophically respired CO_2, which can ultimately degas from the soil, tends to be depleted in ^{13}C by about 2‰, leaving behind microbial biomass and microbial decomposition solid byproducts that are enriched by about 2‰ (Wynn et al. 2005; Wynn 2007). As you continue deeper below the surface, authigenic carbonate formed from soils-respired CO_2 can be overprinted by recrystallization, diagenetic precipitation, and inherited carbonate from soil parent materials (Wynn 2007). Pedogenic carbonates are only found in arid land soils (Cerling & Quade 1993), and thus are not useful for paleoecological interpretations from mesic environments. Because the reaction is kinetically driven, the enrichment of $\delta^{13}C$ of soil organic carbon with depth through a soil column can be summarized by Rayleigh distillation (Fig. 1.6b). The fractionation of carbon isotope values within the soil column is not comparable across all soils, and is impacted by how water-logged a soil is, which once again relates to precipitation and regional water cycles as well as soil texture, soil temperature, and microbes present (Wynn 2007). Nonetheless, the carbon isotope composition of soil carbon ($\delta^{13}C_{SOM}$) in the uppermost horizons of a soil closely matches the integrated composition of the plants growing on that soil. This suggests that quantitative relationships between $\delta^{13}C_{leaf}$ and MAP could potentially be reflected between $\delta^{13}C_{leaf}$ and MAP could potentially be reflected by $\delta^{13}C_{SOM}$ as well. This potential relationship is explored in **Chapter IV.**

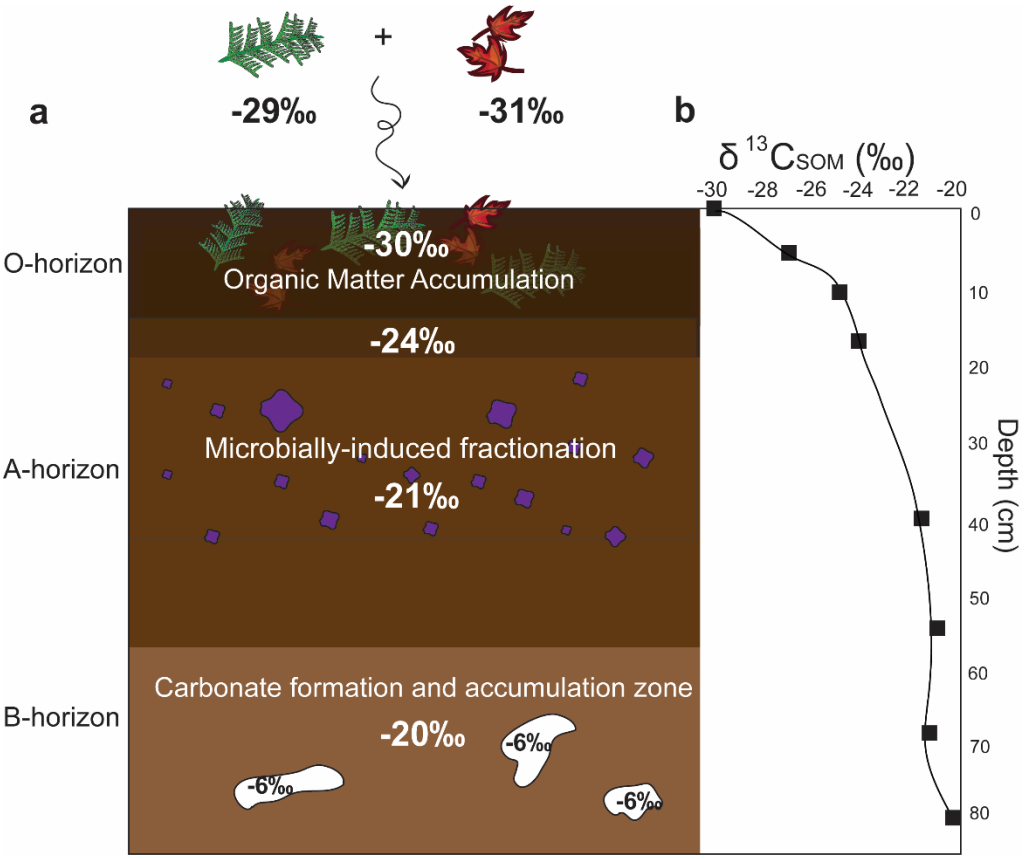

Figure 1.6 Diagram of soil carbon isotopes in a soil profile including O- through B- horizons and major driving processes. (a) An example soil profile including common horizons O- through B- and major fractionation processes, in addition to common $\delta^{13}C$ values found at each level (b) an example soil profile demonstrating Rayleigh fractionation with depth, created based on combined data from Wynn's (2007, Fig. 1) measured profiles from Kakamega Forest Reserve (Kenya), Goodwin Creek (Mississippi USA), Zengoaga (Cameroon) and Queensland (Australia).

1.4 Dissertation structure

This dissertation aims to examine the relationship between carbon isotope discrimination recorded in plants and organic matter and the carbon and water cycle in a new context. I approach the carbon isotope ecology of terrestrial ecosystems as they relate to the carbon cycle from several perspectives. This includes a study focused on the relationship between a number of potential climate factors and the carbon isotope ecology of one Great Lakes region gymnosperm (*Thuja occidentalis,* northern white cedar, **Chapter II**), and a complementary study that assesses the particular relationship between CO_2 and carbon isotope ecology of a number of woody C_3 plants (**Chapter III**). **Chapter IV** addresses the integrative properties of soil, and applications

in the fossil record in the context of the findings from previous chapters. This work takes advantage of the natural experiment of Industrialization from several angles, and incorporates the use of museum and herbarium collections to gather highly resolved temporal data. In **Chapter V,** I use findings from the previous three chapters to reconstruct many aspects of a forest ecosystem as recorded in early Eocene (hothouse) sediments. In each of the studies, the results indicate the importance of taxonomic identification and of not over-generalizing across C_3 plants.

Specifically, **Chapter II** explores the relationship between carbon isotope discrimination and fractionation (Δ_{leaf}, $\delta^{13}C_{leaf}$ respectively) and environmental and edaphic factors in a highly resolved single species study throughout Industrialization. This chapter focuses on the relationship between climate variables and the organic chemistry of *Thuja occidentalis* (northern white cedar) collected across the Great Lakes Region from the 1800s to the 2010s (and stored in herbaria). The use of the natural experiment of anthropogenic CO_2 enhancement provides a unique opportunity to look at changes in %C, %N, and carbon isotope biogeochemistry in light of rising CO_2 levels related to fossil fuels. What makes this experiment especially unique is that in addition to CO_2 rising, the isotopic value of atmospheric CO_2 becomes more depleted over this time period.

While **Chapter II** centers around one focal species, with a number of climate variables under scrutiny, **Chapter III** focuses instead around the relationship between one specific climate variable: [CO_2], and carbon isotope biogeochemistry in eight different focal species, including seven gymnosperms: *Thuja koraiensis* (Korean arborvitae)*, Thuja occidentalis* (northern white cedar), *Thuja plicata* (Pacific red cedar), *Thuja standishii* (Japanese arborvitae), *Thuja sutchuenensis* (Sichuan arborvitae), *Pinus strobus* (Eastern white pine), *Platycladus orientalis* (Oriental arborvitae) and one woody angiosperm, *Populus tremuloides* (quaking aspen). This study uses collections to examine a number of species response to anthropogenic carbon enhancement over Industrialization. In addition to using historical specimens to look in depth at the response of certain species to CO_2, this study incorporates many carbon isotope values from literature and meta-analyses to examine the role that taxonomy plays in controlling plant response to CO_2.

Applications from findings in Chapters II and III are applied to **Chapter IV**, which examines previous findings relating precipitation and $\delta^{13}C_{leaf}$ through a different lens: soil. This

chapter tests $\delta^{13}C$ in soil organic matter ($\delta^{13}C_{SOM}$) as a potential complementary proxy, under the premise that soil organic matter acts as an aggregator of aboveground biomass within an ecosystem, and thus is not sensitive to changing taxonomy. This chapter includes modern organic-rich soils from C_3-only ecosystems collected for this study and modern organic rich soils from C_3-only ecosystems aggregated from literature. Findings based on modern studies are applied to fossilized soils (paleosols) with comparable soil and ecosystem development to modern times. Each of these paleosols had independent non- $\delta^{13}C_{SOM}$ based paleoprecipitation estimates for comparison.

Finally, findings from Chapters II, III and IV were applied in ancient early Eocene forested ecosystems (**Chapter V**). Specimens spanning a 70m stratigraphic section of alluvial, fluvial, and pedogenic sediments in the greater Green River basin were collected and analyzed for bulk geochemistry, organic geochemistry, and carbon isotope ecology. Findings from prior chapters related to organic isotope geochemistry in plants and soils are contextualized with pre-established inorganic proxies in soils and sedimentary facies, all together giving a comprehensive, robust ecosystem reconstruction. In this study, I use multiple proxies to constrain aspects of the environment, which, in conjunction with the well-documented floral assemblage of the Blue Rim escarpment, provide an excellent snapshot of the well-rounded depositional environment. Using bulk geochemical tools to constrain provenance, parent material, leaching and weathering, combined with paleosol based tools to reconstruct temperature and precipitation, I parse out climate signals and constrain hydrological inputs into the region. In addition to applying $\delta^{13}C_{SOM}$ to provide precipitation reconstructions to complement previous physiognomy-based ones, $\delta^{13}C_{atm}$ values of *Lygodium kaulfussii* were applied to constrain $\delta^{13}C_{atm}$ during the Early Eocene. In full, **Chapter V** represents the importance of using these tools, researched in Chapters II through IV, in the presence of multiple proxies when possible, to best represent the intricacies of regional ecosystems during a hothouse period often invoked as an analog for future climate change.

1.5 References

Ainsworth, E. A., & Long, S. P. (2005). What have we learned from 15 years of free-air CO_2 enrichment (FACE)? A meta-analytic review of the responses of photosynthesis, canopy properties and plant production to rising CO_2. *New Phytologist*, *165*(2), 351-372.

Andersson, I., & Backlund, A. (2008). Structure and function of Rubisco. *Plant Physiology and Biochemistry*, *46*(3), 275-291.

Apel, P. (1989). Influence of CO_2 on stomatal numbers. *Biologia Plantarum*, *31*(1), 72-74.

Arens, N. C., Jahren, A. H., & Amundson, R. (2000). Can C_3 plants faithfully record the carbon isotopic composition of atmospheric carbon dioxide? *Paleobiology*, 137-164.

Bar-On, Y. M., & Milo, R. (2019). The global mass and average rate of rubisco. *Proceedings of the National Academy of Sciences*, *116*(10), 4738-4743.

Berner, R. A. (1992). Weathering, plants, and the long-term carbon cycle. *Geochimica et Cosmochimica Acta*, *56*(8), 3225-3231.

Bhattacharya, T., Tierney, J. E., Addison, J. A., & Murray, J. W. (2018). Ice-sheet modulation of deglacial North American monsoon intensification. *Nature Geoscience*, *11*(11), 848-852.

Bolin, B. (1970). The carbon cycle. *Scientific American*, *223*(3), 124-135.

Bowes, G. (1991). Growth at elevated CO_2: photosynthetic responses mediated through Rubisco. *Plant, Cell & Environment*, *14*(8), 795-806.

Brooks, J. R., Flanagan, L. B., Buchmann, N., & Ehleringer, J. R. (1997). Carbon isotope composition of boreal plants: functional grouping of life forms. *Oecologia*, *110*(3), 301-311.

Campbell, W. J., Allen, L. H., & Bowes, G. (1988). Effects of CO2 concentration on rubisco activity, amount, and photosynthesis in soybean leaves. *Plant physiology*, *88*(4), 1310-1316.

Cao, M., & Woodward, F. I. (1998). Dynamic responses of terrestrial ecosystem carbon cycling to global climate change. *Nature*, *393*(6682), 249-252.

Cerling, T. E., Solomon, D. K., Quade, J. A. Y., & Bowman, J. R. (1991). On the isotopic composition of carbon in soil carbon dioxide. *Geochimica et Cosmochimica Acta*, *55*(11), 3403-3405.

Cerling, T. E. (1992). Use of carbon isotopes in paleosols as an indicator of the $p(CO_2)$ of the paleoatmosphere. *Global Biogeochemical Cycles*, *6*(3), 307-314.

Cerling, T. E., Quade, J. (1993). Stable carbon and oxygen isotopes in soil carbonates. P. K Swart K. C Lohmann, J McKenzie, and S Savin eds. *Climate change in continental isotopic records. Geophysical Monograph*, *78*, 217-231.

Condon, A. G., Richards, R. A., & Farquhar, G. D. (1992). The effect of variation in soil water availability, vapour pressure deficit and nitrogen nutrition on carbon isotope discrimination in wheat. *Australian Journal of Agricultural Research*, *43*(5), 935-947.

Conroy, J. L., Overpeck, J. T., Cole, J. E., Shanahan, T. M., & Steinitz-Kannan, M. (2008). Holocene changes in eastern tropical Pacific climate inferred from a Galápagos lake sediment record. *Quaternary Science Reviews*, *27*(11-12), 1166-1180.

Crafts-Brandner, S. J., & Salvucci, M. E. (2000). RuBisCO activase constrains the photosynthetic potential of leaves at high temperature and CO2. *Proceedings of the National Academy of Sciences*, *97*(24), 13430-13435.

Cruz-Martínez, K., Rosling, A., Zhang, Y., Song, M., Andersen, G. L., & Banfield, J. F. (2012). Effect of rainfall-induced soil geochemistry dynamics on grassland soil microbial communities. *Applied and environmental microbiology*, *78*(21), 7587-7595.

Ehleringer, J. R. (1993). Carbon and water relations in desert plants: an isotopic perspective. In *Stable isotopes and plant carbon-water relations* (pp. 155-172). Academic Press.

Farquhar, G. D., Ehleringer, J. R., & Hubick, K. T. (1989). Carbon isotope discrimination and photosynthesis. *Annual review of plant biology*, *40*(1), 503-537.

Franks, P. J., Royer, D. L., Beerling, D. J., Van de Water, P. K., Cantrill, D. J., Barbour, M. M., & Berry, J. A. (2014). New constraints on atmospheric CO_2 concentration for the Phanerozoic. *Geophysical Research Letters*, *41*(13), 4685-4694.

Gallagher, T. M., & Sheldon, N. D. (2013). A new paleothermometer for forest paleosols and its implications for Cenozoic climate. *Geology*, *41*(6), 647-650.

Gates, D. M. (1968). Transpiration and leaf temperature. *Annual Review of Plant Physiology*, *19*(1), 211-238.

Gebrekirstos, A., Worbes, M., Teketay, D., Fetene, M., & Mitlöhner, R. (2009). Stable carbon isotope ratios in tree rings of co-occurring species from semi-arid tropics in Africa: patterns and climatic signals. *Global and Planetary Change*, *66*(3-4), 253-260.

Hall, A. E., Thiaw, S., & Krieg, D. R. (1994). Consistency of genotypic ranking for carbon isotope discrimination by cowpea grown in tropical and subtropical zones. *Field Crops Research*, *36*(2), 125-132.

Haworth, M., Elliott-Kingston, C., & McElwain, J. C. (2011). Stomatal control as a driver of plant evolution. *Journal of Experimental Botany*, *62*(8), 2419-2423.

Hendy, I. L., & Kennett, J. P. (2000). Dansgaard-Oeschger cycles and the California Current System: Planktonic foraminiferal response to rapid climate change in Santa Barbara Basin, Ocean Drilling Program hole 893A. *Paleoceanography, 15*(1), 30-42.

Helliker B. H., & Richter S. L. (2008). Subtropical to boreal convergence of tree-leaf temperatures. *Nature 454*(7203), 511-514.

Hessen, D. O., Ågren, G. I., Anderson, T. R., Elser, J. J., & De Ruiter, P. C. (2004). Carbon sequestration in ecosystems: the role of stoichiometry. *Ecology*, *85*(5), 1179-1192.

Hopley, P. J., Weedon, G. P., Marshall, J. D., Herries, A. I., Latham, A. G., & Kuykendall, K. L. (2007). High-and low-latitude orbital forcing of early hominin habitats in South Africa. *Earth and Planetary Science Letters*, *256*(3-4), 419-432.

Jobbágy, E. G., & Jackson, R. B. (2000). The vertical distribution of soil organic carbon and its relation to climate and vegetation. *Ecological applications*, *10*(2), 423-436.

Knapp, A. K., & Smith, W. K. (1990). Stomatal and photosynthetic responses to variable sunlight. *Physiologia Plantarum*, *78*(1), 160-165.

Körner, C. (1988). Does global increase of CO2 alter stomatal density? *Flora*, *181*(3-4), 253-257.

Körner, C., Farquhar, G. D., & Wong, S. C. (1991). Carbon isotope discrimination by plants follows latitudinal and altitudinal trends. *Oecologia*, *88*(1), 30-40.

Leakey, A. D., Ainsworth, E. A., Bernacchi, C. J., Rogers, A., Long, S. P., & Ort, D. R. (2009). Elevated CO_2 effects on plant carbon, nitrogen, and water relations: six important lessons from FACE. *Journal of experimental botany*, *60*(10), 2859-2876.

Long, S. P., Ainsworth, E. A., Rogers, A., & Ort, D. R. (2004). Rising atmospheric carbon dioxide: plants FACE the future. *Annual Reviews in Plant Biology*, *55*, 591-628.

Madhavan, S., Treichel, I., & O'Leary, M. H. (1991). Effects of relative humidity on carbon isotope fractionation in plants. *Botanica Acta*, *104*(4), 292-294.

McElwain, J. C. (1998). Do fossil plants signal palaeoatmospheric carbon dioxide concentration in the geological past? *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *353*(1365), 83-96.

McElwain, J. C., & Steinthorsdottir, M. (2017). Paleoecology, ploidy, paleoatmospheric composition, and developmental biology: a review of the multiple uses of fossil stomata. *Plant Physiology*, *174*(2), 650-664.

Norby, R. J., & Zak, D. R. (2011). Ecological lessons from free-air CO_2 enrichment (FACE) experiments. *Annual review of ecology, evolution, and systematics*, *42*.

Nowak, R. S., Ellsworth, D. S., & Smith, S. D. (2004). Functional responses of plants to elevated atmospheric CO_2–do photosynthetic and productivity data from FACE experiments support early predictions? *New Phytologist*, *162*(2), 253-280.

O'Leary, M. H. (1981). Carbon isotope fractionation in plants. *Phytochemistry*, *20*(4), 553-567.

Ojima, D. S., Dirks, B. O., Glenn, E. P., Owensby, C. E., & Scurlock, J. O. (1993). Assessment of C budget for grasslands and drylands of the world. *Water, Air, and Soil Pollution*, *70*(1-4), 95-109.

Pennisi, E. (2008). Getting to the root of drought responses. *Science*, *320*(5873), 173-173.

Peppe, D. J., Royer, D. L., Cariglino, B., Oliver, S. Y., Newman, S., Leight, E., Enikolopov, G., Fernandez-Burgos, M., Herrera, F., Adams, M. J. & Correa, E. (2011). Sensitivity of leaf size and shape to climate: global patterns and paleoclimatic applications. *New Phytologist*, *190*(3), 724-739.

Peppe, D. J., Baumgartner, A., Flynn, A., & Blonder, B. (2018). Reconstructing paleoclimate and paleoecology using fossil leaves. In *Methods in Paleoecology* (pp. 289-317). Springer, Cham.

Ponton, S., Flanagan, L. B., Alstad, K. P., Johnson, B. G., Morgenstern, K. A. I., Kljun, N., Black, T. A., & Barr, A. G. (2006). Comparison of ecosystem water-use efficiency among Douglas-fir forest, aspen forest and grassland using eddy covariance and carbon isotope techniques. *Global Change Biology*, *12*(2), 294-310.

Royer, D. L. (2001). Stomatal density and stomatal index as indicators of paleoatmospheric CO_2 concentration. *Review of Palaeobotany and Palynology*, *114*(1-2), 1-28.

Sage, R. F. (2008). Environmental and evolutionary preconditions for the origin and diversification of the C_4 photosynthetic syndrome. *Plant Biology*, *3*(3), 202-213.

Schlanser, K., Diefendorf, A. F., Greenwood, D. R., Mueller, K. E., West, C. K., Lowe, A. J., Basinger, J. F., Currano, E. D., Flynn, A. G., Fricke, H. C. & Geng, J. (2020). On geologic timescales, plant carbon isotope fractionation responds to precipitation similarly to modern plants and has a small negative correlation with pCO_2. *Geochimica et Cosmochimica Acta*, *270*, 264-281.

Schlesinger, W. H., & Jasechko, S. (2014). Transpiration in the global water cycle. *Agricultural and Forest Meteorology*, *189*, 115-117.

Scholz, C. A., Johnson, T. C., Cohen, A. S., King, J. W., Peck, J. A., Overpeck, J. T., Talbot, M. R., Brown, E. T., Kalindekafe, L., Amoako, P. Y. & Lyons, R. P. (2007). East African megadroughts between 135 and 75 thousand years ago and bearing on early-modern human origins. *Proceedings of the National Academy of Sciences*, *104*(42), 16416-16421.

Schubert, B. A., & Jahren, A. H. (2018). Incorporating the effects of photorespiration into terrestrial paleoclimate reconstruction. *Earth-Science Reviews*, *177*, 637-642.

Schulze, E. D., & Küppers, M. (1979). Short-term and long-term effects of plant water deficits on stomatal response to humidity in *Corylus avellana* L. *Planta*, *146*(3), 319-326.

Sharifi, M. R., & Rundel, P. W. (1993). The effect of vapour pressure deficit on carbon isotope discrimination in the desert shrub *Larrea tridentata* (creosote bush). *Journal of Experimental Botany*, *44*(2), 481-487.

Sheldon, N. D., Retallack, G. J., & Tanaka, S. (2002). Geochemical climofunctions from North American soils and application to paleosols across the Eocene-Oligocene boundary in Oregon. *The Journal of geology*, *110*(6), 687-696.

Sheldon, N. D., Smith, S. Y., Stein, R., & Ng, M. (2020). Carbon isotope ecology of gymnosperms and implications for paleoclimatic and paleoecological studies. *Global and Planetary Change*, *184*, 103060.

Stein, R. A., Sheldon, N. D., & Smith, S. (2019). Rapid response to anthropogenic climate change by *Thuja occidentalis*: implications for past climate reconstructions and future climate predictions. *PeerJ*, *7*, e7378.

Sterling, T. M. (2005). Transpiration: water movement through plants. *Journal of Natural Resources and Life Sciences Education*, *34*(1), 123-123.

Stewart, G. R., Turnbull, M. H., Schmidt, S., & Erskine, P. D. (1995). ^{13}C natural abundance in plant communities along a rainfall gradient: a biological integrator of water availability. *Functional Plant Biology*, *22*(1), 51-55.

Teodoridis, V., Mazouch, P., Spicer, R. A., & Uhl, D. (2011). Refining CLAMP—investigations towards improving the Climate Leaf Analysis Multivariate Program. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *299*(1-2), 39-48.

Tierney, J. E., Lewis, S. C., Cook, B. I., LeGrande, A. N., & Schmidt, G. A. (2011). Model, proxy and isotopic perspectives on the East African Humid Period. *Earth and Planetary Science Letters*, *307*(1-2), 103-112.

Tierney, J. E., Pausata, F. S., & deMenocal, P. B. (2017). Rainfall regimes of the Green Sahara. *Science advances*, *3*(1), e1601503.

Tipple, B. J., & Pagani, M. (2007). The early origins of terrestrial C_4 photosynthesis. *Annual Reviews of Earth and Planetary Science*, *35*, 435-461.

Tognetti, R., Minnocci, A., Peñuelas, J., Raschi, A., & Jones, M. B. (2000). Comparative field water relations of three Mediterranean shrub species co-occurring at a natural CO_2 vent. *Journal of Experimental Botany*, *51*(347), 1135-1146.

Tu, T. T. N., Kürschner, W. M., Schouten, S., & Van Bergen, P. F. (2004). Leaf carbon isotope composition of fossil and extant oaks grown under differing atmospheric CO_2 levels. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *212*(3-4), 199-213.

Uhl, D., & Walther, H. (2000). Sun leaf or shade leaf?–Known facts in the light of new data with implications for palaeobotany. *Feddes Repertorium*, *111*(3-4), 165-174.

Warren, C. R., & Adams, M. A. (2001). Distribution of N, Rubisco and photosynthesis in *Pinus pinaster* and acclimation to light. *Plant, Cell & Environment*, *24*(6), 597-609.

Woodward, F. I. (1987). Stomatal numbers are sensitive to increases in CO_2 from pre-industrial levels. *Nature*, *327*(6123), 617-618.

Woodward FI, Bazzazz FA (1988). The responses of stomatal density to CO_2 partial pressure. *Journal of Experimental Botany, 39*(12), 1771-1781.

Tipple, B. J., Meyers, S. R., & Pagani, M. (2010). Carbon isotope ratio of Cenozoic CO_2: A comparative evaluation of available geochemical proxies. *Paleoceanography*, *25*(3), PA3202.

Vatén A., Bergmann, D. C. (2012). Mechanisms of stomatal development: an evolutionary view. *EvoDevo*, 3(11).

Wu, M. S., Feakins, S. J., Martin, R. E., Shenkin, A., Bentley, L. P., Blonder, B., /Salinas, N., Asner, G. P., & Malhi, Y. (2017). Altitude effect on leaf wax carbon isotopic composition in humid tropical forests. *Geochimica et Cosmochimica Acta*, *206*, 1-17.

Wynn, J. G., Bird, M. I., & Wong, V. N. (2005). Rayleigh distillation and the depth profile of $^{13}C/^{12}C$ ratios of soil organic carbon from soils of disparate texture in Iron Range National Park, Far North Queensland, Australia. *Geochimica et cosmochimica acta*, *69*(8), 1961-1973.

Wynn, J. G. (2007). Carbon isotope fractionation during decomposition of organic matter in soils and paleosols: implications for paleoecological interpretations of paleosols. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *251*(3-4), 437-448.

Xiao, L., Yang, H., Sun, B., Li, X., & Guo, J. (2013). Stable isotope compositions of recent and fossil sun/shade leaves and implications for paleoenvironmental reconstruction. *Review of Palaeobotany and Palynology*, *190*, 75-84.

Zhu, J., Poulsen, C. J., & Tierney, J. E. (2019). Simulation of Eocene extreme warmth and high climate sensitivity through cloud feedbacks. *Science advances*, *5*(9), eaax1874.

CHAPTER II

Rapid Response to Anthropogenic Climate Change by *Thuja occidentalis:* Implications for Past Reconstructions and Future Climate Predictions[1]

2.1 Abstract

Carbon isotope values of leaves ($\delta^{13}C_{leaf}$) from meta-analyses and growth chamber studies of C_3 plants have been used to propose generalized relationships between $\delta^{13}C_{leaf}$ and climate variables such as mean annual precipitation (MAP), atmospheric concentration of carbon dioxide ([CO_2]), and other climate variables. These generalized relationships are frequently applied to the fossil record to create paleoclimate reconstructions. Although plant evolution influences biochemistry and response to environmental stress, few studies have assessed species-specific carbon assimilation as it relates to climate outside of a laboratory. We measured $\delta^{13}C_{leaf}$ values and C:N ratios of a wide-ranging evergreen conifer with a long fossil record, *Thuja occidentalis* (Cupressaceae) collected 1804–2017, in order to maximize potential paleo-applications of our focal species. This high-resolution record represents a natural experiment from pre-Industrial to Industrial times, which spans a range of geologically meaningful [CO_2] and $\delta^{13}C_{atm}$ values. Δ_{leaf} values (carbon isotope discrimination between $\delta^{13}C_{atm}$ and $\delta^{13}C_{leaf}$) remain constant across climate conditions, indicating limited response to environmental stress. Only $\delta^{13}C_{leaf}$ and $\delta^{13}C_{atm}$ values showed a strong relationship (linear), thus, $\delta^{13}C_{leaf}$ is an excellent record of carbon isotopic changes in the atmosphere during Industrialization. In contrast with previous free-air concentration enrichment experiments, no relationship was found between C:N ratios and increasing [CO_2]. Simultaneously static C:N ratios and Δ_{leaf} in light of increasing CO_2 highlights plants' inability to match rapid climate change with increased carbon assimilation as previously expected; Δ_{leaf} values are not reliable tools to reconstruct MAP and [CO_2], and $\delta^{13}C_{leaf}$ values only decrease with [CO_2] in line with atmospheric carbon isotope changes.

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2.2. Introduction

The concentration ([CO_2]) and isotopic value ($\delta^{13}C_{atm}$) of atmospheric CO_2 are changing at a pace unprecedented in geologic time (Keeling et al., 2005; Zhang et al., 2013). These changes have been accompanied by regional changes in mean annual temperature (MAT), mean annual precipitation (MAP), maximum summer temperature, and other climate variables (Yonetani & Gordon, 2001). The rapid decline in the carbon isotopic composition of CO_2 ($\delta^{13}C_{atm}$) due to fossil fuel combustion, deforestation, and other human inputs, is known as the Suess Effect, and is a chemical representation of anthropogenic changes to the atmosphere—and more broadly, the environment. $\delta^{13}C_{atm}$ values provide a useful way to see changes in CO_2 sources, sinks, and fluxes in the modern environment (Keeling, 1979; Boutton, 1991; Deines, 1992). It can also be applied to geologic problems (Schmitt et al., 2012) due to the naturally differing isotopic compositions of different CO_2 sources (e.g., methane, volcanism). $\delta^{13}C_{atm}$ values are particularly useful because they are parameters in models that reconstruct past changes to atmospheric [CO_2] using paleosol carbonates (Cerling et al., 1991, 1992) or atmospheric [CO_2] using plant stomatal parameters (Franks et al., 2014). Direct measurements of $\delta^{13}C_{atm}$ values only go back 50 years due to technological limitations, and longer-reaching ice core CO_2 bubbles (~800,000 years) are poorly resolved for recent times and limited by the presence of glacial ice (Keeling & Whorf, 2004; Augustin et al., 2004; Barnola et al., 1987; Trudinger et al., 1999; Petit et al., 1999). The biosphere provides an excellent system that directly interacts with the atmosphere and fills the gap to provide high-resolution recent and long-term records, potentially extending into geologic time (Arens, Jahren & Amundson, 2000).

This direct interaction means that plants potentially provide a robust record of $\delta^{13}C_{atm}$ values in their own leaf carbon isotope values ($\delta^{13}C_{leaf}$) and fractionation values (Δ_{leaf}, Equation 2.1; Farquhar, Ehleringer & Hubick, 1989; Feng, 1999; Farquhar & Sharkey, 1982), which gives insight into changes in carbon assimilation over time. In Equation 2.1, *a* represents the fractionation of $\delta^{13}C$ due to diffusion in air (4.4‰) and *b* represents the fractionation due to the carboxylation (instigated by the Rubisco enzyme, 27‰; Farquhar, Ehleringer & Hubick, 1989). These fractionation factors are compiled and multiplied by the ratio of C_i (intercellular [CO_2]) to C_a (atmospheric [CO_2]), a ratio that is often used to represent water use efficiency.

$$\Delta_{leaf} = \frac{\delta^{13}C_{atm} - \delta^{13}C_{leaf}}{(1+\delta^{13}C_{leaf}/1000)} = a + (b-a)(\frac{C_i}{C_a}) \quad \text{(Equation 2.1)}$$

While *a* and *b* are thought to be constant, we know that $\delta^{13}C_{atm}$ and C_a are changing rapidly. This could result in a corresponding change in Δ_{leaf} values as plants adapt to increased [CO_2] or subsequent regional climate changes, for example, systematic changes in local precipitation). Alternatively, Δ_{leaf} values of leaves may stay constant but show marked changes in $\delta^{13}C_{leaf}$ values corresponding to changes in $\delta^{13}C_{atm}$ values if leaves are incorporating $\delta^{13}C_{atm}$ into leaf tissues at a rate unaffected by other climate conditions.

2.2.1 Carbon isotopes related to climate variables

Previous studies have related Δ_{leaf} values to climate variables such as MAP, water availability and soil moisture (Diefendorf et al., 2010; Kohn, 2010; Wernerehl & Givnish, 2015; Mårtensson et al., 2017), MAT (Troughton & Card, 1975; O'Leary, 1993); latitude (Diefendorf et al., 2010; Kohn, 2010), [CO_2] (Schubert & Jahren, 2012, 2018), altitude (Korner, Farquhar & Wong, 1991; O'Leary, 1993), seasonality (Ehleringer, Phillips & Comstock, 1992), and $\delta^{13}C_{atm}$ values during growth seasons (Peñuelas & Azcón-Bieto, 1992; Arens, Jahren & Amundson, 2000; Pedicino et al., 2002). The studies that incorporate potential influence from a wide range of climate variables have been conducted via meta-analysis with no normalized collection procedure or investigated species, or via growth chamber experiment conducted under idealized conditions. The few studies that have used naturally-obtained specimens (i.e., natural history collections such as herbaria) to look at isotope change over time and changing atmospheric conditions ([CO_2] and $\delta^{13}C_{atm}$ values) have focused on localized regions with little range in climate (i.e., all dry, mid- to high- altitude, hot regions of eastern Arizona/western New Mexico, or the Mediterranean climate of Catalonia; Peñuelas & Azcón-Bieto, 1992; Pedicino et al., 2002). These collections-based experiments are limited in scope and while they provide information on specific ecosystems, do not address these biosphere-atmosphere interactions across climate regimes or on a regional and global scale. Very little is known about whether individual species respond to any, some, or all of these potential forcings across a range of climatic conditions.

2.2.2 Potential Climate Drivers

2.2.2.1 CO_2 and elevation

We would expect higher [CO_2] to affect biochemical discrimination because of the known effects elevated [CO_2] has on stomata (size, density, and conductance; Woodward, 1987; Woodward & Bazzaz, 1988; Tognetti et al., 2000; Ainsworth & Rogers, 2007). In a meta-analysis of trees in European temperate and boreal forests, leaves responded to an increase in [CO_2] with a significant (21%) decrease in stomatal conductance (the rate of passage of atmospheric CO_2 into plant tissue; Medlyn et al., 2001). Increased [CO_2] also causes a decrease in stomatal density (the number of pores on a leaf surface) and stomatal index (the number of pores compared to the number of total epidermal cells); these indices have been liberally applied to the geologic record to reconstruct [CO_2] (Retallack, 2001; Beerling & Royer, 2002; Roth-Nebelsick et al., 2014). Because stomata directly control the flow of carbon dioxide into leaves and control carbon isotope fractionation by diffusion (Farquhar, Ehleringer & Hubick, 1989), changes in stomatal parameters could affect fractionation as well. Additional factors must be considered; the dependence of Δ_{leaf} on [CO_2] may in part be due to isotopic discrimination associated with photorespiration (Schubert & Jahren, 2018). Indeed, previous growth chamber studies in prescribed CO_2 environments showed increased carbon isotope fractionation with increased [CO_2]; Schubert & Jahren (2012) found a strong hyperbolic correlation ($r > 0.94$) between [CO_2] and Δleaf values in two species of herbaceous angiosperms. Based upon these growth chamber experiments (Schubert & Jahren, 2012, 2018), the relationship between [CO_2] and Δleaf is expected to be most sensitive at geologically low [CO_2] (including pre-Industrial to present values) as it was in the levels present during plant growth in this study.

Elevation has been shown to factor into carbon isotope discrimination but is frequently not evaluated independently, due to its covariant relationship with climate variables such as temperature, vapor pressure, partial pressure of CO_2 (pCO_2), soil [CO_2], and soil texture (Diefendorf et al., 2010). A study looking at *Salix herbacea* leaves along an altitudinal gradient (2,000–2,800 m) in Austria showed a decrease in carbon isotope value with increased altitude, did not account for corresponding changes in other climate variables (Beerling, Mattey & Chaloner, 1993). Another study done in Utah and New Mexico using a number of desert and woodland species, including angiosperms and gymnosperms, found similar negative trends in $\delta^{13}C_{leaf}$ with increased altitude without controlling for other climate variables (Van de Water, Leavitt & Betancourt, 2002). In 2010, a meta-analysis assessing carbon isotope fractionation and discrimination values across a wide range of C_3 plants (Diefendorf et al., 2010) found that when

combined with MAP, elevation explained 61% of variability in Δleaf values. Based upon these studies, we included elevation as a potential variable in our study, however, we chose sample locations to minimize changes in elevation because it is difficult to completely separate this variable from regional variation in [CO_2] and $\delta^{13}C_{atm}$.

2.2.2.2 $\delta^{13}C_{atm}$

With the current increase in [CO_2], we have observed the aforementioned Suess Effect, wherein $\delta^{13}C_{atm}$ has changed in response to increased inputs of more isotopically negative CO_2 into the atmosphere (Keeling, 1979). The composition of CO_2 involved in the making of organic tissue is likely to affect the composition of that organic tissue (Arens, Jahren & Amundson, 2000); our study will test if this effect is compounded or mitigated by changes in other climate variables over this chronologically robust natural experiment.

2.2.2.3 Latitude

Latitude is expected to affect stomatal traits and therefore be related to carbon isotope fractionation due to its inverse relationship with light (specifically length of growing season and length of day) and temperature, and consequent effects on the maximum operating times for photosynthesis. A meta-analysis across 760 species in nine Chinese forest ecosystems showed a latitudinal variation in stomatal density and stomatal length at the community level (Wang et al., 2015). Given these morphological changes due to latitude, and the relationship between latitude and temperature, we might expect that Δ_{leaf} values would be inversely related to latitude as well (Farquhar, Ehleringer & Hubick, 1989; Equation 2.1). The relationship between Δ_{leaf} and latitude (15.9°S through 69.5°N) was observed in results of a meta-analysis of plants that used C_3 photosynthetic pathways (n = 506) (Diefendorf et al., 2010), but any changes in Δ_{leaf} as a function of latitude disappeared when latitude was decoupled from temperature and precipitation.

2.2.2.4 Precipitation

The stomata act as an inlet for CO_2 uptake as well as an outlet for leaf water loss via transpiration, which is why one might expect a relationship between carbon isotope fractionation and available water (represented in the paleo-record as reconstructed MAP). With decreased available water (i.e., decreased MAP) comes increased need for plant "water use efficiency" (as

measured by the ratio of water used in photosynthesis to water lost through transpiration); plants therefore minimize water loss through the same stomata by fully closing, resulting in decreased carbon isotope fractionation (Farquhar, Ehleringer & Hubick, 1989). Previous meta-analyses, such as those by Diefendorf et al. (2010) and Kohn (2010), compared Δleaf values of a wide variety of modern C_3 plants from many regions with MAP and found that Δ_{leaf} varied significantly with MAP (p-value = 0.0001 and $R^2 = 0.57$; Diefendorf et al., 2010).

2.2.2.5 Temperature and seasonality

In addition to the climate variables with pre-established and applied relationships with Δleaf values ($[CO_2]$, MAP), various hypotheses have been proposed about the relationships between carbon isotope discrimination and other climate variables. For example, MAT could also constrain photosynthetic processes and associated carbon isotope fractionation because it gives a rough representation of extreme conditions and growing season length during which carbon assimilation occurs. For this reason, MAT is a well-addressed climate variable in previous isotope fractionation studies, but none have identified a relationship between fractionation and MAT (Arens, Jahren & Amundson, 2000; Diefendorf et al., 2010; Kohn, 2010; Schubert & Jahren, 2012). Furthermore, Helliker & Richter (2008) found that leaves maintained a constant internal temperature ideal for photosynthesis of 21.4 ± 2.2 °C (total range of measurements), independent of external temperatures. In addition to MAT, maximum summer temperatures (particularly, the extreme highs associated with a warming climate) are expected to increase (Mirza, 2003). Increased maximum summer temperatures lead to increased evapotranspiration and more plant stress, which might affect carbon assimilation rates and stomatal conductivity (Farquhar, Ehleringer & Hubick, 1989; Diefendorf et al., 2010).

Seasonal variation is also thought to affect isotopic discrimination, resulting in a change in $\delta^{13}C_{leaf}$ of up to 1–2‰ (Ehleringer, Phillips & Comstock, 1992; Arens, Jahren & Amundson, 2000), or in some deciduous trees such as maples, up to 6‰ between early spring and late fall (Lowdon & Dyck, 1974). Typically, more positive values are found in the winter (indicative of less isotopic discrimination) and more negative values occur in the summer (indicative of more discrimination). This effect strongest in arid and semiarid environments because they experience amplified seasonal temperature, precipitation, and evaporation effects (up to 4‰; Ehleringer,

Phillips & Comstock, 1992). Our choice of sample locations should minimize this effect, as our specimens come from humid regions.

Though we do not expect a correlation between temperature and seasonality with Δ_{leaf} values, nor are there good proxies for these variables in the fossil record, we include them here for completeness. This ensures that any observed noise is random or unaccountable for in the fossil record, rather than related to variables that are commonly measured and potentially relevant in plant isotope discrimination (Farquhar, Ehleringer & Hubick, 1989; Arens, Jahren & Amundson, 2000).

2.2.2.6 Finding a focal species

In addition to potentially confounding climate variables, variation in $\delta^{13}C_{leaf}$ and Δ_{leaf} values can be related to species-inherent carbon isotope fractionation. In a recent meta-analysis of C_3 plants conducted by Diefendorf et al. (2010), Δ_{leaf} values ranged from 13.4‰ for *Pinus edulis* in Utah, USA (Van de Water, Leavitt & Betancourt, 2002) to 28.4‰ for *Cryptocarya concinna* in Guangdong Province, China (Ehleringer, Phillips & Comstock, 1992). However, the focus on geographic and climatic variability within that dataset resulted in a small number of analyses of any individual species. Thus, while some previous studies have proposed a universal Δ_{leaf} value that represents C_3 plants on average (Arens, Jahren & Amundson, 2000; Gröcke, 2002), we focus here instead on an individual species (*Thuja occidentalis;* Cupressaceae) in order to avoid interspecific variation and phylogenetic/evolutionary effects in plant biochemistry.

Thuja occidentalis is a widespread evergreen gymnosperm with a distribution today extending throughout temperate deciduous and boreal forests in North America, and an extensive fossil record in localities across North America dating back to the Late Cretaceous (~71 million years ago; LePage, 2003; Eckenwalder, 2009). *T. occidentalis* leaves have longer life spans (>1 year) than deciduous trees (Givnish, 2002; Pease, 1917), which makes them less vulnerable to seasonal variability and hardier in sedimentary archives (Diefendorf, Leslie & Wing, 2015). While some studies of other individual species have demonstrated unexplained internal isotopic variation of up to 3‰ (Tieszen, 1991), Mervenne (2015) found that Δ_{leaf} values of *T. occidentalis* showed the least amount of internal isotopic variation within a single species grown in a common garden site (e.g., 18.91 ± 0.46‰ vs. *Taxus:* 20.05 ± 1.93‰) when compared to 56

species native to temperate forests. This makes *T. occidentalis* an excellent focal taxon for a single-species study.

This study incorporates the natural shifts in [CO_2] concentrations as driven by fossil fuel combustion and other anthropogenic inputs since the Industrial Revolution (280 ppm: Pre-Industrial, to ~410 ppm in 2014; IPCC, 2014) and $\delta^{13}C_{atm}$ values (from −6.5‰: Pre-Industrial to −8.5‰: present; Araus & Buxó, 1993; Elsig et al., 2009; White, Vaughn & Michel, 2015) to examine the relationship between *T. occidentalis'* carbon isotope fractionation and leaf chemistry (C:N ratios) within a range of climate variables. The patterns of Δ_{leaf} values over a range of $\delta^{13}C_{atm}$ values highlight the limitations of $\delta^{13}C_{leaf}$ change as a tool for better understanding the biosphere and atmosphere. If $\delta^{13}C_{leaf}$ values change in sync with $\delta^{13}C_{atm}$ values, this could mean that carbon assimilation is continuing in this species as it was prior to Industrialization, perhaps indicating *T. occidentalis'* lack of adaptation to increased [CO_2]. Additionally, it may indicate that $\delta^{13}C_{leaf}$ provides another way to track anthropogenic changes to the environment in the recent past and the future.

2.3 Materials and Methods

We measured $\delta^{13}C_{leaf}$ values of *T. occidentalis* extending from present-day to Pre-Industrial historical records using both newly collected and herbarium material. This included collecting leaf material of *T. occidentalis* specimens (n = 142 collected between 1804 and 2017 with four unknown dates of collection) from across the Great Lakes region from herbaria (Figs. 2.1A and 2.1B; Table A1) and in natural present-day occurrences across a range of climate conditions (see Table A2). *Thuja* has small, 1–10 mm long scale-leaves adpressed along a small branch. Three cm portions of branches representing a single growth year with multiple scale-leaves were cleaned in an ultrasonic bath of deionized water to remove surface debris, oven dried at 50 °C for 48 h and homogenized; this removes any within-leaf isotopic variation. Aliquots of each *T. occidentalis* specimen (0.6–0.8 mg) were placed into tin capsules and placed in a Costech elemental analyzer to measure %C and %N (as well as C:N ratio). Second aliquots of each *T. occidentalis* specimen (0.6–0.8 mg) were placed into tin capsules and placed in a combustion module inlet coupled to a Picarro G2201-i cavity ring-down spectrometer (CRDS) to measure $\delta^{13}C$ values of each specimen. Duplicates were run on both machines to insure homogeneity. Results of each CRDS run were internally calibrated using nine acetanilide standards ($\delta^{13}C$ =

−28.17 ± 0.16‰), two IAEA-600 caffeine standards ($\delta^{13}C$ = −27.77 ± 0.04‰) and two IAEA-CH-6 sucrose standards ($\delta^{13}C$ = −10.45 ± 0.03‰) in each run, as seen in Cotton, Sheldon & Strömberg (2012) study. Reproducibility of replicate analyses was better than 0.3‰.

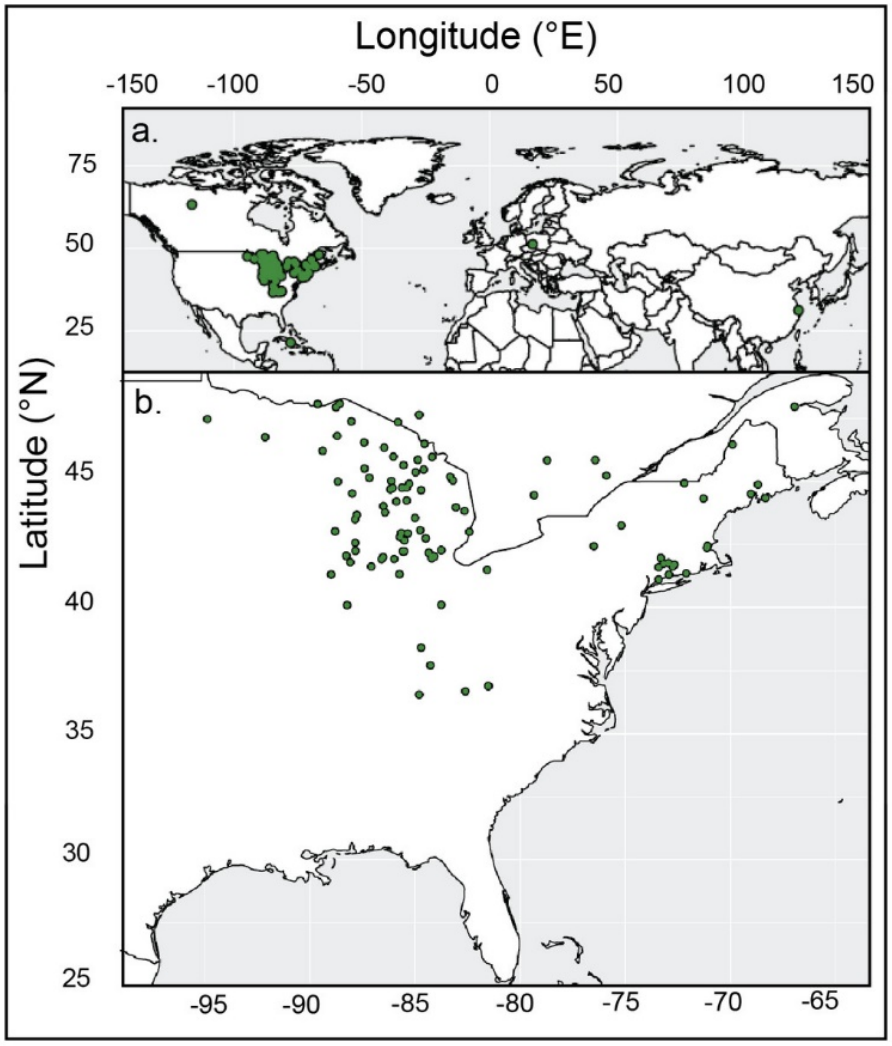

Figure 2.1 Map of locations of *Thuja occidentalis* specimens. Locations of (A) collections of *Thuja occidentalis* from across the world. (B) Specimens collected in Eastern North America (in the typical habitat of *Thuja occidentalis*).

To test whether other climate variables confounded the relationship between $\delta^{13}C_{atm}$ and $\delta^{13}C_{leaf}$, we calculated carbon isotope fractionation values (Δ_{leaf}) for each specimen using known yearly $\delta^{13}C_{atm}$ values (Equation 2.1). We derived global $\delta^{13}C_{atm}$ values from direct (Rubino et al., 2013) and interpolated ice and firn core measurements according to the year of sampling (White, Vaughn & Michel, 2015). This does not account for ecosystem or microbiome-level deviations in $\delta^{13}C_{atm}$, but does account for the greater source isotopic value. Δ_{leaf} values made it possible to

de-couple the human-driven relationship between increased [CO_2] and decreased $\delta^{13}C_{leaf}$ values (the Suess Effect; Keeling, 1979) because they were calculated by isolating leaf isotope ratios from the atmospheric isotopic signal.

For each specimen locality, environmental data expected to affect $\delta^{13}C_{leaf}$ values (MAP, MAT, and maximum summer temperature; Farquhar, Ehleringer & Hubick, 1989) were derived from global databases using exact latitude and longitude coordinates of specimen origin (PRISM Climate Group, 2004; Fick & Hijmans, 2017; Government of Canada, 2018). All contiguous United States data was compiled from Oregon State University's PRISM database, which interpolates data from local weather stations at a resolution of four km (PRISM Climate Group, 2004). $\delta^{13}C_{leaf}$ values were also compared with $\delta^{13}C_{atm}$ and [CO_2] values at collection times, as retrieved from NOAA databases documenting values found at Mauna Loa Observatory in Hawaii (White, Vaughn & Michel, 2015) and measured on an isotope-ratio mass spectrometer at the institute of arctic and alpine research (INSTAAR) in the University of Colorado, Boulder. $\delta^{13}C_{leaf}$ values for which $\delta^{13}C_{atm}$ values were unavailable were not included in Δ_{leaf} calculations or comparisons to climate variables (Table A3). While Δ_{leaf} values combine $\delta^{13}C$ values measured in this experiment on the CRDS with $\delta^{13}C_{atm}$ values measured on the IRMS at INSTAAR, we did not have access to individual errors for $\delta^{13}C_{atm}$ and could not propagate the error. Therefore, we used our reproducibility error of 0.3‰, which is larger than the expected error for the IRMS (0.1‰), to be conservative.

Five-point moving averages of $\delta^{13}C_{leaf}$ values were calculated to eliminate random noise caused by estimating older specimens' exact collection dates (a result of long collecting expeditions and limited recording resources). We regressed isotope values against climate variables (MAT, MAP, $\delta^{13}C_{atm}$ and annual [CO_2]) to examine potential drivers of the $\delta^{13}C_{leaf}$ values. We calculated the best-fit line using linear least squares regression to minimize the average distance between modeled y-values and actual y-values ($\delta^{13}C_{leaf}$ and Δ_{leaf}) and calculated coefficients of determination. We used R^2 to determine predictive relationship between the given x-variable and y-variable. Additionally, we calculated p-values using the F-test to determine the chance of null hypothesis (p-value > 0.05).

The map of sampling location was created using R version 3.5.0 (R Core Team, 2014), and the ggplot2 (Wickham, 2016) and maps (v3.3.0, Becker & Wilks, 2018) packages. The full code is available in the Supplemental Files.

2.4 Results

Values of $\delta^{13}C_{leaf}$ ranged from −21.92‰ (collected in 1899) to −28.51‰ (collected in 2017), with a mean of −25.05 ± 1.32‰ (standard deviation; Table A2). Δ_{leaf} values ranged from 15.11‰ to 20.97‰ (mean: 17.93 ± 1.11‰ standard deviation). Minimum, maximum, and mean values for climate variables are shown in Table A2. All data can be found in Table A3.

2.4.1 Δ_{leaf} vs MAT, maximum summer temperature, latitude, seasonality and MAP

There was no relationship between Δ_{leaf} values of *T. occidentalis* and MAT (Fig. A1A; R^2 = 0.0152, p-value = 0.19), nor between Δ_{leaf} of *T. occidentalis* and maximum summer temperature (Fig. A1B; R^2 = 0.0051, p-value = 0.51) in the temperature range listed in Table A2. No relationship was found between Δ_{leaf} and latitude (Fig. A1C; R^2 = 0.0057, p-value = 0.42). Additionally, no relationship was found using a multivariate linear regression approach to combine codependent variables: MAT and latitude (R^2 = 0.002, p-values = 0.92, 0.79 respectively). There was no relationship between Δ_{leaf} of *T. occidentalis* and MAP (Fig. 2.2; Fig. AD; R^2 = 0.0138, p-value = 0.21), nor was there a relationship between Δ_{leaf} of *T. occidentalis* and elevation (Fig. A4A; R^2 = 0.0138, p-value = 0.55).

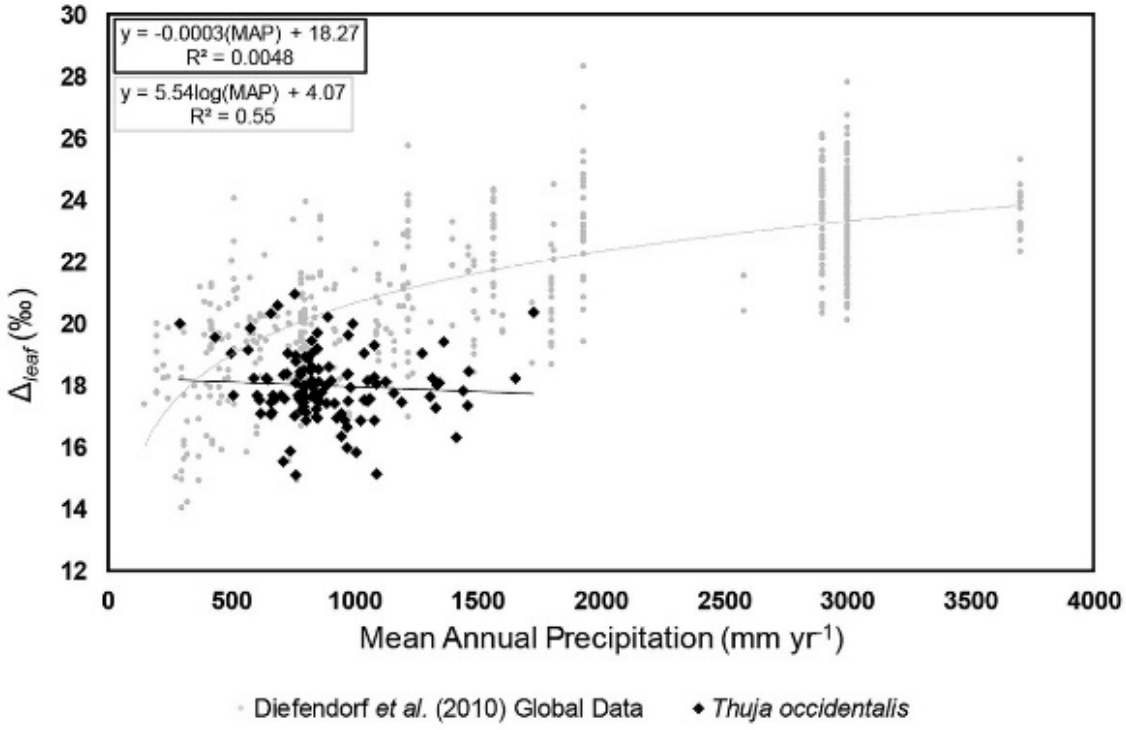

Figure 2.2 Δ_{leaf} vs. mean annual precipitation for *Thuja occidentalis* (black filled diamonds; Δ_{leaf} = −0.0003(MAP) + 18.75, $R^2 < 0.01$). Data are compared with Diefendorf et al.'s (2010) global study (gray circles; Δleaf = 5.54(logMAP) + 4.07, $R^2 = 0.55$), showing C_3 specimens growing from 147 to 3,700 mm yr^{-1}. Error bars along the y-axis represent the ±0.3‰ replicate reproducibility of standards.

There was no relationship between Δ_{leaf} of *T. occidentalis* and month of collection. T-test results showed that the mean residual Δ_{leaf} values for each season were not significantly different (Spring: 0.19, Summer: −0.13, Fall: −0.01, Winter: −0.20; Fig. A5A; Month-by-month R^2 = 0.0057; Fig. A5B).

2.4.2 %C, %N and C:N ratios

Values of %C ranged from 30.56 weight % to 61.44 weight % (±7.90%), with a dataset average of 48.86 %C. %N values ranged from 0.55 weight % to 2.28 weight %, with a dataset average of 1.31% (±0.21%). C:N ratios ranged from 20.1:1 (due to high %N) to 86.2:1 with an average C:N value of 40.7:1 (±7.9 C:N). There was no relationship between C:N ratios and time, $\delta^{13}C_{leaf}$, Δ_{leaf}, or [CO_2] (R^2 = 0.0227, p-value = 0.25; R^2 = 0.0297, p-value = 0.68; R^2 = 0.0157, p-value = 0.94; and R^2 = 0.0029, p-value = 0.18, respectively; Fig. 2.3; Figs. A2A–A2C).

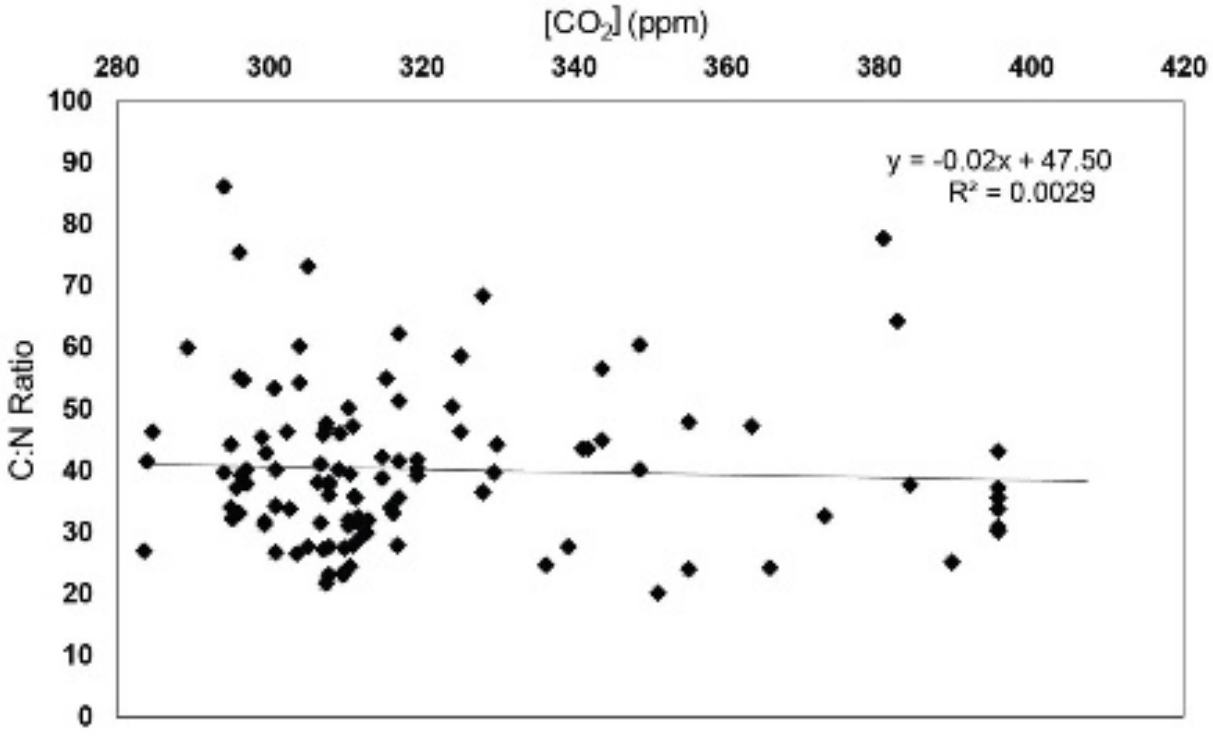

Figure 2.3 C:N ratios of specimens vs. [CO_2] (ppm) from 280–410 ppm. Error bars are associated with the 0.9% replicate reproducibility of standards.

2.4.3 The atmosphere: $\delta^{13}C_{leaf}$ and Δ_{leaf} vs [CO_2]

There was a linear relationship between $\delta^{13}C_{leaf}$ and [CO_2] (Fig. A3; $R^2 = 0.61$, p-value < 0.001), but there was no relationship between Δ_{leaf} and [CO_2] (Fig. 2.4; Fig. A4; $R^2 = 0.0059$, p-value = 0.38). Because Δ_{leaf} stayed constant, with simultaneous changes in $\delta^{13}C_{leaf}$ and $\delta^{13}C_{atm}$, we can determine that changing $\delta^{13}C_{leaf}$ with increased CO_2 was an effect of the changing isotopic composition of atmospheric CO_2 ($\delta^{13}C_{atm}$) and was not related to [CO_2].

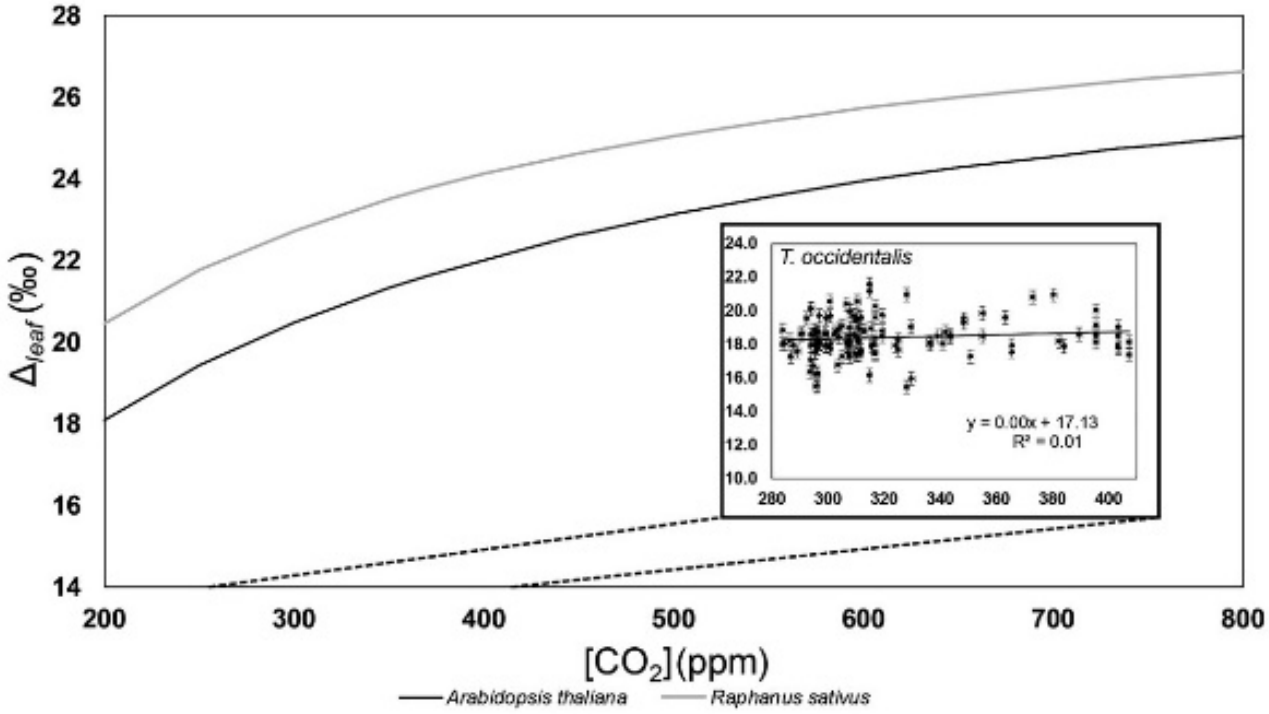

Figure 2.4. Δ_{leaf} vs. [CO_2] for *Thuja* and dicots. Shown are *Thuja occidentalis* (black empty triangles; $\Delta_{leaf} = 0.0029([CO_2]) + 17.04$, $R^2 = 0.0085$) and Schubert & Jahren's (2012) growth chamber studies with replicates of *Raphanus sativus* and *Arabidopsis thaliana* (black and grey smooth lines). Schubert & Jahren's data shows C_3 specimens growing at 15 levels of [CO_2] from 370 to 4,200 ppm.

2.4.4 $\delta^{13}C_{atm}$ and $\delta^{13}C_{leaf}$

There was a relationship between $\delta^{13}C_{leaf}$ and $\delta^{13}C_{atm}$ (Fig. 2.5; $R^2 = 0.74$, p-value < 0.001) as represented by Equation 2.2. The y-intercept (−16.52) represents the average offset between $\delta^{13}C_{atm}$ and $\delta^{13}C_{leaf}$, otherwise expressed as the fractionation value, Δ_{leaf}. The slope of 1.20 (with 95% confidence intervals between 1.07 and 1.32) further indicates relatively little impact of other environmental variables on leaf fractionation from atmospheric CO_2. This relationship was compared to that as extrapolated from the regression found in Jahren, Arens & Harbenson (2008; Equation 2.3; Fig. 2.5) study using *Raphanus sativus* in growth chamber experiments.

$$\delta^{13}C_{leaf} = 1.20\ (\pm 0.06)\ x\ \delta^{13}C_{atm} - 16.52(\pm 0.44) \qquad \text{(Equation 2.2)}$$

$$\delta^{13}C_{leaf} = 0.95\ x\ \delta^{13}C_{atm} - 25.4 \qquad \text{(Equation 2.3)}$$

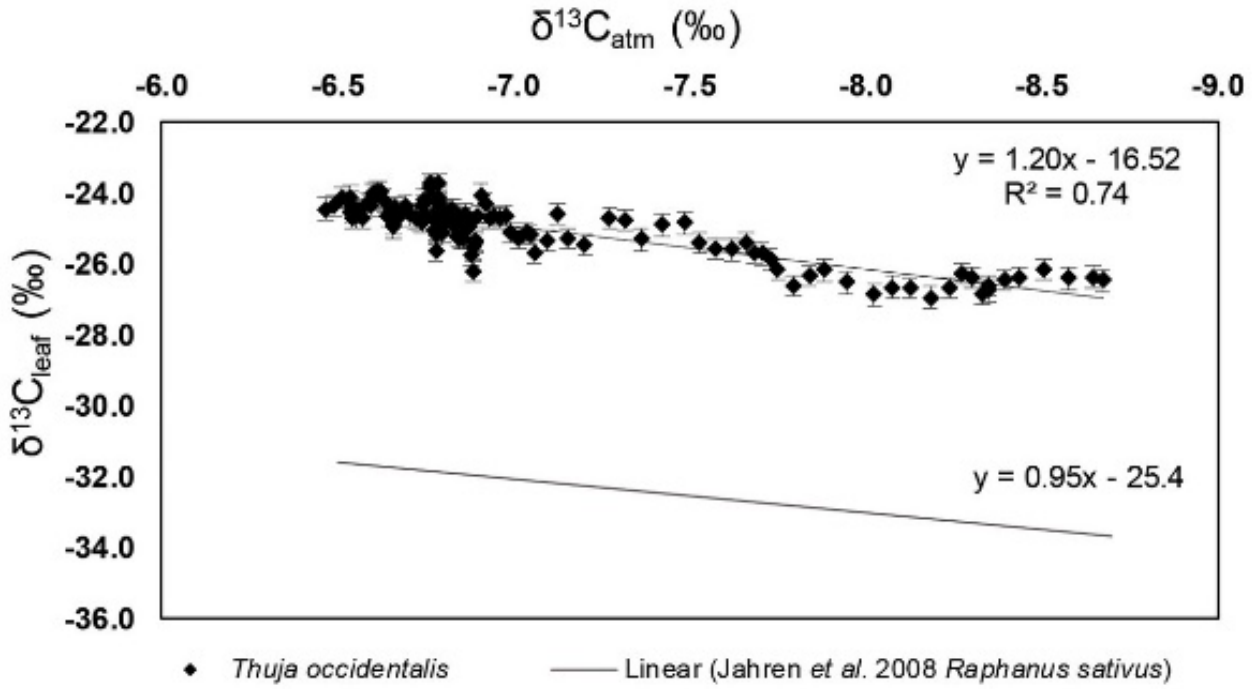

Figure 2.5 $\delta^{13}C_{atm}$ versus $\delta^{13}C_{leaf}$ values (‰) of *T. occidentalis*. This linear relationship is defined by $\delta^{13}C_{leaf}$ = 1.20 (±0.06 standard error) * ($\delta^{13}C_{atm}$) − 16.52(±0.44 standard error) with an R^2 value of 0.74 and a p-value <0.001. Error bars along the y-axis represent the ±0.3‰ replicate reproducibility of standards, error bars along the x-axis represent the ±0.1‰ replicate reproducibility associated with the isotope-ratio mass spectrometer at the Institute of Arctic and Alpine Research (INSTAAR) in Boulder, Colorado. Data points represent specimens collected for this study. The regression line below is derived from Jahren, Arens & Harbenson (2008), which used Raphanus sativus grown under elevated [CO_2] within growth chambers to look at the relationship between $\delta^{13}C_{leaf}$ and $\delta^{13}C_{atm}$ values.

2.5 Discussion

2.5.1 Potentially complicating factors

Herbarium specimens are a useful way to look in high-resolution on this time scale, but were not necessarily consistently sampled between expeditions and years. Thus some factors such as maturity and height of tree, which have been shown to relate to carbon isotope discrimination (Brienen et al., 2017), are not specifically accounted for here. However, Brienen et al. (2017) found that height was not a significant factor in $\delta^{13}C_{leaf}$ values of the gymnosperm used (*P. sylvestris*), in contrast to broadleaf species (*Quercus robur, Fagus sylvatica, Cedrela odorata*) where there was an influence. Additionally, regional variations in $\delta^{13}C_{atm}$ resulting from proximity to respiring soil could provide a different baseline $\delta^{13}C_{atm}$ value than the global one

used based upon Mauna Loa Observatory's gas samples (Wehr & Saleska, 2015). While we were unable to control exactly where on the tree each sample was taken from nor the ecosystem-specific parameters that might influence $\delta^{13}C_{atm}$, each herbarium record includes notes on the sampling location, often including approximate maturity of the tree and height sampled from. Additionally, as expeditions are done without heavy machinery, it is likely that our specimens were sampled from approximately the height of a human, which is well out of the range of isotopic influence from soil respired CO_2 (Bazzaz & Williams, 1991). Finally, differences in $\delta^{13}C_{leaf}$ values differ depending on where on the leaf isotopes are sampled from (Gao et al., 2015). We controlled for this effect by homogenizing several entire leaves per sample and running duplicate isotope analyses, which all came within machine error (0.3‰) of one another.

Complex nitrogen dynamics, as well as those of other macro- and micro-nutrients, may play a role in vital effects that relate ultimately to carbon assimilation and/or carbon isotope fractionation, but these changes are very difficult and complicated to reconstruct in the geologic record and thus were not investigated in this study (Godfrey & Glass, 2011). It is not possible to understand shifts in regional nitrogen availability fully even within the historical record: without soil cores collected and preserved from the same sites and times of leaf collection, it is not straightforward to consider anything other than nitrogen content. Given that no one collected soils at each historical site, we cannot address changes in nitrogen dynamics quantitatively. Furthermore, for geologic applications fossil leaves and corresponding paleosols (fossil soils) are not typically preserved together. In order to account for the potential range in nitrogen dynamics, we focus here on using many specimens from across a wide landscape of different land-uses and thus a wide range of potential nitrogen dynamics, but under known [CO_2] conditions. To account for historical and geological limitations of reconstructing the nitrogen cycle, this study focuses instead on the relationship between systemic changes in C:N ratios in relation to $\delta^{13}C_{leaf}$, $\delta^{13}C_{atm}$, or as indication of changes in carbon dynamics.

2.5.2 Δ_{leaf}, temperature, latitude and seasonality

There were a number of climate variables that we did not expect to have a correlative relationship with Δ_{leaf}, but we addressed to ensure that they were not confounding variables (MAT, maximum summer temperature, latitude, seasonality). Due to the consistent internal temperature and lack of relationship between Δ_{leaf} to MAT in previous studies, we expected no

relationship between Δ_{leaf} and MAT nor maximum summer temperature. As we expected, MAT showed no significant relationship with Δ_{leaf} values neither in meta-analyses, growth chamber experiments (Diefendorf et al., 2010; Schubert & Jahren, 2012) nor this study (Fig. A1A).

Because MAT and latitude are inherently related, we expected Δ_{leaf} values to relate to latitude in the same way as when compared to MAT. As predicted, there was no relationship between Δleaf of *T. occidentalis* and latitude. In order to ensure that these two codependent variables were treated as such, we ran a multiple linear regression, which gave a similarly low coefficient of determination ($R^2 = 0.002$) comparing actual Δ_{leaf} values with Δ_{leaf} values predicted using this regression. Thus, we are confident that both treated as independent and co-dependent variables, MAT and latitude do not play a role in variance of Δ_{leaf} values.

Additionally, we took into account variation in time of year specimen was collected and found no significant relationship between season and Δ_{leaf} (Figs. A5A and A5B). This is likely because *T. occidentalis* is not deciduous and does not shed its leaves annually, thus, once homogenized, the isotopic composition of the leaf is representative of average discrimination during the leaf's exposure.

2.5.3 Δ_{leaf} and CO_2

In this study we found no relationship between Δ_{leaf} and [CO_2] from 280 to 410 ppm (Fig. 2.4; Fig. A4). It is possible that the relationship observed by Schubert & Jahren (2012) exists only for idealized controlled growth chamber conditions and not in natural environments (Lomax et al., 2019). Alternatively, gymnosperms may respond more slowly than angiosperms to increases in [CO_2] due to their longer average lifespans and lack of senescence (Brodribb, Pittermann & Coomes, 2012). The changes in carbon assimilation as represented by increased carbon fractionation under short-term, ideal growth chamber conditions cannot be used to predict biological response to rapid changes in [CO_2]. In other words, plants, especially slow-growing woody plants, may not successfully adapt to anthropogenic changes of the present and future (Jump & Peñuelas, 2005).

2.5.4 Δ_{leaf} and mean annual precipitation

When Δ_{leaf} values of *T. occidentalis* were compared with MAP, Diefendorf et al.'s (2010) previously established relationship did not hold (Fig. 2.2), especially in low precipitation regimes

(<1,000 mm yr−1) where the change in Diefendorf et al.'s Δ_{leaf} values was most sensitive to changes in MAP. One explanation for the lack of relationship between Δ_{leaf} of *T. occidentalis* and MAP is that this relationship breaks down on the single-species, or even plant functional type, level. In the aforementioned meta-analyses, plant functional type, species, and region were not controlled. Δ_{leaf} values may be inherent to specific biomes but may not be representative of a general trend of any given plant or plant type to MAP. It is possible that the relationships seen in the meta-analyses by Diefendorf et al. (2010) and Kohn (2010) instead represent an array of taxon-specific constant isotopic values that collectively show a meta-relationship. This experiment could be further explored by performing the same experiment in natural settings across different biomes and different plant functional types. Assuming that Δ_{leaf} values are indicative of water use (Givnish, 1979; Farquhar, Ehleringer & Hubick, 1989), this lack of relationship may also mean that plants with specific water use efficiencies and representative Δ_{leaf} values are generally located in areas where they are not living in conditions that are stressed for water given their evolutionary adaptations. Geologically, this could mean that the presence of a particular taxon in fossil localities could provide a quantitative estimate for range of MAP, which could allow more specificity of paleoclimate regimes based on macrofossils (Nearest Living Relative and/Coexistence Approach; Mosbrugger & Utescher, 1997; Mosbrugger, 2009). In terms of future climate, this is indication that the chemistry of C_3 plants may not respond to regional changes as previously thought. This is of particular concern because the velocity of climate change, especially for continued high emission rate scenarios, is substantially faster than trees will be able to adapt to (Loarie et al., 2009; Diffenbaugh & Field, 2013).

It is also possible that the predicted relationship between Δ_{leaf} and MAP is present for plants that are more responsive to their environment and/or have less extensive roots (to access deeper water sources), and thus the signal seen by Diefendorf et al. (2010) is a result of incorporating sensitive plants. Indeed, other studies using rapidly growing, highly sensitive herbaceous angiosperms have found a relationship between water treatment and carbon isotope discrimination (Lomax et al., 2019). However, the fossil record is biased toward preserving less sensitive, often woody plants due to preservation potential as well as presence within the fossil record (Looy et al., 2014); therefore, the utility of relationships based on highly sensitive plants may be muted in the fossil record.

Another explanation is that MAP is not an appropriate metric for measuring plant-available water, and while Δ_{leaf} is still a measure of water use efficiency and this value is dynamic over conditions, snowmelt volumes and/or soil water—as driven by soil porosity and other factors—are better indicators of plant-available water. Further investigations using these variables will better constrain which water-related variables affect Δ_{leaf} values of leaf tissues. The weak R^2 value between Δ_{leaf} of *T. occidentalis* and MAP (0.0138) means that Δ_{leaf} of *T. occidentalis* cannot be used to reconstruct paleo-MAP using the relationship determined by Diefendorf et al. (2010). Additional single-species experiments, particularly within angiosperms, should be conducted to look for correlations between Δ_{leaf} and MAP to test whether the lack of relationship is due to a difference inherent to gymnosperms.

2.5.5 Carbon biomass (%C) and elemental leaf chemistry (%N, C:N ratios) as related to climate variables

In addition to the response of $\delta^{13}C_{leaf}$ values to climate variables, %C alone has been shown to respond directly to elevated [CO_2]. Ci/Ca ratios (the ratio of internal [CO_2] to atmospheric [CO_2]) of old growth *T. occidentalis* trees along Lac Duparquet, Quebec, increased under anthropogenic CO_2 fertilization, indicating tree response to enhanced CO_2 (Giguère-Croteau et al., 2019). This increase in tree productivity was demonstrated in the results of free-air concentration enrichment (FACE) experiments as well; in northern USA mid-latitude forests with loblolly pines (P. taeda), FACE experiment results indicated that elevated CO_2 induced increased carbon assimilation, resulting in increased carbon biomass, in woody tissues and increased %C of foliar storage as compared to trees grown under ambient CO_2 (Oren et al., 2001; Ainsworth & Long, 2005; Talhelm et al., 2013). Preliminary work in herbarium leaves found that increased [CO_2] related to Industrialization resulted in an increase in foliar %C with no change in %N (as source of N remains constant), and thus increased C:N ratios in some species (Mervenne, 2015). In order to contextualize changes in $\delta^{13}C_{leaf}$, this study examined coeval trends in leaf chemistry through elemental analysis of C and N (using N as a comparison point to see whether %C changes significantly with time).

These FACE experiments also showed that when run over longer time scales, trees reached a point of CO_2 acclimation and stopped increased carbon assimilation under enhanced CO_2; thus, predicted shifts in tree C-uptake may be short-lived, a pattern that will be inevitably

discernable in a long-term study incorporating pre-Industrial leaf tissues through the present (Nowak, Ellsworth & Smith, 2004). Based on FACE experiments, we expected %C to have increased in leaves sampled from the early 1800s to the present, though we might see the rate of increase slow with time. However, we saw no relationship between %C, nor C:N ratios and time nor increase in [CO_2].

In fact, *T. occidentalis* specimens collected between 1804 and 2017 did not show changes in assimilation rates due to elevated CO_2. C:N values of *T. occidentalis* showed no response to changes over time (with increased [CO_2]) or with atmospheric isotopic value (Figs. A2A and A2B). Though other organs in previous experiments responded to [CO_2], leaves, which are instrumental in the photosynthetic process as they are the organs directly in-taking atmospheric CO_2, do not. A better understanding of all plant organ behavior is imperative to defining and quantifying potential carbon sinks or plant chemistry responses to global change (Goodale et al., 2002).

2.5.6 $\delta^{13}C_{leaf}$ and $\delta^{13}C_{atm}$

Strong relationships have been found between above ground tissue and $\delta^{13}C_{atm}$ values ($p < 0.001$; Jahren, Arens & Harbenson, 2008; Fig. 2.5), and this study provides a higher resolution look at the relationship between $\delta^{13}C_{leaf}$ and $\delta^{13}C_{atm}$ in a long-lived species within a natural system. In this initial natural experiment, the $\delta^{13}C_{leaf}$ of *T. occidentalis* tracked changes in $\delta^{13}C_{atm}$ ($R^2 = 0.74$, p-value < 0.0001), mostly unencumbered by other climate factors. The slope for the linear relationship between $\delta^{13}C_{leaf}$ and $\delta^{13}C_{atm}$ is close to, but not exactly, 1, likely because the rate of change for $\delta^{13}C_{atm}$ has not been linear, and acceleration in the change of $\delta^{13}C_{atm}$ may not have been recorded immediately. Additionally, while there is no statistically significant relationship between any of the climate variables we tested and Δ_{leaf}, it is unlikely that climate variables, especially in aggregate, play no role in carbon isotope discrimination within this species. Because $\delta^{13}C_{leaf}$ showed a strong coefficient of determination with $\delta^{13}C_{atm}$, and no climate variables showed significant relationships with Δ_{leaf} values, we can assume that $\delta^{13}C_{leaf}$ values of modern *T. occidentalis* are strongly affected by $\delta^{13}C_{atm}$ values. Additional work must be done to evaluate error in paleo uses of $\delta^{13}C_{leaf}$ values of *T. occidentalis*, and future experiments should recreate more geologically reasonable conditions and climate changes (independent of anthropogenic factors). The relationship between $\delta^{13}C_{leaf}$ and $\delta^{13}C_{atm}$ values has

implications for paleoclimate reconstructions of $\delta^{13}C_{atm}$ as well as reconstructions of [CO_2] (Cerling et al., 1991; Franks et al., 2014). We emphasize how important it is to identify the value of $\delta^{13}C_{atm}$, such as in Tipple, Meyers & Pagani (2010) study, rather than just using the Pre-Industrial value of −6.5‰ (Cerling et al., 1991) because the $\delta^{13}C_{atm}$ value has such a dramatic effect on the terrestrial part of the carbon cycle.

2.6 Conclusions

Though $\delta^{13}C_{leaf}$ and Δ_{leaf} values have been proposed as a proxy for [CO_2] and MAP based on previous research, this natural-world, species-controlled study shows no indication of such relationships. Thus, the use of Δ_{leaf} values to reconstruct MAP and [CO_2] in the fossil record without taxonomic identification should be reconsidered. The relationship between $\delta^{13}C_{leaf}$ and $\delta^{13}C_{atm}$ values is more informative, and may provide a new proxy ($\delta^{13}C_{leaf}$ values of *Thuja*) for reconstructing paleo-$\delta^{13}C_{atm}$ or may indicate a lag in plant adaptation to unprecedentedly rapid climate change. *Thuja* extends up to 100 million years back to the Late Cretaceous, which makes this relationship potentially useful throughout the Cenozoic and into the Mesozoic era (Berry, 1915).

While this study focuses on one single species, further work is needed to assess other taxa at the species, genus, and family levels to examine whether the relationship between $\delta^{13}C_{atm}$ and $\delta^{13}C_{leaf}$ is consistent, and furthermore, generalizable. $\delta^{13}C_{leaf}$ values of individual fossil leaves (in particular of *Thuja* leaves) cannot be used to reconstruct paleo-MAP as proposed by Kohn (2010), but average $\delta^{13}C_{leaf}$ values of sites, as recorded in bulk soil organic matter, may allow us to predict precipitation ranges. Aboveground $\delta^{13}C_{leaf}$ is thought to translate directly into the isotopic value of soil carbon ($\delta^{13}C_{org}$; Arens, Jahren & Amundson, 2000). Bulk soil organic matter ($\delta^{13}C_{org}$) is the combination of $\delta^{13}C$ of all decaying material from the ecosystem, with leaves especially abundant due to sheer volume. The average $\delta^{13}C_{leaf}$ value of all trees found in a certain region will be found in the soil; therefore, soil $\delta^{13}C_{org}$ values could be more reflective of particular precipitation at time of deposition than $\delta^{13}C_{leaf}$ values. Further studies could evaluate the reliability of $\delta^{13}C_{org}$ as a tool for MAP prediction and reconstruction.

This study implies constant carbon and nitrogen use and isotope fractionation relative to $\delta^{13}C_{atm}$ by *T. occidentalis*. Due to the unprecedentedly rapid changes $\delta^{13}C_{atm}$ and [CO_2] throughout Industrialization, this lack of change in carbon assimilation patterns, despite previous

studies using modern $\delta^{13}C_{leaf}$ values to reconstruct [CO_2], may indicate that modern systems are not appropriate analogues for many periods of the geologic record during which climate evolved more slowly. Modern climate change may be too rapid for plants to adapt, though more research should be done to evaluate whether this response is replicable in other species, genera, and plant functional types. It is possible that the pace of anthropogenic climate change makes modern relationships inappropriate analogues for paleoclimate.

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2.8 References

Ainsworth E .A. & Long S. P. (2005). What we have learned from 15 years of free-air CO_2 enrichment (FACE)? A meta-analytic review of the responses of photosynthesis, canopy properties, and plant production to rising CO_2. *New Phytologist 165*(2):351-371

Ainsworth E. A., & Rogers A. (2007). The response of photosynthesis and stomatal conductance to rising [CO_2]: mechanisms and environmental interactions, *Plant, Cell & Environment 30*(3), 258-270

Araus J. L., & Buxó R. (1993). Changes in carbon isotope discrimination in grain cereals from the north-western Mediterranean Basin during the past seven millennia. *Functional Plant Biology 20*(1), 117-128

Arens N. C., Jahren A. H., & Amundson R. (2000). Can C_3 plants faithfully record the carbon isotopic composition of atmospheric carbon dioxide? *Paleobiology 26*(1), 137-164

Augustin L., Barbante C., Barnes P. R., Barnola J. M., Castellano E., & Dreyfus G. (2004). Eight glacial cycles from an Antarctic ice core. *Nature 429*(6992), 623-628

Barnola J. M., Raynaud D., Korotkevich Y. S., & Lorius C. (1987). Vostok ice core provides 160,000-year record of atmospheric CO_2. *Nature 329*(6138), 408-414

Bazzaz F. A., & Williams W. E. (1991). Atmospheric CO_2 concentrations within a mixed forest: implications for seedling growth. *Ecology 72*(1):12-16

Beerling D. J., Mattey D. P., & Chaloner W. G. (1993). Shifts in the $\delta^{13}C$ composition of *Salix herbacea* L. leaves in response to spatial and temporal gradients of atmospheric CO_2 concentration. *Proceedings of the Royal Society of London. Series B: Biological Sciences 253*(1336), 53-60

Beerling D. J., & Royer D. L. (2002). Fossil plants as indicators of the Phanerozoic global carbon cycle. *Annual Review of Earth and Planetary Sciences 30*(1), 527-556

Berry E. W. (1915). The age of the Cretaceous flora of southern New York and New England. *Journal of Geology 23*(7), 608-618

Boutton T. W. (1991). Stable carbon isotope ratios of natural materials: II. Atmospheric, terrestrial, marine, and freshwater environments. *Carbon Isotope Techniques 1*, 173-185

Brienen R. J. W., Gloor E., Clerici S., Newton R., Arppe L., Boom A., Bottrell S., Callaghan M., Heaton T., Helama S., Helle, G., Leng, M. J., Mielikainen, K., Oinonen, M., Timonen, M. (2017). Tree height strongly affects estimates of water-use efficiency responses to climate and CO_2 using isotopes. *Nature Communications 8*(299), 1-10

Brodribb T. J., Pittermann J., Coomes D. A. (2012). Elegance versus speed: examining the competition between conifer and angiosperm trees. *International Journal of Plant Sciences 173*(6), 673-694

Cerling T. E. (1992). Use of carbon isotopes in paleosols as an indicator of the $p(CO_2)$ of the paleo atmosphere. *Global Biogeochemical Cycles, 6*(3), 307-314

Cerling T. E., Solomen D. K., Quade J., Bowman J. R. (1991). On the isotopic composition of carbon in soil carbon dioxide. *Geochimica et Cosmochimica Acta 55*(11), 3403-3405

Cotton J. M., Sheldon N. D., Strömberg C. A. E. (2012). High-resolution isotopic record of C_4 photosynthesis in a Miocene grassland. *Palaeogeography, Palaeoclimatology, Palaeoecology 337–338*, 88-98

Deines P. (1992). Mantle carbon: concentration, mode of occurrence, and isotopic composition. In: Schidlowski M., Golubic S., Kimberley M. M., McKirdy D. M., Trudinger P. A., eds. Early Organic Evolution: Implications for Mineral and Energy Resources. Berlin, Heidelberg: Springer.

Diefendorf A. F., Leslie A. B., Wing S. L. (2015). Leaf wax composition and carbon isotopes vary among major conifer groups. *Geochimica et Cosmochimica Acta 170*, 145-156

Diefendorf A. F., Mueller K. E., Wing S. L., Koch P. L., Freeman K. H. (2010). Global patterns in leaf ^{13}C discrimination and implications for studies of past and future climate. *Proceedings of the National Academy of Sciences 107*(13), 5738-5743

Diffenbaugh N. S., & Field C. B. (2013). Changes in ecologically critical terrestrial climate conditions. *Science, 341*(6145), 486-492

Eckenwalder J. E. (2009). Conifers of the world: the complete reference. China: Timber Press.

Ehleringer J. R., Phillips S. L., Comstock J. P. (1992). Seasonal variation in the carbon isotopic composition of desert plants. *Functional Ecology 6*(4), 396-404

Elsig J., Schmitt J., Leuenberger D., Schneider R., Eyer M., Leuenberger M., Stocker T. F. (2009). Stable isotope constraints on Holocene carbon cycle changes from an Antarctic ice core. *Nature 461*(7263), 507-510

Farquhar G. D., Ehleringer J. R., Hubick K. T. (1989). Carbon isotope discrimination and photosynthesis. *Annual Review of Plant Biology and Plant Molecular Biology 40*(1), 503-537.

Farquhar G. D., Sharkey T. D. (1982). Stomatal conductance and photosynthesis. *Annual Review of Plant Physiology 33*(1), 317-345

Feng X. (1999). Trends in intrinsic water-use efficiency of natural trees for the past 100–200 years: a response to atmospheric CO_2 concentration. *Geochimica et Cosmochimica Acta 63*(13–14), 1891-1903

Fick S. E., Hijmans R. J. (2017). Wordclim 2: new 1-km spatial resolution climate surfaces for global land areas. *International Journal of Climatology 37*(12), 4302-4315

Franks P. J., Royer D. L., Beerling D. J., Van de Water P. K., Cantrill D. J., Barbour M. M., Berry J. A. (2014). New constraints on atmospheric CO_2 concentration for the Phanerozoic. *Geophysical Research Letters 41*(13), 4685-4694

Gao L., Guimond J., Thomas E., Huang Y. (2015). Major trends in leaf wax abundance, δ^2H and $\delta^{13}C$ values along leaf venation in five species of C_3 plants: physiological and geochemical implications. *Organic Geochemistry 78*,144-152

Giguère-Croteau C., Boucher E., Bergeron Y., Girardin M. P., Drobyshev I., Silva L. C. R., Helie J. F., Garneau M. (2019). North America's oldest boreal trees are more efficient water users due to increased [CO_2], but do not grow faster. *Proceedings of the National Academy of Sciences116*(7), 2749-2754

Givnish T. (1979). On the adaptive significance of leaf form. In: Solbrig OT, Jain S, Johnson GB, Raven PH, eds. Topics in Plant Population Biology. London: Palgrave. 375-407

Givnish T. (2002). Adaptive significance of evergreen vs. deciduous leaves: solving the triple paradox. *Silva Fennica* 36(3):703-743

Godfrey L. V., Glass J. B. (2011). The geochemical record of the ancient nitrogen cycle, nitrogen isotopes, and metal cofactors. *Methods in Enzymology 486*, 483-506

Goodale C. L., Apps M. J., Birsey R. A., Field C. B., Heath L. S., Houghton R. A., Jenkins J. C., Kohlmaier G. H., Kurz W., Liu S., Nabuurs, G-J., Nilsson, S., Shvidenko, A. Z. (2002). Forest carbon sinks in the northern hemisphere. *Ecological Applications 12*(3), 891-899

2018. 1981–2010 Climate Normals & Averages. Retrieved from Canadian Climate Normals website (accessed 15 February 2018)

Gröcke D. R. (2002). The carbon isotope composition of ancient CO_2 based on higher-plant organic matter. *Philosophical Transactions of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences 360*(1793), 633-658

Helliker B. H., & Richter S. L. (2008). Subtropical to boreal convergence of tree-leaf temperatures. *Nature 454*(7203), 511-514.

IPCC. 2014. Intergovernmental panel on climate change guidelines. IPCC Fifth Assessment Report

Jahren A. H., Arens N. C., Harbenson S. A. (2008). Prediction of atmospheric $\delta^{13}CO_2$ using fossil plant tissues. *Reviews of Geophysics 46*(1),1-12

Jump A. S., Peñuelas J. (2005). Running to stand still: adaptation and the response of plants to rapid climate change. *Ecology Letters 8*(9), 1010-1020.

Keeling C. D. (1979). The Suess effect: ^{13}Carbon-^{14}Carbon interrelations. *Environment International 2*(4–6), 229-300

Keeling C. D., Piper S. C., Bascatow R. B., Wahlen M., Whorf T. P., Heimann M., Meijer H. A. (2005). Exchanges of atmospheric CO_2 and $^{13}CO_2$ with the terrestrial biosphere and oceans from 1978-2000: observations and carbon cycle implications. In: Ehleringer J. R., Cerling T., Dearing M. D., eds. A History of Atmospheric CO_2 and its Effects on Plants, Animals, and Ecosystems. New York: Springer. 177:83-113

Keeling C. D., & Whorf T. P. (2004). Atmospheric CO_2 from continuous air samples at Mauna Loa observatory. Hawaii: Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory.

Kohn M. J. (2010). Carbon isotope compositions of terrestrial C_3 plants as indicators of (paleo) ecology and (paleo) climate. *Proceedings of the National Academy of Sciences 107*(46), 19691-19695

Korner C., Farquhar G. D., Wong S.C. (1991). Carbon isotope discrimination by plants follows latitudinal and altitudinal trends. *Oecologia 88*(1), 30-40

LePage B. A. (2003). A new species of *Thuja* (Cupressaceae) from the Late Cretaceous of Alaska: implications of being evergreen in a polar environment. *American Journal of Botany 90*(2), 167-174

Loarie S. R., Duffy P. B., Hamilton H., Asner G. P., Field C. B., Ackerly D. D. (2009). The velocity of climate change. *Nature 462*, 1052-1055

Lomax B. H., Lake J. A., Leng M. J., Jardine P. E. (2019). An experimental evaluation of the use of $\Delta^{13}C$ as a proxy for palaeoatmospheric CO_2. *Geochimica et Cosmochimica Acta 247,* 162-174

Looy C., Kerp H., Duijnstee I., DiMichele B. (2014). The late Paleozoic ecological-evolutionary laboratory, a land-plant fossil record perspective. *Sedimentary Record 12*(4), 4-18

Lowdon J., & Dyck W. (1974). Seasonal variations in the isotope ratios of carbon in maple leaves and other plants. *Canadian Journal of Earth Sciences 11*(1), 79-88

Mårtensson L. M., Carlsson G., Prade T., Kørup K., Lærke P. E., Jensen E. S. (2017). Water use efficiency and shoot biomass production under water limitation is negatively correlated to the discrimination against ^{13}C in the C_3 grasses *Dactylis glomerata, Festuca arundinacea* and *Phalaris arundinacea*. *Plant Physiology and Biochemistry 113*, 1-5

Medlyn B. E., Barton C. V. M., Broadmeadow M. S. J., Ceulemans, R., De Angelis, P., Forstreuter, M., Freeman, M., Jackson, S. B., Kellomaki, S., Laitat, E., Rey A., Roberntz P., Sigurdsson B. D., Strassemeyer J., Wang K., Curtis P. S., Jarvis P. G. (2001). Stomatal conductance of European forest species after long-term exposure to elevated [CO_2]: a synthesis of experimental data. *New Phytologist 149*, 247-264

Mervenne C. (2015). *Isotope ecology of temperate conifers*. (Master's Thesis University of Michigan, Ann Arbor, MI, United States of America).

Mirza M. M. Q. (2003). Climate change and extreme weather events: can developing countries adapt? *Climate Policy 3*(3), 233-248

Mosbrugger V. (2009). Nearest-living-relative method. In: Gornitz V., ed. Encyclopedia of Paleoclimatology and Ancient Environments. Dordrecht: Springer. 607-609

Mosbrugger V., Utescher T. (1997). The coexistence approach—a method for quantitative reconstructions of Tertiary terrestrial paleaeoclimate data using plant fossils. *Palaeogeography, Palaeoclimatology, Palaeoecology 134*(1–4), 61-86.

Nowak R. S., Ellsworth D. S., Smith S. D. (2004). Functional responses of plants to elevated atmospheric CO_2- do photosynthetic and productivity data from FACE experiments support early predictions? *New Phytologist 162*(2), 253-280.

O'Leary M. H. (1993). Biochemical basis of carbon isotope fractionation. Stable Isotopes and Plant Carbon-Water Relations 1993, 19-28.

Oren R., Ellsworth D. S., Johnsen K. H., Phillips N., Ewers B. E., Maier C., Schafer K. R., McCarthy H., Hendrey G., McNulty S. G., Katul, G. G. (2001). Soil fertility limits carbon sequestration by forest ecosystems in a CO_2-enriched atmosphere. *Nature 411*(6836), 469-472.

Original S code by Richard A. Becker, Allan R. Wilks. R version by Ray Brownrigg. Enhancements by Thomas P Minka and Alex Deckmyn. 2018. Maps: draw geographical maps. R package Version 3.3.0 software

Pease V. A. (1917). Duration of leaves in evergreens. *American Journal of Botany 4*(3), 145-160

Pedicino L. C., Leavitt S. W., Betancourt J. L., Van de Water P. K. (2002). Historical variations in $\delta^{13}C_{leaf}$ of herbarium specimens in the southwestern U. S. *Western North American Naturalist 62*(3), 348-359

Peñuelas J., & Azcón-Bieto J. (1992). Changes in leaf $\Delta^{13}C$ of herbarium plant species during the last 3 centuries of CO_2 increase. *Plant, Cell & Environment 15*(4), 485-489

Petit J. R., Jouzel J., Raynaud D., Barkov N. I., Barnola J. M., Basile I., Bender M., Chappellaz J, Davis M., Delaygue G., Delmotte, M., Kotlyakov, V. M., Legrand, M., Lipenkov, V. Y., Lorius, C., Pepin, L., Ritz, C., Saltzman, E., Stievenard, M. (1999). Climate and Atmospheric History of the Past 420,000 years from the Vostok Ice Core, Antarctica. *Nature 399*, 429-436

PRISM Climate Group. 2004. Oregon State University. created 4 February 2004

R Core Team. 2014. R: a language and environment for statistical computing. Vienna: R Foundation for Statistical Computing.

Retallack G. J. (2001). A 300-million-year record of atmospheric carbon dioxide from fossil plant cuticles. *Nature 411*(6835), 287-290

Roth-Nebelsick A., Oehm C., Grein M., Utescher T., Kunzmann L., Friedrich J. P., Konrad W. (2014). Stomatal density and index data of Platanus neptuni leaf fossils and their evaluation as a CO_2 proxy for the Oligocene. *Review of Palaeobotany and Palynology 206*, 1-9

Rubino M., Etheridge D. M., Trudinger C. M., Allison C. E., Battle M. O., Langenfelds R. L., Jenk T. M. (2013). A revised 1000 year atmospheric $\delta^{13}C$-CO_2 record from Law Dome and South Pole, Antarctica. *Journal of Geophysical Research: Atmospheres 118*(15), 8482-8499

Schmitt J., Schneider R., Elsig J., Leuenberger D., Lourantou A., Chappellaz J., Köhler P., Joos F., Stocker T. F., Leuenberger M., Fischer H. (2012). Carbon isotope constraints on the deglacial CO_2 rise from ice cores. *Science 336*(711), 711-713

Schubert B. A., & Jahren A. H. (2012). The effects of atmospheric CO_2 concentration on carbon isotope fractionation in C_3 land plants. *Geochimica et Cosmochimica Acta 96,* 29-43

Schubert B. A., & Jahren A. H. (2018). Incorporating the effects of photorespiration into terrestrial paleoclimate reconstruction. *Earth-Science Reviews 177*,637-642

Talhelm A. F., Pregitzer K., Kubiske M., Zak D., Campany C., Burton A. (2013). Elevated CO_2 and O3 alter productivity and carbon storage in Northern Temperate Forests: results from Aspen FACE. *AGUFM, 2013,* B21A-0461.

Tieszen L. L. (1991). Natural variations in the carbon isotope values of plants: implications for archaeology, ecology, and paleoecology. *Journal of Archaeological Science 18*(3), 227-248

Tipple B. J., Meyers S. R., Pagani M. (2010). Carbon isotope ratio of Cenozoic CO_2: a comparative evaluation of available geochemical proxies. *Paleoceanography 25*(3).

Tognetti R., Minnocci A., Penuelas J., Rachi A., Jones M. B. (2000). Comparative field water relations of three Mediterranean shrub species co-occurring at a natural CO_2 vent. *Journal of Experimental Botany 51*(347), 1135-1146.

Troughton J. H., & Card K. A. 1975. Temperature effects on the carbon-isotope ratio of C_3, C_4 and Crassulacean-acid-metabolism (CAM) plants. *Planta 123*(2), 185-190

Trudinger C. M., Enting I. G., Francey R. J., Etheridge D. M., Rayner P. J. (1999). Long-term variability in the global carbon cycle inferred from a high-precision CO_2 and $\delta^{13}C$ ice-core record. *Tellus B: Chemical and Physical Meteorology 51*(2), 233-248

Van de Water P. K., Leavitt S. W., Betancourt J. L. (2002). Leaf $\delta^{13}C$ variability with elevation, slope aspect, and precipitation in the southwest United States. *Oecologia 132*(3), 332-343

Wang R., Yu G., He N., Wang Q., Zhao N., Xu Z., Ge J. (2015). Latitudinal variation of leaf stomatal traits from species to community level in forests: linkage with ecosystem productivity. *Scientific Reports 5*, 14454

Wehr R., & Saleska S. R. (2015). An improved isotopic method for partitioning net ecosystem-atmosphere CO_2 exchange. *Agricultural and Forest Meteorology 214–215*, 515-531

Wernerehl R. W., & Givnish T. J. (2015). Relative roles of soil moisture, nutrient supply, depth, and mechanical impedance in determining composition and structure of Wisconsin prairies. *PLOS ONE 10*(9), e0137963

White J. W. C., Vaughn B. H., Michel S. E. (2015). University of Colorado, Institute of Arctic and Alpine Research (INSTAAR), stable isotopic composition of atmospheric carbon dioxide (^{13}C and ^{18}O) from the NOAA ESRL carbon cycle cooperative global air sampling network, 1990–2014. Version 2015-10-26 software.

Wickham H. (2016). ggplot2: elegant graphics for data analysis. New York: Springer-Verlag.

Woodward F. I. (1987). Stomatal numbers are sensitive to increases in CO_2 from pre-industrial levels. Nature 327(6123):617-618

Woodward F. I., & Bazzaz F. A. (1988). The responses of stomatal density to CO_2 partial pressure. Journal of Experimental Botany 39(12), 1771-1781

Yonetani T., & Gordon H. B. (2001). Simulated changes in the frequency of extremes and regional features of seasonal/annual temperature and precipitation when atmospheric CO_2 is doubled. *Journal of Climate 14*(8), 1765-1779

Zhang Y. G., Pagani M., Liu Z., Bohaty S. M., DeConto R. (2013). A 40-million-year history of atmospheric CO_2. *Philosophical Transactions of the Royal Society: Mathematical, Physical and Engineering Sciences 371*(2001), 20130096

CHAPTER III

C_3 Plant Carbon Isotope Discrimination Does Not Respond to CO_2 Concentration on Decadal to Centennial Timescales[2]

3.1 Abstract

(1) Plant carbon isotope discrimination is complex, and could be driven by climate, evolution, and/or edaphic factors. We tested the climate drivers of carbon isotope discrimination in modern and historical plant chemistry, and focus in particular on the relationship between rising [CO_2] over Industrialization and carbon isotope discrimination.

(2) We generated temporal records of plant carbon isotopes from museum specimens collected over a climo-sequence to test plant response to climate and atmospheric change over the past 200 years (including *Pinus strobus, Platycladus orientalis, Populus tremuloides, Thuja koraiensis, Thuja occidentalis, Thuja plicata, Thuja standishii, Thuja sutchuenensis*). We aggregated our results with a meta-analysis of a wide range of C_3 plants to do a comprehensive study of the distribution of carbon isotope discrimination and values among different plant types.

(3) We show that climate variables (e.g. mean annual precipitation, temperature, and *key to this study*, CO_2 in the atmosphere) do not drive carbon isotope discrimination.

(4) Plant isotope discrimination is intrinsic to each taxon, and could link phylogenetic relationships and adaptation to climate quantitatively over ecological to geological time scales.

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3.2 Introduction

Plants grow in direct contact with the changing atmosphere and surrounding environment, so they have the potential to record changes in environmental conditions and related stress (Farquhar et al. 1989; Arens et al. 2000). The carbon isotope chemistry of plants has been used by both the geological and ecological scientific communities to monitor climate change, plant biochemistry, and plant productivity (e.g. Feng et al. 1999; Diefendorf et al. 2010; Kohn 2010). Carbon isotope discrimination in plants (represented by $\Delta^{13}C_{plant}$ values) is the combined effects of fractionation selecting for light carbon due to diffusion through the leaf surface (^{12}C; 4.4‰; noted as "a" in Equation 3.1), fractionation due to Rubisco's selective preference for light carbon (27–30‰; noted as "b" in Equation 3.1), and an array of biochemical and environmental factors that are sometimes collectively termed "water use efficiency" (c_i/c_a is the ratio of internal to atmospheric CO_2 concentration; Equation 3.1; e.g. Farquhar et al. 1989).

$$\Delta^{13}C_{plant} = a + (b - a)\,\frac{C_i}{C_a} \quad \text{(Equation 3.1)}$$

Plant carbon isotope discrimination ($\Delta^{13}C_{plant}$) represents the difference between the isotopic composition of the atmosphere ($\delta^{13}C_{CO2}$) and plants ($\delta^{13}C_{plant}$; Farquhar et al. 1989; Feng et al. 1999; Equation 3.2).

$$\Delta^{13}C_{plant} = \frac{\delta^{13}C_{CO_2} - \delta^{13}C_{plant}}{1 + \frac{\delta^{13}C_{plant}}{1000}} \quad \text{(Equation 3.2)}$$

Scientists typically interpret carbon isotope values ($\delta^{13}C_{plant}$) and $\Delta^{13}C_{plant}$ values as related to and affected by environmental drivers like mean annual precipitation (Diefendorf et al. 2010; Kohn 2010; Kohn 2016) or the amount of carbon dioxide in the atmosphere ($[CO_2]$; Schubert and Jahren, 2012; Cui and Schubert, 2016; Cui & Schubert 2020), or to reflect a fundamental plant trait with variability due to local effects like edaphic factors (Araus et al. 2002; Bonal et al. 2007). Our ability to use carbon isotope discrimination as recorded in plants to think about either past or future problems is dependent on understanding which combination of those factors drive discrimination.

3.2.1 Background

The direct interaction that plants have with the environment around them makes it such that leaf (and other plant part) tissues record environmental conditions (Schlanser et al. 2020). Global change biologists and geologists aim to leverage this fact in order to look at past ecosystems and to understand biotic responses to elevated carbon dioxide concentration of the atmosphere ($[CO_2]$) as well as related changes in seasonal and annual temperature, evapotranspiration, and precipitation (Jones et al. 1998). Previous studies have suggested that $\Delta^{13}C_{plant}$ values are sensitive to changes in $[CO_2]$ (Ehleringer & Cerling 1995; Schubert & Jahren 2012) and workers have proposed a $\Delta^{13}C_{plant}$-paleobarometer to reconstruct $[CO_2]$ in the fossil record based upon those empirical relationships (Schubert & Jahren 2012; Cui & Schubert 2017). In this scenario, $\Delta^{13}C_{plant}$ values increase as the pool of available CO_2 increases, indicating that the mechanism of $[CO_2]$ uptake is altered in response to elevated $[CO_2]$ (Cornwell et al. 2018). Other studies have argued that water use efficiency, c_i/c_a (Equation 3.1), is not constant and that plants modify their leaf gas exchange properties in response to CO_2, meaning that discrimination and CO_2 cannot be directly linked (Ehleringer & Cerling 1995; Beerling & Royer 2002).

$\Delta^{13}C_{plant}$ values also are cited as representative of intrinsic water use efficiency (iWUE; Farquhar & Richards 1984; Farquhar et al. 1989; Araus et al. 2002; Bonal et al. 2007); this is likely related to evolutionary components. If $\Delta^{13}C_{plant}$ values are genetically influenced, members of the same species should have constant $\Delta^{13}C_{plant}$ values (with minor variability within a species related to genotypic diversity and local environmental factors regardless of global drivers). Because genetic and edaphic drivers are measurable in the present, relationships between $\Delta^{13}C_{plant}$ and those drivers can be used directly to predict future ecosystem response to local and regional environmental change (Ainsworth & Long 2005; Nowak et al. 2004; Mueller et al. 2016; Yan et al. 2017). An additional implication of using $\Delta^{13}C_{plant}$ values as intrinsic traits is that other variables used to link physiologically-driven fractionation to isotopic values (Equation 3.1) become solvable. These assumptions still have geological implications: if climate variables are not driving $\Delta^{13}C_{plant}$ values, variability in $\Delta^{13}C_{plant}$ values is still representative of water use efficiency (Equation 3.1), which can be reconstructed in deep time to reconstruct water stress of a plant. However, due to the difficulty of measuring genetic diversity in the fossil record and the infrequency of coeval fossil soil and plant preservation due to different taphonomic filters (Looy

2014), the scope of $\Delta^{13}C_{plant}$ applications would be more limited for geologic problems or attempts to use the geologic record to project future change. Furthermore, most ecological validation studies of this concept have been based on single site or single taxon data collection or on short-term free-air concentration experiments (FACE) where environmental variability has either not been considered or has only been examined over short (< 10 years) time periods. As a result, questions remain about whether relationships observed in short-term records (e.g. on annual scale) would persist over the longer time periods necessary to project the impacts of future climate change.

If the previously proposed relationship between $\Delta^{13}C_{plant}$ and [CO_2] is consistent across plants, it indicates that overall, plants are responsive and adaptive to [CO_2] in real time. This paleobarometer potentially circumvents common problems of other deep-time paleo-barometric tools, like high error at high CO_2 concentrations or issues with statistical robustness, taphonomic bias, effects specific to certain taxonomy, and convolved environmental effects (e.g., oceanographic; Royer et al. 2004). The relationship between $\Delta^{13}C_{plant}$ and [CO_2] has been tested previously in growth chamber experiments (Cui & Schubert 2017; Lomax et al. 2019) and fossil plants directly with an independent proxy constraint on CO_2 (Schlanser et al. 2020). Growth chamber experiments showed increased $\Delta^{13}C_{plant}$ values with increasing [CO_2] in *Arabidopsis thaliana* (thale cress) and *Raphanus sativus* (wild radish), two weedy herbaceous angiosperms. This relationship was substantiated with selectively sampled literature values to demonstrate that sensitivity (S) of plant isotopic response to [CO_2] peaked ~200 ppm with S = 0.03‰ ppm^{-1} increase in discrimination and began to flatten around 1000 ppm with values closer to S = 0.0025‰ ppm^{-1} (Schubert & Jahren 2012). The highest sensitivity values were collected from literature, but Shubert and Jahren's (2012) meta-analysis specifically only sampled studies that saw increases in discrimination with [CO_2], excluding all studies that did not. Each of the species used to create this model have completely sequenced genomes and have been widely studied as model organisms; in addition to well-constrained biochemistry, these species are both easy to grow quickly for real-time experiments. Results from experiments using *A. thaliana* and *R. sativus* have been extrapolated to other groups of plants (Schubert & Jahren 2012; Shen et al. 2013; Cui et al. 2020). This empirically-derived relationship has been used with carbon isotope measurements in fossils ($\delta^{13}C_{fossil}$) to reconstruct [CO_2] during geologic warm periods (Cui & Schubert, 2017; Cui et al. 2020), and has been used as evidence to support a future plant

response to anthropogenically-driven rise in [CO_2]. When Lomax et al. (2019) attempted to use $\Delta^{13}C_{plant}$ as a paleobarometer in growth chamber experiments with varied water regimes, they found that low water availability led to under-predicting [CO_2] values for high [CO_2] treatments designed to simulate most of the geologic past. This suggests that [CO_2] cannot be implicated as the main driver for carbon isotope discrimination without considering water availability, but even this may be further complicated by evolution. The studies used to formulate a $\Delta^{13}C_{plant}$ - paleobarometer model have not distinguished plant growth rate nor plant growth habit, and have assumed that there is no difference between angiosperms and any other type of plant. *Raphanus* and *Arabidopsis* have limited fossil records (Miocene–present; e.g., Beilstein et al., 2010) and first evolved during periods of low [CO_2]; therefore, there are questions about the reliability of a *Raphanus sativus*- *Arabidopsis thaliana*-focused model as a paleobarometer for a high CO_2 world or for non-angiosperm plants. This approach to study the relationship between [CO_2] and $\Delta^{13}C_{plant}$ is high resolution and well-controlled, and assumes that [CO_2] is the main driving factor and does not address other climate and edaphic factors (e.g. soil moisture, nitrogen and nutrient availability, salinity; Bowman et al. 1989; Condon et al. 1992; Högberg et al. 1993; Guehl et al. 1995; Dawson et al. 2002).

Additional geological studies to examine the relationship between [CO_2] and $\Delta^{13}C_{plant}$ values in deep time have mixed results. Paleogene plants collected from the Paleocene Fort Union Formation and the Eocene Willwood Formation demonstrate no observable response to large changes in [CO_2] (Diefendorf et al. 2015). Kohn (2016), however, found a small gradual increase in $\Delta^{13}C_{plant}$ values in Pleistocene-Holocene sediments, that, when corrected for mean annual precipitation, could be linked to increased [CO_2]. However, this same study found a slight decrease in $\Delta^{13}C_{plant}$ values in Pleistocene and Tertiary herbivore data (Kohn 2016). Recent work using leaf waxes collected from sediments of both the Cretaceous and Oligocene shows that $\Delta^{13}C_{plant}$ values in these sediments had no clear positive [CO_2]-dependence and in fact, responded negatively, perhaps related to adaptation to minimize water loss (Schlanser et al. 2020). Testing in geological sediments is important and relevant to the utility of this paleobarometer, but would be strengthened by adding an additional timescale between prior geologic studies and growth chamber experiments.

To test to what extent $\Delta^{13}C_{plant}$ values of plants are responsive to changes in [CO_2] and how taxon-specific is this response, we turned to Industrialization as a natural experiment. This historical approach has the benefits of high-resolution, semi-annual data while also accounting for natural influence from environmental, edaphic, and other variables that would be seen in the fossil record and can offset changes in water use efficiency and $\Delta^{13}C_{plant}$ (Giguère-Croteau, et al. 2019). In this study, we measured $\Delta^{13}C_{plant}$ response to the Industrialization-driven rise in [CO_2] in several plant species; non-barometric climate variables are not controlled but are constrained and considered. Industrialization (1850–present) provides a unique, natural [CO_2] enrichment "experiment" wherein [CO_2] values range from 280 ppm to nearly 420 ppm (i.e., an increase of ~50%), allowing us to track actual plant $\Delta^{13}C_{plant}$ responses to rising [CO_2]. Previous works have tested the relationship of $\Delta^{13}C_{plant}$ values to environmental, edaphic, and genetic factors among modern plants (e.g. Cornwell et al. 2018). However, most of those studies reflect only present-day or near present-day CO_2 levels and only rarely have tracked the long-term (> 100 years) response of individual species (e.g. Stein et al. 2019). Based upon growth chamber experiments, Industrialization provides a range of [CO_2] wherein plant $\Delta^{13}C_{plant}$ responses are thought to be extremely sensitive (Schubert & Jahren 2012). In tandem with changes in [CO_2], the isotopic composition of atmospheric CO_2 has changed significantly over this time due to the burning of fossil fuels (from a value of -6.7 to -8.5‰; Keeling et al. 2001), allowing us to examine changes in $\Delta^{13}C_{plant}$ versus changes in $\delta^{13}C_{plant}$ values (Fig. 3.1a-c) during this interval.

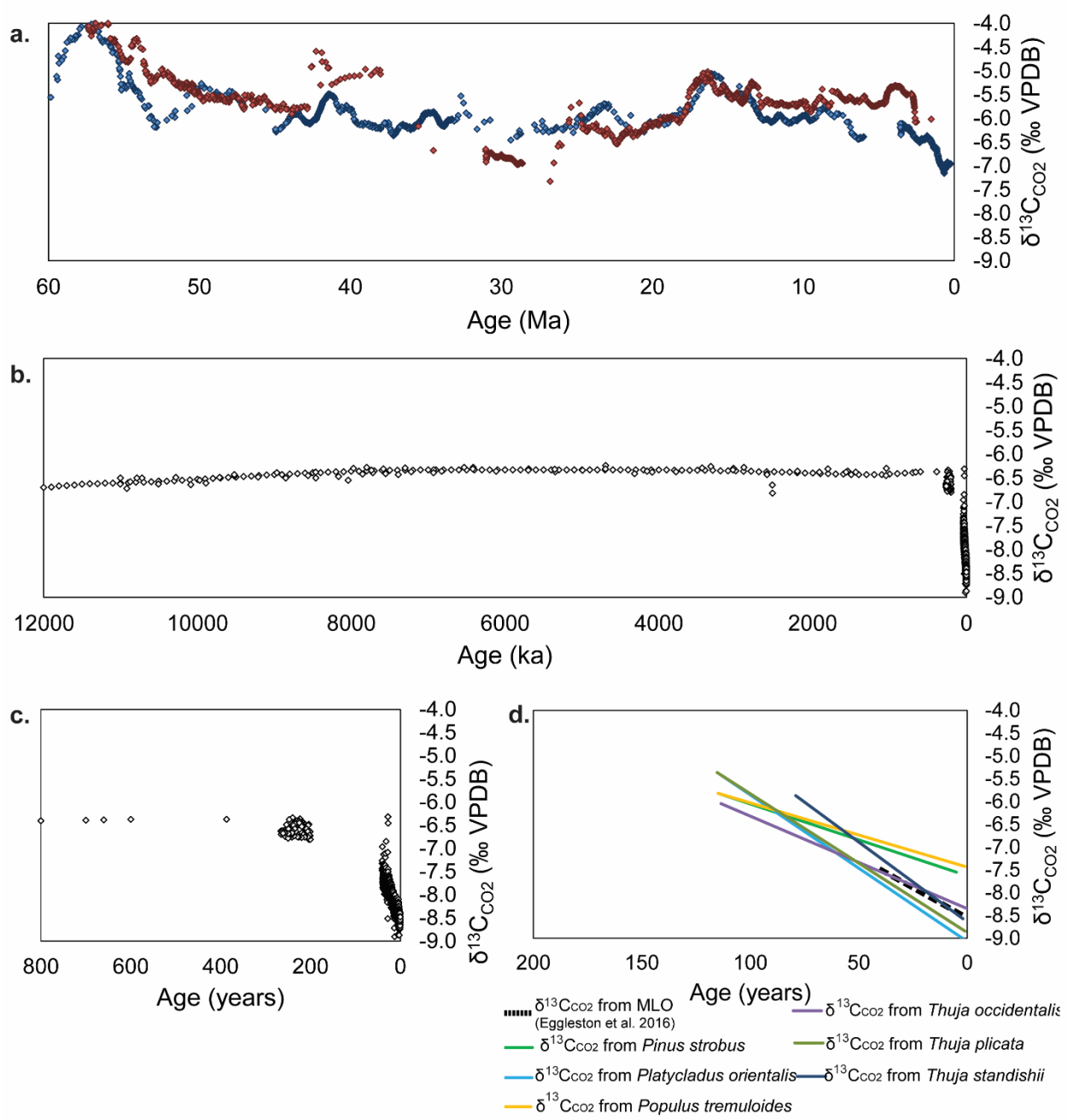

Figure 3.1 Evolution of $\delta^{13}C_{CO2}$ (‰) over time, including the Cenozoic, 12,000 years ago, the past 800 years, and the past 200 years including values reconstructed from $\delta^{13}C_{leaf}$ values. (a) 60 million years ago to present, with red diamonds representing values reconstructed using planktonic foraminifera and blue diamonds representing values reconstructed using benthic foraminifera (Tipple et al. 2010), (b) over the last 12,000 years with white diamonds representing $\delta^{13}C_{CO2}$ from ice cores (Elsig et al. 2009, Bauska et al. 2018), (c) over the past 800 years with white diamonds representing $\delta^{13}C_{CO2}$ from ice cores (Elsig et al. 2009, Bauska et al. 2018), (d) over Industrialization, 200 years ago to present, including $\delta^{13}C_{CO2}$ values as measured from Mauna Loa Observatory (MLO; Keeling et al. 2001, Keeling et al. 2005, Eggleston *et al.*

2016) and $\delta^{13}C_{CO2}$ values reconstructed using $\Delta^{13}C_{plant}$ values from six species we collected ($n \geq 10$ specimens).

The high-resolution temporal datasets tracking several species are supplemented by modern samples of the same species, to examine whether there are relationships between other climate variables and $\Delta^{13}C_{plant}$ values (Sheldon et al. 2020). In addition, we have compiled $\delta^{13}C_{plant}$ values and calculated $\Delta^{13}C_{plant}$ values for a wide range of herbaceous and woody C_3 plants to compare between plant groups and growth strategies. Compiled literature data include herbaceous and woody angiosperms, and bryophytes (Fig. 3.3, Supp. Figs. B2; B3–Supp. Table B1). The total dataset includes 2585 isotope analyses, with data collected for this study accompanied with measured climate variables.

3.3 Materials and Methods

We used records from 11 herbaria and museum collections facilities (COLO, CS, F, HMAS, KHD, KUN, MICH, MSC, SG, WTU, YU) to evaluate the relationship between carbon isotope chemistry ($\Delta^{13}C_{plant}$ and $\delta^{13}C_{plant}$) and changing environmental drivers of a number of woody gymnosperms species and one woody angiosperm over the period of Industrialization. We collected modern gymnosperm (2015-2019) leaf material from across the Northern Hemisphere (n = 469) of *Pinus strobus, Platycladus orientalis, Thuja koraiensis, Thuja occidentalis, Thuja plicata, Thuja standishii,* and *Thuja sutchuenensis* as well as additional modern species from another angiosperm, *Populus tremuloides* species (n = 1264 total specimens for modern and historical specimens, combined) from between 1806 and 2019, spanning a wide range of climate conditions (Table B2). Specimens were washed in deionized (DI) water within an ultrasonic bath for thirty minutes to remove herbarium glue and other sediments, then dried in a 50°C oven for 48 hours, and finally ground to homogeneity with an agate mortar and pestle. Ground specimens were stored in air-tight glass vials within sealed chambers with desiccant to absorb water vapor. Specimen aliquots were weighed into tin capsules from 0.600 mg to 0.800 mg and run on a Picarro Cavity Ring Down Spectroscope (CRDS) for $\delta^{13}C$ values, with official IAEA standards (IAEA-CH6: sucrose, $\delta^{13}C$ = -10.45‰; IAEA-600: caffeine, $\delta^{13}C$ = -27.77‰) and laboratory internal standards (C_3 sugar: $\delta^{13}C$ = -26.14‰, C_4 sugar: $\delta^{13}C$ = -12.71‰, acetanilide: $\delta^{13}C$ = -28.17‰). CRDS machine specifications

indicate reproducibility of ± 0.3‰, but our standard reproducibility was ± 0.12‰. These same specimens were also run on a Costech Elemental Analyzer for %C and %N and C:N ratio using laboratory standards (acetanilide: 71.09%C, 10.34%N, and atropine: 70.56%C, 4.84%N) in University of Michigan's Earth System Science Laboratory.

Climate variables (MAP, MAT, Maximum Summer Temperature) associated with each specimen were obtained from PRISM Climate Group (Prism Climate Group 2004) for samples obtained in the contiguous United States and WorldClim (version 2 at 2.5km resolution; Fick & Hijmans 2017) and Vostok Ice Core ($[CO_2]$, $\delta^{13}C_{CO2;}$ White et al. 2015). Altitude and latitude were also gathered for samples and compared to isotope analysis results. $\Delta^{13}C_{plant}$ values were calculated using $\delta^{13}C_{CO2}$ as collected from the Vostok Ice Core and Mauna Loa Observatory (White et al. 2015) using Equation 3.2 (e.g. Feng et al. 1999; Diefendorf et al. 2010).

We compared our historical findings regarding the relationship between $\delta^{13}C_{plant}$ values and $\delta^{13}C_{CO2}$ with Arens et al.'s (2000) generalized empirical relationship between $\delta^{13}C_{plant}$ values and $\delta^{13}C_{CO2}$ values in C_3 plants (Equation 3.3).

$$\delta^{13}C_{plant} = 1.05(\delta^{13}C_{CO2}) - 18.72\ (Arens\ et\ al. 2000) \text{ (Equation 3.3)}$$

Additional carbon isotopic values were obtained from previously published studies with coincident $[CO_2]$ and $\delta^{13}C_{CO2}$ values to compare this study's focal plant results with a wider range of plant functional types (n = 2585; Dataset B1). We excluded all genera and families with fewer than 20 and 25 isotopic measurements (respectively) when comparing taxa and isotope discrimination values, but included these in plant habit or plant reproductive group comparisons. To test whether these genera, families, and/or plant habits/reproductive strategies $\Delta^{13}C_{plant}$ values had the same mean and variances as the $\Delta^{13}C_{plant}$ values from the Schubert & Jahren (2012) study, we conducted F-tests where the null hypothesis was equal variance, then conducted two sample t-tests assuming unequal variances wherein the null hypothesis was equal mean values (Table B3). We included analysis of plant specimens grown under $[CO_2]$ values from 280–1000 ppm, because although atmospheric $[CO_2]$ is ~410 ppm at present, concentrations of CO_2 as high as 1800 ppm have been observed at ground level within very dense canopy on a very nutrient-rich Mollisol (Bazzaz & Williams 1991) – to account for this potential fluctuation, of our sites,

we included values for plants grown at [CO_2] levels up to 1000 ppm. We excluded values from the literature from plants that were grown at >1000 ppm.

Equation 3.4 (Cui & Schubert 2016) was used to reconstruct values of [CO_2] for each isotope value we collected, then compared reconstructed values with our known values collected from Mauna Loa Observatory and ice cores (Prism Climate Group 2004; White et al. 2015).

$$\Delta^{13}C = [(28.26)(0.21)(pCO_2 + 25)]/[28.26 + (0.21)(pCO_2 + 25)]$$ (Schubert & Jahren 2012; Cui & Schubert 2016; Equation 3.4)

where 28.26 represents A, the maximum fractionation value, while 0.21 and 25 represent B and C, constants derived iteratively to find the best fit curve, and pCO_2 = [CO_2] (Cui & Schubert 2016).

3.4 Results

Six of the eight focal species showed significant shifts in $\delta^{13}C_{plant}$ in tandem with $\delta^{13}C_{CO2}$ values. These plants (*Pinus strobus, Platycladus orientalis, Populus tremuloides, Thuja occidentalis, Thuja plicata, Thuja standishii*), when corrected for each species' average $\Delta^{13}C_{plant}$ values, demonstrated changes in $\delta^{13}C_{CO2}$ over Industrialization comparable to those recorded in ice and at Mauna Loa Observatory (Fig. 3.1c-d). *Populus tremuloides* displayed a slope and intercept similar to the generalized relationship found in the Arens et al. (2000) study (1.08 and -18.77, respectively), though the gymnosperms tested had different responses in $\delta^{13}C_{plant}$ values to changing $\delta^{13}C_{CO2}$ (Table B4). The other focal species (*Thuja koraiensis, Thuja sutchuenensis*) did not span a sufficient period of time to examine the direction; *Thuja sutchuenensis* was only rediscovered recently (Qiaoping et al. 2002) after over a century of being listed as extinct in the wild (EW) by IUCN standards.

Over the span of Industrialization, none of the eight species studied showed any significant changes in $\Delta^{13}C_{plant}$ nor significant relationship with [CO_2] (Fig. 3.2 shows the four largest datasets; others are plotted in Supp. Fig. B3). We examined changes in sensitivities for all data, and for pre-1960 values (280–320 ppm) and post-1960 values (320–410 ppm), with 1960 representing where slope changes in [CO_2] increase due to more rapid industrialization of developing nations (Keeling et al. 2001; MacFarling et al. 2006) (Table B5). Of the seven

species with pre-1960 data points (<320 ppm [CO_2]) and post-1960 values (>320 ppm [CO_2]), only two (*Thuja standishii* and *Thuja occidentalis;* Cupressaceae) showed a change in sensitivity to [CO_2], and both declined rather than increasing as would have been predicted by growth chamber experiments. The sensitivity to [CO_2] (*S*; change in ‰ of $\Delta^{13}C_{plant}$ per ppm of [CO_2]) exhibited by *Arabidopsis thaliana* and *Raphanus sativus* in growth chamber experiments was not observed in any of the Industrialization-spanning historical records (Table B5). In fact, we found negative shifts in *S* for *Populus tremuloides* (Salicaceae) and *Thuja koraiensis*; none of the modern/historical species exhibited sensitivity to [CO_2] similar to the growth chamber experiments of Schubert & Jahren (2012).

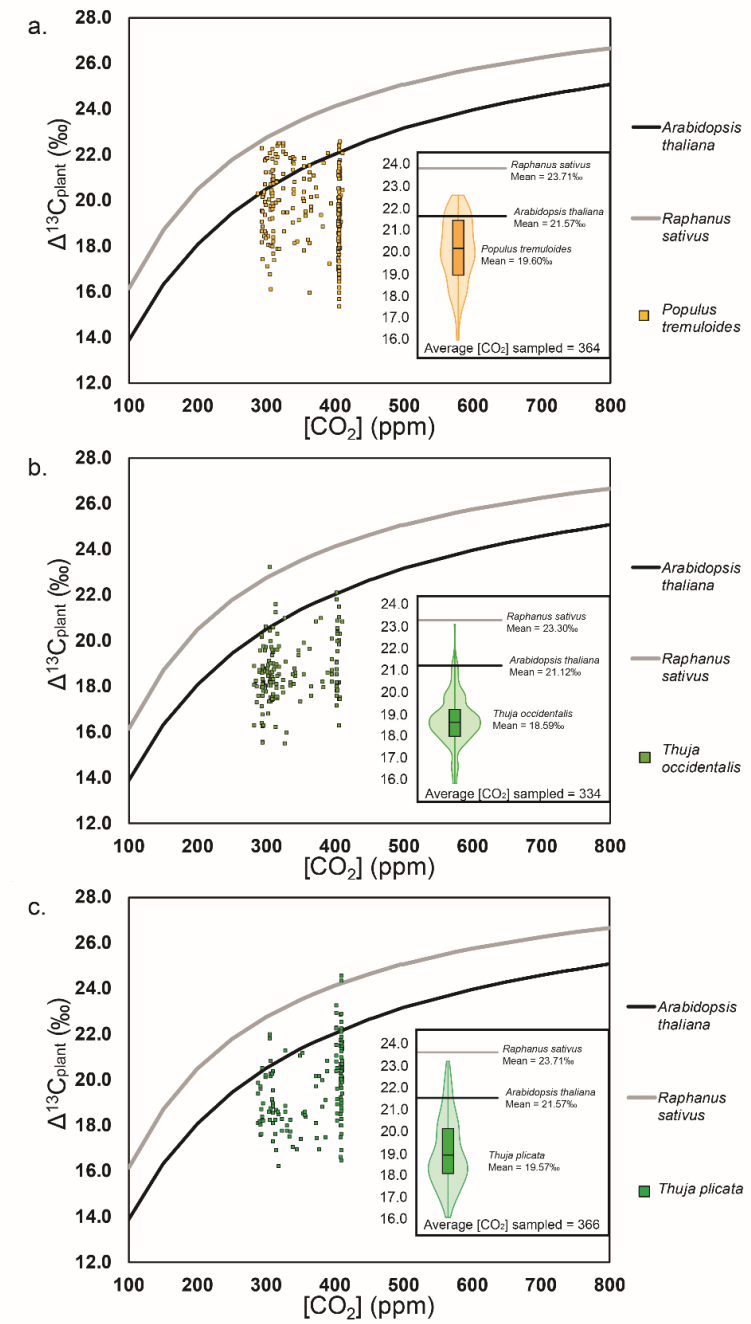

Figure 3.2 [CO_2] values plotted against $\Delta^{13}C_{plant}$ for species with high-resolution records of the period of Industrialization. Data are for: (a) *Populus tremuloides* (quaking aspen), (b) *Thuja occidentalis* (northern white cedar), and (c) *Thuja plicata* (western red cedar). The outer panel shows change in $\Delta^{13}C_{plant}$ vs. [CO_2] over Industrialization, while the inner panel shows the range and distribution of $\Delta^{13}C_{plant}$ values for this species. Each of the species occupies different geographic ranges and different ranges of climatic variability, but none shows a significant $\Delta^{13}C_{plant}$ response to rising [CO_2] over the period of Industrialization.

This study compares $\Delta^{13}C_{plant}$ values of *Arabidopsis* and *Raphanus* with a breadth of C_3 plant functional types, representing taxa with different reproduction styles (angiosperms, gymnosperms, and bryophytes), growth habits (woody and herbaceous), and vascular systems (vascular and non-vascular). When comparing the long historical records of $\Delta^{13}C_{plant}$ with modern data from a variety of plant types from the literature, we found a distinct difference between gymnosperms, woody angiosperms, herbaceous angiosperms, and bryophytes, and *A. thaliana* and *R. sativus* for any CO_2 level <1000 ppm (Fig. 3.3). This was true even for other herbaceous, fast-growing members of the same family as the $\Delta^{13}C_{plant}$-paleobarometer model organisms (Brassicaceae; *A. thaliana, R. sativus*). Values above 1000 ppm are unlikely to be found at woody tree sampling height (~1–2m), despite the source of soil-respired CO_2 rising from the ground (Bazzaz & Williams 1991). When performing a t-test for the mean values of each of these plant functional types as compared to the two tested weeds, we found that all of the tested differences were statistically significant (Fig. 3.3; Fig. B1; Table B3), indicating that none of the wild-grown species were behaving like the growth chamber experiments. When further analyzed at higher taxonomic levels, all genera and families showed statistically different $\Delta^{13}C_{plant}$ values than *A. thaliana* and *R. sativus.*

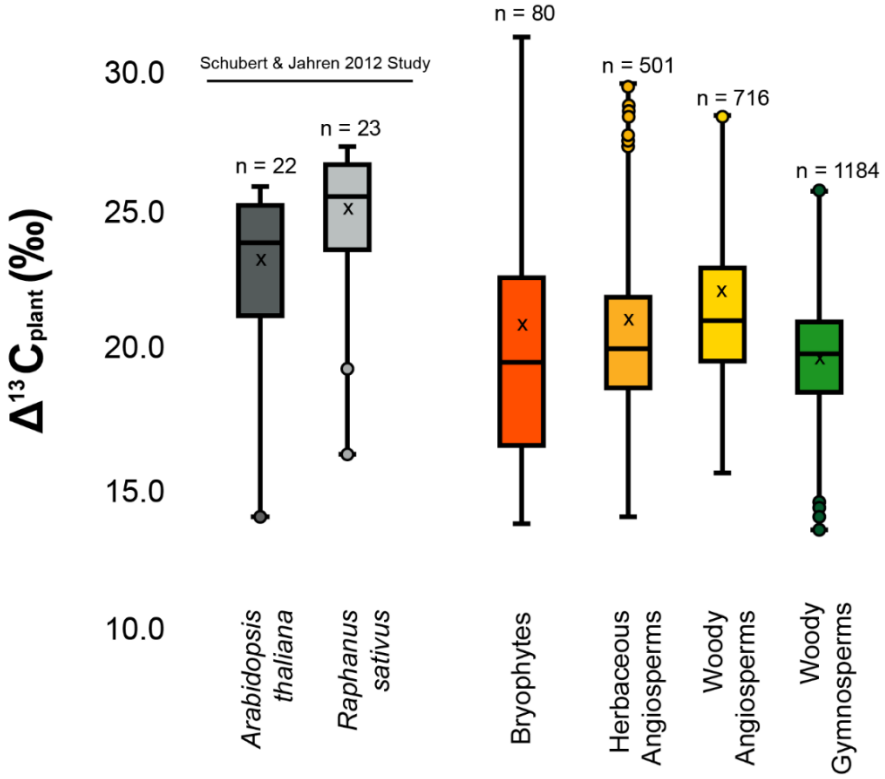

Figure 3.3 $\Delta^{13}C_{plant}$ values of plants divided by growth form, as collected from literature and this study. Meta-analysis plants are shown in color, compared to *Arabidopsis* and *Raphanus* values in grey. Xs denote mean values and circles denote outlier $\Delta^{13}C_{plant}$ values. Boxes show 75th percentile of data, while whiskers show remaining 25th percentile of data.

To test the idea that $\Delta^{13}C_{plant}$ should be related to [CO_2], we compared the measured [CO_2] with [CO_2] reconstructed using an empirical relationship derived from growth chamber experiments (see *Methods*, Equation 3.4). The actual [CO_2] values showed no significant relationship with reconstructed [CO_2] values (Fig. 3.4; p-value = 0.63); often the model-reconstructed [CO_2] values underestimated measured [CO_2] (Fig. 3.4), which is consistent with other recent growth chamber experiments that included water stress as a variable (Lomax et al. 2019). Thus, we find no evidence that $\Delta^{13}C_{plant}$ is related to [CO_2]. Instead, the historical data showed consistent linear relationships between $\delta^{13}C_{plant}$ and $\delta^{13}C_{CO2}$ for all tested species, with each having a slope close to 1:1 (Stein et al. 2019; Sheldon et al. 2020), and where the observed $\delta^{13}C_{atm}$ values correspond closely to $\delta^{13}C_{atm}$ values reconstructed using $\delta^{13}C_{plant}$ measurements (Fig. 3.1d). In addition, most individual measurements of a given species' $\Delta^{13}C_{plant}$ value are within ± 1.5 ‰ of the mean $\Delta^{13}C_{plant}$ value found for that species, independent of other climate variables (Fig. 3.3; Fig. B2; Fig. B3; Sheldon et al. 2020).

3.5 Discussion

3.5.1 Carbon isotope discrimination and [CO_2]

Our results indicate that $\Delta^{13}C_{plant}$ values are not driven by [CO_2] for any of the studied plants. $\Delta^{13}C_{plant}$ values remained flat for a given genus, plant functional type, and species as [CO_2] increased over Industrialization (Fig. 3.2; Fig. B1). $\delta^{13}C_{plant}$ values, in contrast, closely tracked observed changes in $\delta^{13}C_{CO2}$ driven by human-combusted fossil fuels, which are isotopically more negative than natural CO_2 sources (i.e. volcanic emissions; Keeling et al. 2001). $\delta^{13}C_{plant}$ values tracked $\delta^{13}C_{CO2}$ in multiple species, though individual species exhibited stronger or weaker carbon isotope discrimination. Our study confirms the previously evaluated connection between $\delta^{13}C_{plant}$ values and atmospheric CO_2 sources in the geologic record (Arens et al. 2000).

Regardless of growth habit or reproductive mode (i.e., angiosperm versus gymnosperm; seed vs. spore), the newly collected data and collated literature values for our aggregate meta-analysis exhibited $\Delta^{13}C_{plant}$ values significantly lower than expected under current and historic [CO_2] ranges based upon growth-chamber derived values. These results indicate $\Delta^{13}C_{plant}$ values of all of our tested plants, including herbaceous, fast-growing plants and bryophytes, which are known for their high discrimination against ^{13}C due to their primitive vascular system (Rundel et al. 1979; Proctor et al. 1992; Royles et al. 2016), are driven by something other than the atmospheric [CO_2]. Thus, previously observed $\Delta^{13}C_{plant}$-[CO_2] dependence may instead represent an intrinsic trait of a limited range of highly water-use efficient, weedy plants, may reflect plant response under unnaturally consistent conditions in growth chambers, or may be related to the range of [CO_2] studied or length of study. This affirms previous findings that though short-term [CO_2] enhancement experiments can result in increased $\Delta^{13}C_{plant}$ values, decadal-scale plant responses, like adjustment of stomatal size and density, counteract this effect (Peñuelas & Azcón-Bieto 1992; Saurer et al. 2004; Diefendorf & Freimuth 2017). This is important for modern ecological studies that look to extrapolate broad implications from smaller, shorter, and/or local experiments. We add a note of caution not to over-generalize results.

While our historical records confirm that the $\Delta^{13}C_{plant}$-paleobarometer typically under-predicted [CO_2] in the natural world (Fig. 3.4), in the context of previous findings (Stein et al. 2019; Sheldon et al. 2020), we interpret this as due to $\Delta^{13}C_{plant}$ values being an intrinsic plant trait, and not driven by individual climate parameters. Previous workers (e.g. Kohn 2016, Lomax et al. 2019) have suggested that while there is potential for this $\Delta^{13}C_{plant}$–paleobarometer, climate factors related to water availability (e.g. mean annual precipitation, humidity) and/or nutrient availability (Giguère-Croteau et al. 2019) could confound the relationship between [CO_2] and $\Delta^{13}C_{plant}$ values because of water's fundamental role in controlling photosynthesis and carbon uptake (Diefendorf et al. 2010; Franks et al. 2013). We found that none of those other climate variables significantly impacted the $\Delta^{13}C_{plant}$ at the species to family level, nor did a combination of [CO_2] and precipitation (Stein et al. 2019; Sheldon et al. 2020; Supp. Table B6). The most parsimonious explanation is that the previous $\Delta^{13}C_{plant}$–paleobarometer predicts a much greater sensitivity (*S;* expressed in ‰ $\Delta^{13}C_{plant}$/ppm [CO_2]; Table B5) than is observable in nature; this demonstrates that [CO_2] is not the main driver of $\Delta^{13}C_{plant}$ values based on highly-selected, single or few-species experiments over limited ranges in [CO_2] (e.g. Van de Water et al. 1994; Peñuelas

& Estiarte 1997; Saurer et al. 2004). By sampling a wide range of taxa, we show that the discrepancy between our $\Delta^{13}C_{plant}$ values and those expected based on a $\Delta^{13}C_{plant}$-paleobarometer are not due to the taxa used and that $\Delta^{13}C_{plant}$ values vary between taxa. In other words, $\Delta^{13}C_{plant}$ values are intrinsic to a given taxon; the evolutionary implications of intrinsic discrimination could quantitatively link phylogenetic relationships and adaptation to climate. Variability within species' $\Delta^{13}C_{plant}$ values is related to genotypic diversity and/or unmeasured but relevant-to-growth edaphic effects, but not related to the measured climate drivers and not sensitive to $[CO_2]$.

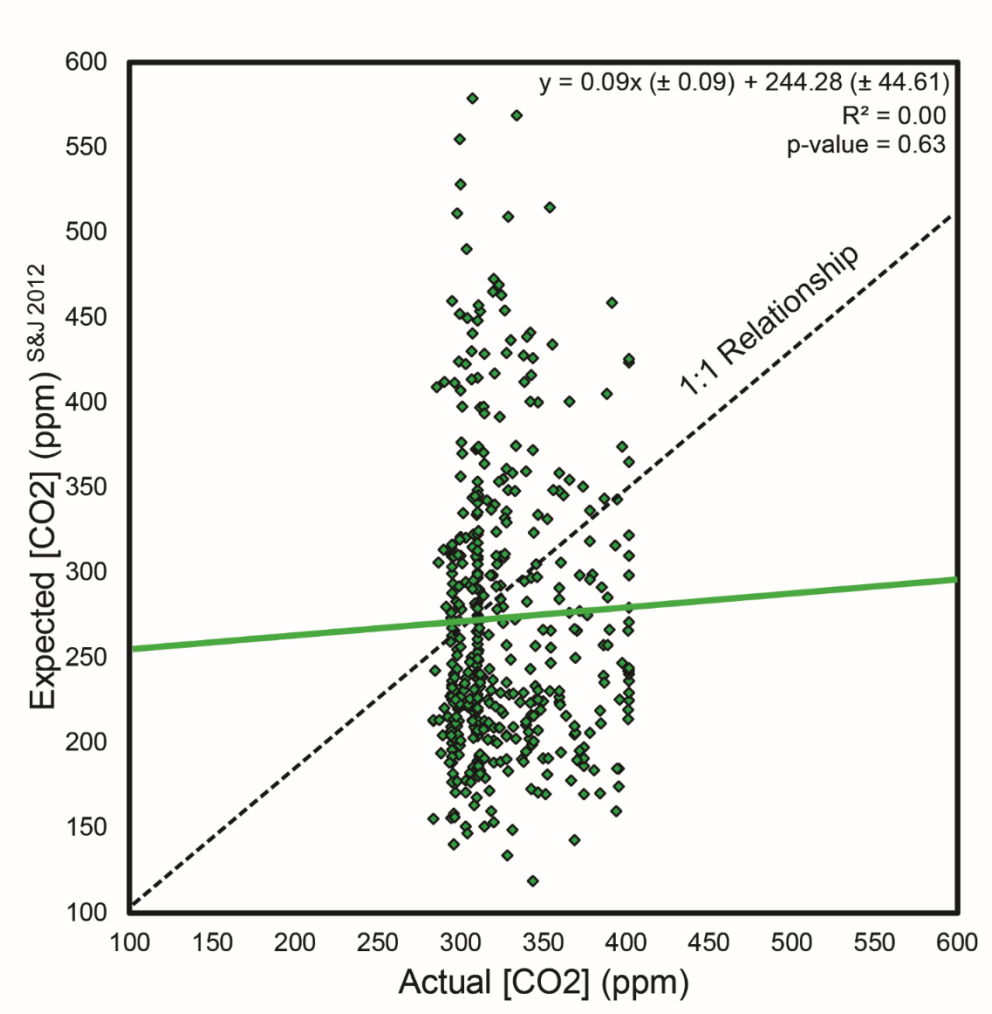

Figure 3.4 $[CO_2]$ (ppm) values as measured at MLO ($[CO_2]_a$), compared to reconstructed $[CO_2]$ values ($[CO_2]_r$) based on the proposed $\Delta^{13}C_{plant}$-paleobarometer (Equation 3.4; Schubert & Jahren 2012; Cui & Schubert 2016). Solid line shows trendline for our data ($[CO_2]_r = 0.09 (\pm 0.09)*[CO_2]_a + 244.28 (\pm 44.61)$; $R^2 = 0.00$, p-value = 0.63), while dashed line shows expected relationship if reconstructed $[CO_2]$ values were equal to measured $[CO_2]$ values ($[CO_2]_r = [CO_2]_a$).

3.5.2 Ancient bio-atmosphere implications

Our results indicate we may be able to use $\delta^{13}C_{plant}$ values to reconstruct paleo-$\delta^{13}C_{CO2}$ values as experimented with in previous studies (i.e. Arens et al. 2000; Fig. 3.1d) given that the other tested environmental factors were not significant drivers of $\delta^{13}C_{plant}$ (Supp. Table B6). We suggest that using species-specific plant-atmosphere isotope relationships to track $\delta^{13}C_{CO2}$, rather than a generalized relationship, will add certainty, and takes a step to address the critiques raised by Beerling & Royer (2002) that the generalized empirical relation by Arens et al. (2000; Equation 3.3) does not account for variability in c_i/c_a within or between plant lineages. While this "universal" relationship based on a range of species works, we found that the responses of each species in our historical dataset to changing $\delta^{13}C_{CO2}$ were different (as represented by equations relating the $\delta^{13}C_{plant}$ values of each species to $\delta^{13}C_{CO2}$ values; Table B4). The woody angiosperm, *Populus tremuloides*, behaved similarly to the generalized relationship found in the Arens et al. (2000) study, but the other species tested, all gymnosperms, had vastly different responses in $\delta^{13}C_{plant}$ values to changing $\delta^{13}C_{CO2}$. This highlights the importance of evolution in response to changing climate and atmospheric variables.

For plants with pre-instrument or fossil records, modern $\Delta^{13}C_{plant}$ values are a key input parameter in many other tools (including paleo-barometric techniques) previously applied in the fossil record, and are a key tracer of [CO_2] sources and fluxes in deep time (Franks et al. 2014). With the depth and breadth of our study, we provide robustly constrained $\Delta^{13}C_{plant}$ values of several species (*Thuja occidentalis, Thuja plicata, Pinus strobus, Populus tremuloides*), and validate that $\Delta^{13}C_{plant}$ values are approximately constant. Although carbon isotope discrimination is complex and influenced by many factors (Diefendorf & Freimuth 2017), in tandem with previous works (Mervenne 2015; Stein et al. 2019; Sheldon et al. 2020), we support that many measures of temperature (e.g., MAT, growing season temperature) and moisture (e.g. MAP, wettest three months) do not have predictive relationships with $\Delta^{13}C_{plant}$ values (Supp. Table B6). This means that while there are diagenetic and preservation-related factors to take into account before using $\delta^{13}C_{plant}$ to reconstruct paleo-$\delta^{13}C_{CO2}$, it is plausible to look at relative perturbations in $\delta^{13}C_{CO2}$ in time using plants over time scales from hundreds to millions of years to track

changes in the carbon cycle. This would be an excellent terrestrial complement to Tipple et al.'s (2010) foraminifera–derived $\delta^{13}C_{CO2}$ record and would provide a way to compare marine-terrestrial reconstructions and to time-calibrate major paleoclimatic transitions.

Our results affirm previous experiments that calculated paleo-water use efficiency in *Metasequoia* and *Thuja* fossils based on $\delta^{13}C$ values, which assumed no confounding climate factors (e.g. Sheldon et al. 2020; Supp. Table B6). While $\Delta^{13}C_{plant}$ values should not be used to reconstruct environmental drivers like [CO_2], they can be used to identify water use efficiency in ancient plants. Ancient plants' water use efficiency provides insight into general adaptation to climate events and evolutionary history—a critical aspect of how the past can inform the future (McElwain 2018).

3.5.3 Modern and future climate change

This study's markedly longer duration of the "natural experiments" considered provides context and validation for important shorter experiments, like growth chamber (Lomax et al. 2019) and FACE experiments (Ainsworth & Long 2005; Norby & Zak 2011). These experiments have been used to show short-term plant adaptation to enhanced CO_2 in certain plants, but muted response with longer time and a wider breadth of plant types (Long et al. 2006; Hickler et al. 2011; Norby & Zak 2011). We have demonstrated responses over the entirety of Industrialization, validating the value of those shorter-term experiments for predicting future response. Our results suggest that extending these experiments and incorporating a number of comparative species of different plant functional types grown in the same environment would be useful to determine longer-term and broader plant reactions to elevated CO_2.

If $\Delta^{13}C_{plant}$ values are inherent to species, soil chemistry, a catchment of aboveground ecosystem inputs, may demonstrate relationships with environmental drivers related to the biogeography of plant adaptation and distribution (Cornwell et al. 2018). Previous works have demonstrated that $\Delta^{13}C_{plant}$ values provide insight into plant health associated with measurable genotypic and edaphic effects (Reich et al. 2006); to isolate the effects of these variables, additional future studies could examine foliar to critical zone carbon isotope variability over natural experiment of Industrialization with measured soil parameters (e.g. soil moisture, texture, pH, nutrient availability, microbiota; Kaplan et al. 2002; McKee et al. 2002; Cornwell et al.

2018). With deeper understanding of what edaphic, morphological, and genetic factors drive variability, we can use $\Delta^{13}C_{plant}$ values to understand plant biochemistry in response to things like water stress, yield, and growth success and strategically manage landscapes to maximize plants as a biological carbon sink.

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3.7 References

Ainsworth, E. A., & Long, S. P. (2005). What have we learned from 15 years of free-air CO_2 enrichment (FACE)? A meta-analytic review of the responses of photosynthesis, canopy properties and plant production to rising CO_2. *New Phytologist*, *165*(2), 351-372.

Araus, J. L., Slafer, G. A., Reynolds, M. P., & Royo, C. (2002). Plant breeding and drought in C_3 cereals: what should we breed for? *Annals of botany*, *89*(7), 925-940.

Arens, N. C., Jahren, A. H., & Amundson, R. (2000). Can C_3 plants faithfully record the carbon isotopic composition of atmospheric carbon dioxide? *Paleobiology*, *26*(1), 137-164.

Bauska, T. K., Brook, E. J., Marcott, S. A., Baggenstos, D., Shackleton, S., Severinghaus, J. P., & Petrenko, V. V. (2018). Controls on millennial-scale atmospheric CO_2 variability during the last glacial period. *Geophysical Research Letters*, *45*(15), 7731-7740.

Bazzaz, F. A., & Williams, W. E. (1991). Atmospheric CO_2 concentrations Within a Mixed Forest: Implications for Seedling Growth. *Ecology*, *72*(1), 12-16.

Beerling, D. J., & Royer, D. L. 2002. Fossil plants as indicators of the Phanerozoic global carbon cycle. *Annual Review of Earth and Planetary Sciences*, *30*(1), 527-556.

Beilstein, M. A., Nagalingum, N. S., Clements, M. D., Manchester, S. R., & Mathews, S. (2010). Dated molecular phylogenies indicate a Miocene origin for *Arabidopsis thaliana*. *Proceedings of the National Academy of Sciences*, *107*(43), 18724-18728.

Bowman, W. D., Hubick, K. T., von Caemmerer, S., & Farquhar, G. D. (1989). Short-term changes in leaf carbon isotope discrimination in salt-and water-stressed C_4 grasses. *Plant physiology*, *90*(1), 162-166.

Bonal, D., Born, C., Brechet, C., Coste, S., Marcon, E., Roggy, J. C., & Guehl, J. M. (2007). The successional status of tropical rainforest tree species is associated with differences in leaf carbon isotope discrimination and functional traits. *Annals of Forest Science*, *64*(2), 169-176.

Condon, A. G., Richards, R. A., & Farquhar, G. D. (1992). The effect of variation in soil water availability, vapour pressure deficit and nitrogen nutrition on carbon isotope discrimination in wheat. *Australian Journal of Agricultural Research*, *43*(5), 935-947.

Cornwell, W. K., Wright, I. J., Turner, J., Maire, V., Barbour, M. M., Cernusak, L. A., Dawson, T., Ellsworth, D., Farquhar, G.D., Griffiths, H., Keitel, C., Knohl, A., Reich, P.B., Williams, D.G., Bhaskar, R., Cornelissen, J.H.C., Richards, A., Schmidt, S., Valladares, F., Korner, C., Schulze, E-D., Buchmann, N., & Santiago, L.S. (2018). Climate and soils together regulate photosynthetic carbon isotope discrimination within C_3 plants worldwide. *Global Ecology and Biogeography*, *27*(9), 1056-1067.

Cui, Y., & Schubert, B. A. (2016). Quantifying uncertainty of past pCO_2 determined from changes in C_3 plant carbon isotope fractionation. *Geochimica et Cosmochimica Acta*, *172*, 127-138.

Cui, Y., & Schubert, B. A. (2017). Atmospheric pCO_2 reconstructed across five early Eocene global warming events. *Earth and Planetary Science Letters*, *478*, 225-233.

Cui, Y., Schubert, B. A., & Jahren, A. H. (2020). A 23-my record of low atmospheric CO2. *Geology*, *48,* (9), 888-892.

Dawson, T. E., Mambelli, S., Plamboeck, A. H., Templer, P. H., & Tu, K. P. (2002). Stable isotopes in plant ecology. *Annual review of ecology and systematics*, *33*(1), 507-559.

Diefendorf, A. F., Mueller, K. E., Wing, S. L., Koch, P. L., & Freeman, K. H. (2010). Global patterns in leaf ^{13}C discrimination and implications for studies of past and future climate. *Proceedings of the National Academy of Sciences*, *107*(13), 5738-5743.

Diefendorf, A. F., Freeman, K. H., Wing, S. L., Currano, E. D., & Mueller, K. E. (2015). Paleogene plants fractionated carbon isotopes similar to modern plants. *Earth and Planetary Science Letters*, *429*, 33-44.

Diefendorf, A. F., & Freimuth, E. J. (2017). Extracting the most from terrestrial plant-derived n-alkyl lipids and their carbon isotopes from the sedimentary record: A review. *Organic Geochemistry*, *103*, 1-21.

Eggleston, S., Schmitt, J., Bereiter, B., Schneider, R., & Fischer, H. (2016). Evolution of the stable carbon isotope composition of atmospheric CO_2 over the last glacial cycle. *Paleoceanography*, *31*(3), 434-452.

Ehleringer, J. R., & Cerling, T. E. (1995). Atmospheric CO_2 and the ratio of intercellular to ambient CO_2 concentrations in plants. *Tree physiology*, *15*(2), 105-111.

Elsig, J., Schmitt, J., Leuenberger, D., Schneider, R., Eyer, M., Leuenberger, M., ... & Stocker, T. F. (2009). Stable isotope constraints on Holocene carbon cycle changes from an Antarctic ice core. *Nature*, *461*(7263), 507-510.

Farquhar, G. D., & Richards, R. A. (1984). Isotopic composition of plant carbon correlates with water-use efficiency of wheat genotypes. *Functional Plant Biology*, *11*(6), 539-552.

Farquhar, G. D., Ehleringer, J. R., & Hubick, K. T. (1989). Carbon isotope discrimination and photosynthesis. *Annual review of plant biology*, *40*(1), 503-537.

Feng, X. (1999). Trends in intrinsic water-use efficiency of natural trees for the past 100–200 years: a response to atmospheric CO_2 concentration. *Geochimica et Cosmochimica Acta*, *63*(13-14), 1891-1903.

Fick, S. E., & Hijmans, R. J. (2017). WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas. *International journal of climatology*, *37*(12), 4302-4315.

Franks, P., Adams, M., Amthor, J. S., Barbour, M., Berry, J., Ellsworth, D. S, Ghannoum, O., Lloyd, J., Lloyd, J., McDowell, N.G., Norby, R.J., Tissue, D., von Caemmerer, S., & Farquhar, G.D. (2013). Sensitivity of plants to changing atmospheric CO_2 concentration: from the geological past to the next century. *New Phytologist, 197*(4), 1077-1094.

Franks, P. J., Royer, D. L., Beerling, D. J., Van de Water, P. K., Cantrill, D. J., Barbour, M. M., & Berry, J. A. (2014). New constraints on atmospheric CO_2 concentration for the Phanerozoic. *Geophysical Research Letters*, *41*(13), 4685-4694.

Giguère-Croteau, C., Boucher, É., Bergeron, Y., Girardin, M. P., Drobyshev, I., Silva, L. C., Hélie, J-F. & Garneau, M. (2019). North America's oldest boreal trees are more efficient water users due to increased [CO_2], but do not grow faster. *Proceedings of the National Academy of Sciences*, *116*(7), 2749-2754.

Guehl, J. M., Fort, C., & Ferhi, A. (1995). Differential response of leaf conductance, carbon isotope discrimination and water-use efficiency to nitrogen deficiency in maritime pine and pedunculate oak plants. *New Phytologist*, *131*(2), 149-157.

Hickler, T., Smith, B., Prentice, I. C., Mjöfors, K., Miller, P., Arneth, A., & Sykes, M. T. (2008). CO_2 fertilization in temperate FACE experiments not representative of boreal and tropical forests. *Global Change Biology*, *14*(7), 1531-1542.

Högberg, P., Johannisson, C., & Hällgren, J. E. 1993. Studies of ^{13}C in the foliage reveal interactions between nutrients and water in forest fertilization experiments. *Plant and Soil*, *152*(2), 207-214.

Jones, T. H., Thompson, L. J., Lawton, J. H., Bezemer, T. M., Bardgett, R. D., Blackburn, T. M., ... & Howson, G. 1998. Impacts of rising atmospheric carbon dioxide on model terrestrial ecosystems. *Science*, *280*(5362), 441-443.

Kaplan, J. O., Prentice, I. C., & Buchmann, N. (2002). The stable carbon isotope composition of the terrestrial biosphere: Modeling at scales from the leaf to the globe. *Global Biogeochemical Cycles*, *16*(4), 8-1.

Keeling, C.D., Piper, S.C., Bacastow, R.B., Wahlen, M., Whorf, T.P., Heimann, M., & Meijer, H.A. 2005. Atmospheric CO_2 and $^{13}CO_2$ exchange with the terrestrial biosphere and oceans from 1978 to 2000: Observations and carbon cycle implications. In *A history of atmospheric CO_2 and its effects on plants, animals, and ecosystems* (pp. 83-113). Springer, New York, NY.

Kohn, M. J. (2010). Carbon isotope compositions of terrestrial C_3 plants as indicators of (paleo) ecology and (paleo) climate. *Proceedings of the National Academy of Sciences*, *107*(46), 19691-19695.

Kohn, M. J. (2016). Carbon isotope discrimination in C_3 land plants is independent of natural variations in pCO_2. *Geochemical Perspectives Letters*, *2*(1), 35-43.

Lomax, B. H., Lake, J. A., Leng, M. J., & Jardine, P. E. (2019). An experimental evaluation of the use of $\Delta^{13}C$ as a proxy for palaeoatmospheric CO2. *Geochimica et Cosmochimica Acta*, *247*, 162-174.

Long, S. P., Ainsworth, E. A., Leakey, A. D., Nösberger, J., & Ort, D. R. (2006). Food for thought: lower-than-expected crop yield stimulation with rising CO2 concentrations. *Science*, *312*(5782), 1918-1921.

Looy, C., Kerp, H., Duijnstee, I., & DiMichele, B. (2014). The late Paleozoic ecological-evolutionary laboratory, a land-plant fossil record perspective. *The Sedimentary Record*, *12*(4), 4-18.

Macfarling Meure, C., Etheridge, D., Trudinger, C., Steele, P., Langenfelds, R., Van Ommen, T., Smith, A. & Elkins, J. (2006). Law Dome CO_2, CH_4 and N_2O ice core records extended to 2000 years BP. *Geophysical Research Letters*, *33*(14).

McElwain, J. C. (2018). Paleobotany and global change: Important lessons for species to biomes from vegetation responses to past global change. *Annual review of plant biology*, *69*, 761-787.

Mervenne, C. (2015). *Isotope ecology of temperate conifers* (Masters' Thesis, University of Michigan, Ann Arbor, MI, United States of America).

McKee, K. L., Feller, I. C., Popp, M., & Wanek, W. (2002). Mangrove isotopic ($\delta^{15}N$ and $\delta^{13}C$) fractionation across a nitrogen vs. phosphorus limitation gradient. *Ecology*, *83*(4), 1065-1075.

Mueller, K. E., Blumenthal, D. M., Pendall, E., Carrillo, Y., Dijkstra, F. A., Williams, D. G., Follett R. F., & Morgan, J. A. (2016). Impacts of warming and elevated CO_2 on a semi-arid grassland are non-additive, shift with precipitation, and reverse over time. *Ecology Letters*, *19*(8), 956-966.

Norby, R. J., & Zak, D. R. (2011). Ecological lessons from free-air CO_2 enrichment (FACE) experiments. *Annual Review of Ecology, Evolution, and Systematics*, *42*, 181-203.

Nowak, R. S., Ellsworth, D. S., & Smith, S. D. (2004). Functional responses of plants to elevated atmospheric CO_2–do photosynthetic and productivity data from FACE experiments support early predictions? *New Phytologist*, *162*(2), 253-280.

Peñuelas, J., & Azcón-Bieto, J. (1992). Changes in leaf $\Delta^{13}C$ of herbarium plant species during the last 3 centuries of CO_2 increase. *Plant, Cell & Environment*, *15*(4), 485-489.

PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, created 4 Feb 2004.

Proctor, M. C. F., Raven, J. A., & Rice, S. K. (1992). Stable carbon isotope discrimination measurements in *Sphagnum* and other bryophytes: physiological and ecological implications. *Journal of Bryology*, *17*(2), 193-202.

Qiaoping, X., Fajon, A., Zhenyu, L., Likuo, F., & Zhengyu, L. (2002). *Thuja sutchuenensis*: a rediscovered species of the Cupressaceae. *Botanical Journal of the Linnean Society*, *139*(3), 305-310.

Reich, P. B., Hungate, B. A., & Luo, Y. (2006). Carbon-nitrogen interactions in terrestrial ecosystems in response to rising atmospheric carbon dioxide. *Annual Review of Ecology, Evolution, and Systematics*, *37*, 611-636.

Royer, D. L., Berner, R. A., Montañez, I. P., Tabor, N. J., & Beerling, D. J. (2004). CO_2 as a primary driver of Phanerozoic climate. *GSA today*, *14*(3), 4-10.

Royles, J., Amesbury, M. J., Roland, T. P., Jones, G. D., Convey, P., Griffiths, H., Hodgson, D.A., & Charman, D. J. (2016). Moss stable isotopes (carbon-13, oxygen-18) and testate amoebae reflect environmental inputs and microclimate along a latitudinal gradient on the Antarctic Peninsula. *Oecologia*, *181*(3), 931-945.

Rundel, P. W., Stichler, W., Zander, R. H., & Ziegler, H. (1979). Carbon and hydrogen isotope ratios of bryophytes from arid and humid regions. *Oecologia*, *44*(1), 91-94.

Saurer, M., Siegwolf, R. T., & Schweingruber, F. H. (2004). Carbon isotope discrimination indicates improving water-use efficiency of trees in northern Eurasia over the last 100 years. *Global Change Biology*, *10*(12), 2109-2120.

Schlanser, K., Diefendorf, A. F., Greenwood, D. R., Mueller, K. E., West, C. K., Lowe, A. J., Basinger, J. F., Currano, E. D., Flynn, A. G., Fricke, H. C., Geng, J., Meyer, H. W., Peppe, D. J. (2020). On geologic timescales, plant carbon isotope fractionation responds to precipitation similarly to modern plants and has a small negative correlation with pCO_2. *Geochimica et Cosmochimica Acta*, *270*, 264-281.

Schubert, B. A., & Jahren, A. H. (2012). The effect of atmospheric CO_2 concentration on carbon isotope fractionation in C_3 land plants. *Geochimica et Cosmochimica Acta*, *96*, 29-43.

Shen, D., Sun, H., Huang, M., Zheng, Y., Qiu, Y., Li, X., & Fei, Z. (2013). Comprehensive analysis of expressed sequence tags from cultivated and wild radish (*Raphanus* spp.). *BMC genomics*, *14*(1), 721.

Sheldon, N. D., Smith, S. Y., Stein, R., & Ng, M. (2020). Carbon isotope ecology of gymnosperms and implications for paleoclimatic and paleoecological studies. *Global and Planetary Change*, *184*, 103060.

Stein, R. A., Sheldon, N. D., & Smith, S. (2019). Rapid response to anthropogenic climate change by *Thuja occidentalis*: implications for past climate reconstructions and future climate predictions. *PeerJ*, *7*, e7378.

Tipple, B. J., Meyers, S. R., & Pagani, M. (2010). Carbon isotope ratio of Cenozoic CO_2: A comparative evaluation of available geochemical proxies. *Paleoceanography*, *25*(3), PA3202.

White, J.W.C., Vaughn, B.H., Michel, S.E. (2015). University of Colorado, Institute of Arctic and 720 Alpine Research (INSTAAR), Stable Isotopic Composition of Atmospheric Carbon Dioxide (^{13}C and ^{18}O) from the NOAA ESRL Carbon Cycle Cooperative Global Air Sampling Network, 722 1990-2014, Version: 2015-10-26.

Yan, W., Zhong, Y., & Shangguan, Z. (2017). Contrasting responses of leaf stomatal characteristics to climate change: a considerable challenge to predict carbon and water cycles. *Global Change Biology*, *23*(9), 3781-3793.

CHAPTER IV

Soil Carbon Isotope Values and Paleo-Precipitation Reconstruction[3]

4.1 Abstract

Anthropogenic climate change has significant impacts at the ecosystem scale including widespread drought, flooding, and other natural disasters related to precipitation extremes. To contextualize modern climate change, scientists often look to ancient environmental changes, such as shifts to ancient precipitation ranges. Previous studies have used fossil leaf organic chemistry and paleosol inorganic chemistry as paleo-precipitation proxies, but have largely ignored the organic soil layer, which acts as a bridge between aboveground biomass and belowground inorganic accumulation, as a potential recorder of precipitation. We investigate the relationship between carbon isotope values in soil organic matter ($\delta^{13}C_{SOM}$) and a variety of seasonal and annual climate parameters in modern ecosystems and find a significant relationship between $\delta^{13}C_{SOM}$ values and mean annual precipitation (MAP). After testing the relationship between actual and reconstructed precipitation values in modern systems, we test this potential paleo-precipitation proxy in the geologic record by comparing precipitation values reconstructed using $\delta^{13}C_{SOM}$ to other reconstructed paleoprecipitation values based on the same paleosols. This study provides a promising new proxy that can be applied to ecosystems post-Devonian to the Miocene, and in mixed C_3/C_4 ecosystems in the geologic record with additional paleobotanical and palynological information. It also extends paleo-precipitation reconstruction to more weakly developed paleosol types, such as those lacking B- horizons, than previous inorganic proxies and is calibrated for wetter environments.

4.2 Introduction

Anthropogenic climate change has caused major shifts in global and regional precipitation regimes (IPCC 2007), and it is imperative that we understand the impacts these

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Stein, R. A., Sheldon, N. D., & Smith, S. Soil carbon isotope values can be used to reconstruct paleo-precipitation.

shifts have on ecosystems to drive effective conservation. In addition to being a fundamental necessity to life, precipitation and subsequent plant water availability controls ecosystems' distribution and health and the magnitude of soil carbon sinks (Cotton et al. 2013). Major changes in precipitation could cause complete turnover of ecosystems; our understanding of the impacts of global climate change on future precipitation distributions is often influenced by ancient precipitation changes, especially as they relate to recorded ecosystem turnover.

In order to reconstruct ancient precipitation, we use clues from the geologic record, often in the form of chemical records in sediments or preserved micro- and macro geology (Thompson et al. 1999; Shucheng & Evershed 2001; Stinchcomb et al. 2016). Ancient precipitation patterns clarify changes in precipitation as a function of modern climate change, and can affect climate model outputs (Dai 2006). They also inform interpretations of other parameters, including paleo-topography and soil CO_2 concentration (Cerling et al. 1991; Cerling et al. 1992; Ekart et al. 1999; Breecker et al. 2009). Furthermore, paleo-precipitation plays an important role in our understanding of paleo-temperature reconstructions (Gallagher et al. 2019), as the magnitude and timing of precipitation constrains the effects of ground heating in soils and the offset between water temperature and air temperate in lakes (Hren and Sheldon, 2012).

Previous workers have used $\delta^{13}C$ values of aboveground plant mass ($\delta^{13}C_{leaf}$) to reconstruct precipitation (Weiguo et al. 2005; Youfeng et al. 2008; Wang et al. 2013). This approach relies on the premise that $\delta^{13}C_{leaf}$ values are linked to water availability because stomata (leaf pores) are the centralized location where plant-atmosphere gas exchange occurs, including associated processes such as carbon isotope fractionation and transpiration (Livingston & Spittlehouse 1996; Farquhar 1989; Arens et al. 2000). This relationship has been substantiated by empirical studies, which have demonstrated a reasonably strong logarithmic relationship between carbon isotope discrimination in C_3 plants (Δ_{leaf}; Equation 4.1) and mean annual precipitation ($\Delta_{leaf} = 5.54(\log MAP) + 4.07$; $R^2 = 0.55$, p-value < 0.001; Diefendorf et al. 2010; Kohn et al. 2010).

$$Equation\ (4.1) \quad \Delta_{leaf} = \frac{\delta^{13}C_{atm} - \delta^{13}C_{leaf}}{\left(1 + \frac{\delta^{13}C_{leaf}}{1000}\right)}$$

These meta-analyses indicate a systemic relationship between water availability and plant isotope discrimination, but this relationship does not carry over on a species-specific scale (Stein et al. 2019; Sheldon et al. 2020; Stein et al. in press). Within any given precipitation regime, there is significant variation in $\delta^{13}C_{leaf}$ values among plants, and for any given taxon, the $\delta^{13}C_{leaf}$ values are essentially invariant regardless of whether the plant is growing in wetter or dryer conditions. Instead, $\delta^{13}C_{leaf}$ values reflect species-specific C isotope discrimination behavior and the atmospheric input isotopic composition (Stein et al., 2019; Sheldon et al. 2020; Stein et al. in press). Thus, the meta-relationship observed reflects the integration of the whole ecosystem, rather than any individual taxon's behavior (Sheldon et al. 2020). This makes it difficult to apply the directly measured $\delta^{13}C_{leaf}$ values of geologic plants (Kohn 2010) or reconstructed $\delta^{13}C_{leaf}$ values based on fossil teeth (Quade et al. 1995; Wang et al. 2008; Passey 2017) as paleo-precipitation proxies without taxonomic identification. However, an aggregated record of an ecosystem (i.e. carbon isotope values of soil, $\delta^{13}C_{SOM,}$ or the difference between the carbon isotope value of the atmosphere and of soil; Δ_{SOM}; Equation 4.2) should demonstrate a similar but taxonomically independent relationship as the meta-analyses demonstrated. We propose that soils act as the "great integrator," and that organic matter can be used as an average of the aboveground ecosystem (Powell et al. 2012; Sheldon et al. 2020). This has been previously demonstrated by water isotopes (Deuterium, $\delta^{2}H$ or δD, and oxygen, $\delta^{18}O$) recorded in topsoil along a precipitation transect, where topsoil water isotope values reflected the isotopic value of incoming precipitation (Struck et al. 2020). We expect that the relationship between carbon isotope values in leaves ($\delta^{13}C_{leaf}$) and precipitation will also be recorded as carbon isotopic values in surface-most soil organic matter ($\delta^{13}C_{SOM}$ values).

$$\Delta_{SOM} = \frac{\delta^{13}C_{atm} - \delta^{13}C_{SOM}}{\left(1 + \frac{\delta^{13}C_{SOM}}{1000}\right)} \quad \text{(Equation 4.2)}$$

Previous studies have evaluated the relationship between weathering and precipitation in soils, based on the principle that increased precipitation drives increased chemical weathering and leaching of nutrients (Stewart et al. 2001), which consequently affects soil geochemistry and soil horizonization. The link between weathering and precipitation is an additional reason to expect a demonstrable relationship between mean annual precipitation and soil chemistry. This idea has been evaluated in distribution of mobile versus immobile inorganic compounds,

although it has largely been untested using organic compounds. Past work has used quantifiable weathering (via chemistry) to reconstruct precipitation (CIA, CIA-K, CALMAG, $PPM_{1.0}$; Jenny & Leonard 1934; Retallack 1994; Royer 2001; Sheldon et al. 2002; Nordt & Driese 2010; Stinchcomb et al. 2016; Beverly et al. 2018). Each of these methods for precipitation reconstruction has been applied as a paleoprecipitation proxy, but as tested in modern conditions, each are confined to certain precipitation regimes or soil types (Jenny & Leonard 1934; Retallack 1994; Royer 2001; Sheldon et al. 2002; Nordt & Driese 2010), except for $PPM_{1.0}$ (paleosol-paleoclimate model), a nonlinear spline and partial least squares regression model. Although $PPM_{1.0}$ is generalizable for many soil types, this tool trades versatility for high error and uncertainty (Stinchcomb et al. 2016). The error associated with each of these soil paleoprecipitation proxies increases in soils that receive > 1500 mm yr^{-1}, such as sub-tropical and tropical soils. This limits these proxies during paratropical climate regimes, which are common during geologic times, including the Eocene and many earlier, pre-Cenozoic times (Harrington et al. 2004).

We aim to provide a new tool using organic geochemistry in soils ($\delta^{13}C_{SOM}$, Δ_{SOM}) that can be used to supplement existing paleoprecipitation tools in organic-rich land ecosystems and settings with weaker soil formation. This tool, which should be less susceptible to high precipitation error due to leaching than inorganic proxies, can improve the accuracy of paleo-precipitation reconstruction in high rainfall regimes.

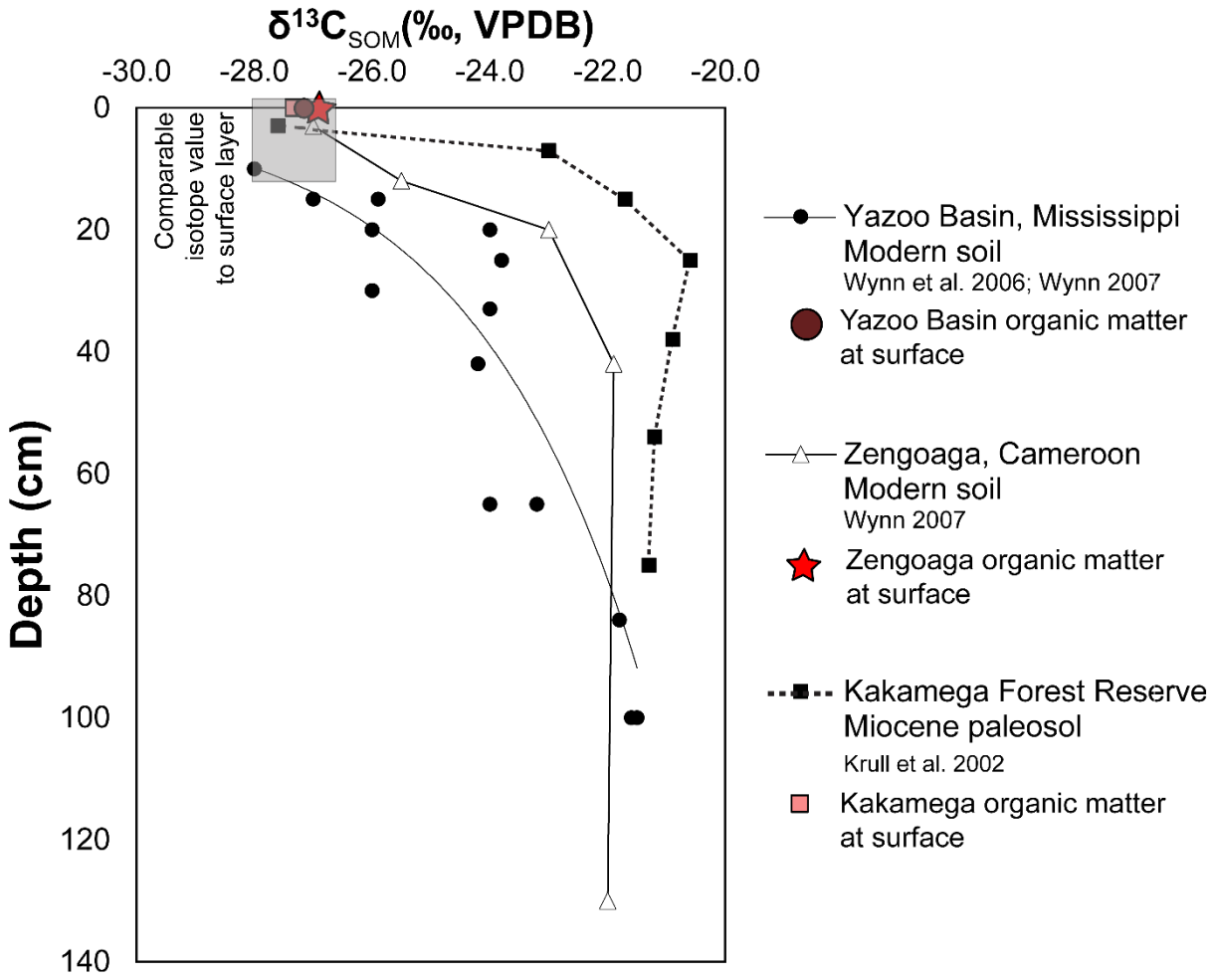

Figure 4.1: Modern soils from Wynn (2007) and a paleosol from Krull et al. (2002), displaying carbon isotope values ($\delta^{13}C_{SOM}$) with depth, demonstrating Rayleigh distillation processes. The surface values are shown in red symbols at 0m. The zone where organic carbon isotope values are comparable to the surface for these soils is shown in transparent grey box (up to ~10cm in depth).

Similar to chemical weathering and sub-surface horizon development, $\delta^{13}C_{SOM}$ is not constant with depth. While topsoil should reflect the above and belowground biomass coming into the system directly, as organic matter is buried, the carbon chemical composition of the soil changes, and processes like microbial recycling and oxidation (driving Rayleigh distillation) cause isotope enrichment through the profile, stabilizing in the B- horizon (e.g. ~70 cm depth; Wynn 2007; Fig. 4.1). This Rayleigh distillation is not constant between all soils; for example, disparate texture results in different carbon isotope changes with depth (Krull et al. 2005). However, as Figure 1 shows, the O horizon and uppermost A horizon of soils closely matches

the vegetation. To evaluate $\delta^{13}C_{SOM}$ as a precipitation proxy, we conducted $\delta^{13}C$ analyses specifically on O-horizon (topsoil) soils from three specific ecosystems (dominated by *Thuja occidentalis, Thuja plicata* and *Populus tremuloides*) across a climosequence and supplemented these ecosystem-specific soils with modern $\delta^{13}C$ values of organic topsoil layers from the literature. We tested the applicability of the new proxy by comparing reconstructed results from Paleozoic-Cenozoic paleosols that had independent paleo-precipitation estimates.

4.3 Methods

We collected O-horizon soils as well as living leaves from tree branches from *Thuja occidentalis* (northern white cedar, including six branchlets and 20 soils), *Thuja plicata* (Pacific red cedar, including three leaves and five soils), and *Populus tremuloides* (quaking aspen, including nine leaves and 23 soils) dominated ecosystems in 15 locations (Fig. 2) using a 2 ¼" diameter auger (n = 67) to compare $\delta^{13}C_{SOM}$ values in conifer and angiosperm-dominated ecosystems, respectively. We determined these locations for collection based on sampling a precipitation gradient and with the assistance of the iNaturalist citizen science observation application (iNaturalist 2018) to find exact locations of these specific tree species.

Upon collection, soils were dried in a 50°C oven to eliminate risk of continued respiration and alteration of isotopic values. Soils were brought to the Earth Systems Science (ESS) Laboratory at the University of Michigan, Ann Arbor, acidified in 5% dilute hydrochloric acid (HCl) solution on a 50°C hotplate to remove authigenic or inherited carbonate, and allowed to settle out for 30 minutes. Excess liquid was removed with transfer pipettes. This process was repeated three times and/or until soils did not exhibit further reactivity to HCl. Soils were rinsed with deionized water as many times as they were exposed to HCl (e.g., three times for three HCl baths, five times for five HCl baths) to remove all excess HCl, then placed in a 50°C oven to dry again.

Soils were loaded into tin capsules and run on low carbon setting (20–200 ppm) on a Picarro G2201-i cavity ring down spectrometer (CRDS; replicate standard deviation ± 0.3‰). Results were calibrated using internal laboratory acetanilide standards (-28.17‰) ranging from 0.100 mg to 1.400 mg, and run with additional standards calibrated by the International Atomic

Energy Agency: IAEA-CH-6 (-10.45‰; sucrose) and IAEA-600 (-27.77‰; caffeine), as well as additional internal laboratory standards: homogenized sugar from C_3 sugarbeet (-26.14‰) and C_4 sugarcane (-12.71‰).

We aggregated climate data (mean annual temperature, maximum summer temperature, vapor pressure deficit, mean annual precipitation, growing season precipitation) for all soils collected for this study using data interpolated on a 10-km scale from PRISM Climate Group through Oregon State University (PRISM Climate Group 2014). We also compared isotopic values to CO_2 gas concentrations collected from ice cores (pre-1958; Etheridge et al. 1998) and Mauna Loa Observatory's *in situ* atmospheric CO_2 measurements (post-1958; Keeling & Whorf 2004; White et al. 2015) from 1900–2017. Because carbon in the O-horizon of soils is recalcitrant, most carbon in soil is hundreds to thousands of years old (Lorenz et al. 2007; Kleber 2010). Therefore, when calculating Δ_{SOM} (Equation 4.2), we used a fixed Pre-Industrial $\delta^{13}C_{atm}$ value (-6.5‰).

To supplement soils collected through the ESS Lab at the University of Michigan, we collated organic carbon isotope values from previous studies with included climate data (n = 106; Supp. Table C1; Supp. Table C3; Fig. 4.2). For any missing climate information for soils from the contiguous United States in the original publications, we supplemented using PRISM Climate Group's interpolated values and other sources (see Supp. Table C3). We collected values only for soils that had been treated to remove carbonate.

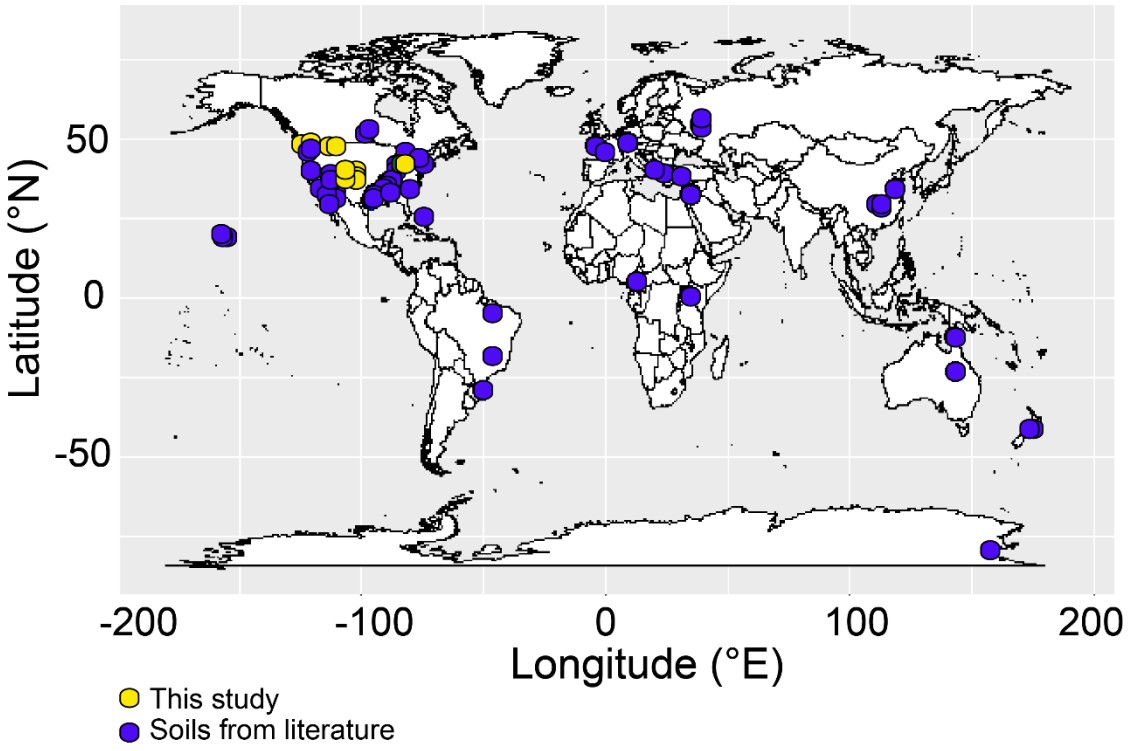

Figure 4.2 Map of modern soils. Yellow circles indicate soils collected by the Earth Systems Science Lab at the University of Michigan; dark blue circles are values collated from previous studies.

Additionally, we collected organic carbon isotope values from geological literature for paleosol analyses (n = 62; Cerling et al. 1992; Mora et al. 1996; Hatte et al. 2001; Nordt et al. 2002; Pustovoytov & Terhorst 2004; Sheldon 2006; Gutierrez & Sheldon 2012; Hyland & Sheldon 2013; Harris et al. 2017; Lukens et al. 2017; Tabor et al. 2017; Supp. Fig. C5; Supp. Table C3). $\delta^{13}C_{SOM}$-reconstructed results provided without coeval precipitation estimates (sometimes from other publications) were excluded.

4.4 Results

There was a significant logarithmic relationship between $\delta^{13}C_{SOM}$ and mean annual precipitation within studied soils ($\delta^{13}C_{SOM}$ = -2.04ln (MAP) - 11.99; R^2 = 0.68; p-value < 0.001; Fig. 4.3). There was also a strong relationship between Δ_{SOM} and mean annual precipitation

(Δ_{SOM} = -2.14ln (MAP) + 5.37; R^2 = 0.64; p-value = 1.29 x 10^{-38}; Fig. 4). There was a demonstrable relationship between growing season precipitation (mm yr^{-1}) and $\delta^{13}C_{SOM}$ ($\delta^{13}C_{SOM}$ = -0.90ln (GSP) – 20.08, R^2 = 0.24; p-value = 4.44 x 10^{-7}; Supp. Fig. C2), but this relationship was only modestly predictive. To determine outliers, we excluded all values from the regressions that had residuals from the expected value greater than twice the standard deviation of the mean of all residuals (n = 3). We found that the $\delta^{13}C_{SOM}$ and Δ_{SOM} values of soils collected in Olympic National Park (MAP = 3350 mm yr^{-1}) were outliers—over two standard deviations (0.95‰) from the expected values based on the full dataset. Each of these soils had $\delta^{13}C_{SOM}$ and Δ_{SOM} values of >2.00‰ from expected. All other soils included in this study (both collected in the field for this study, and from literature) were formed at precipitation regimes <2500 mm yr^{-1}, and the outlier Olympic Peninsula soils collected were sampled at sites with precipitation values of 3350 mm yr^{-1}.

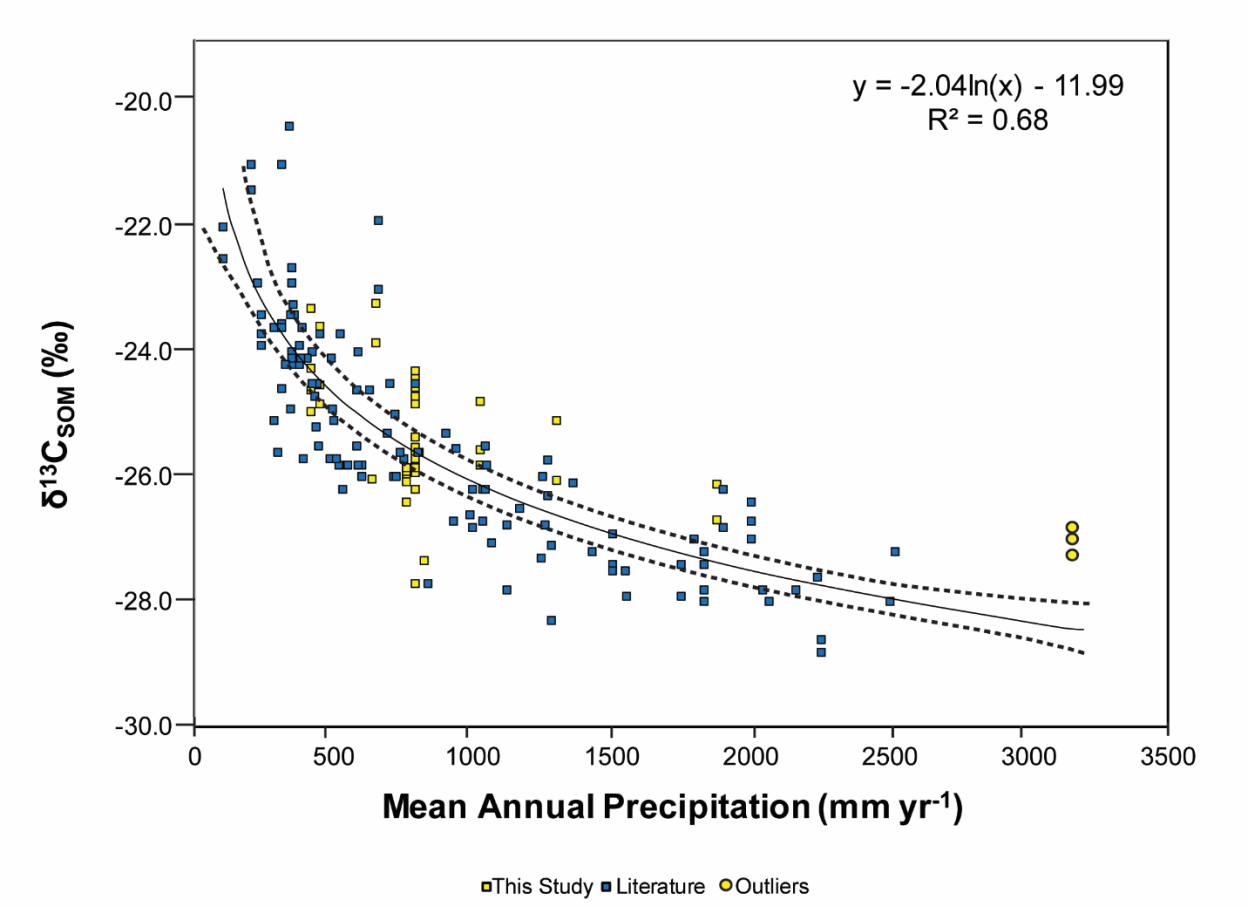

Figure 4.3 $\delta^{13}C_{SOM}$ values compared to mean annual precipitation (mm yr^{-1}) for modern soils. New data are shown in yellow squares, literature data is shown in blue squares, and outliers (from our dataset,

measured MAP = 3350 mm yr^{-1}) are shown in yellow circles. 95% confidence intervals are shown in dashed lines.

All other climate variables tested had coefficients of determination that were not strongly predictive ($R^2 \leq 0.25$). Latitude and $\delta^{13}C_{SOM}$ values did not have any predictive relationship, though there was a change in range related to region (Fig. 4.4). For elevation, longitude, mean annual temperature, maximum growing season temperature, vapor pressure deficit (annual minimum and maximum), predictive relationships were consistently low (Supplemental Fig. C1). Significance (p-values) and coefficients of determination (R^2 values) for relationships between $\delta^{13}C_{SOM}$ values and Δ_{SOM} values and other climate variables are provided in Table 4.1.

Table 4.1 Statistical results (p-value, significance test and R^2-value, coefficient of determination) for carbon isotope values ($\delta^{13}C_{SOM}$ and Δ_{SOM} values) compared to environmental and sampling location variables. Strong predictive relationships ($R^2 > 0.50$) are shown in dark green, moderately predictive relationships (0.25-0.50) are denoted in light green, and weakly predictive relationships are shown in yellow (0.10-0.25). If there was no predictive value in the relationship, it is not highlighted. All relationships that are significant (p-value < 0.001) are shown in light green.

		p-value		R^2 value	
Variable	**Unit**	$\delta^{13}C_{SOM}$ (‰)	Δ_{SOM} (‰)	$\delta^{13}C_{SOM}$ (‰)	Δ_{SOM} (‰)
Latitude	°N	<0.001	<0.001	0.10	0.10
|Latitude|	°	0.02	0.02	0.03	0.03
Longitude	°E	<0.001	<0.001	0.11	0.11
Elevation (m)	meters	<0.001	<0.001	0.25	0.25
Mean Annual Temperature	°C	0.03	0.03	0.04	0.04
Maximum Growing Season Temperature	°C	0.10	0.10	0.03	0.03
Mean Annual Precipitation	mm yr^{-1}	<0.001	<0.001	0.68	0.64
Growing Season Precipitation	mm / season	<0.001	<0.001	0.24	0.24
Vapor Pressure Deficit Minimum	hPa	<0.001	<0.001	0.15	0.15
Vapor Pressure Deficit Maximum	hPa	0.64	0.64	<0.01	<0.01

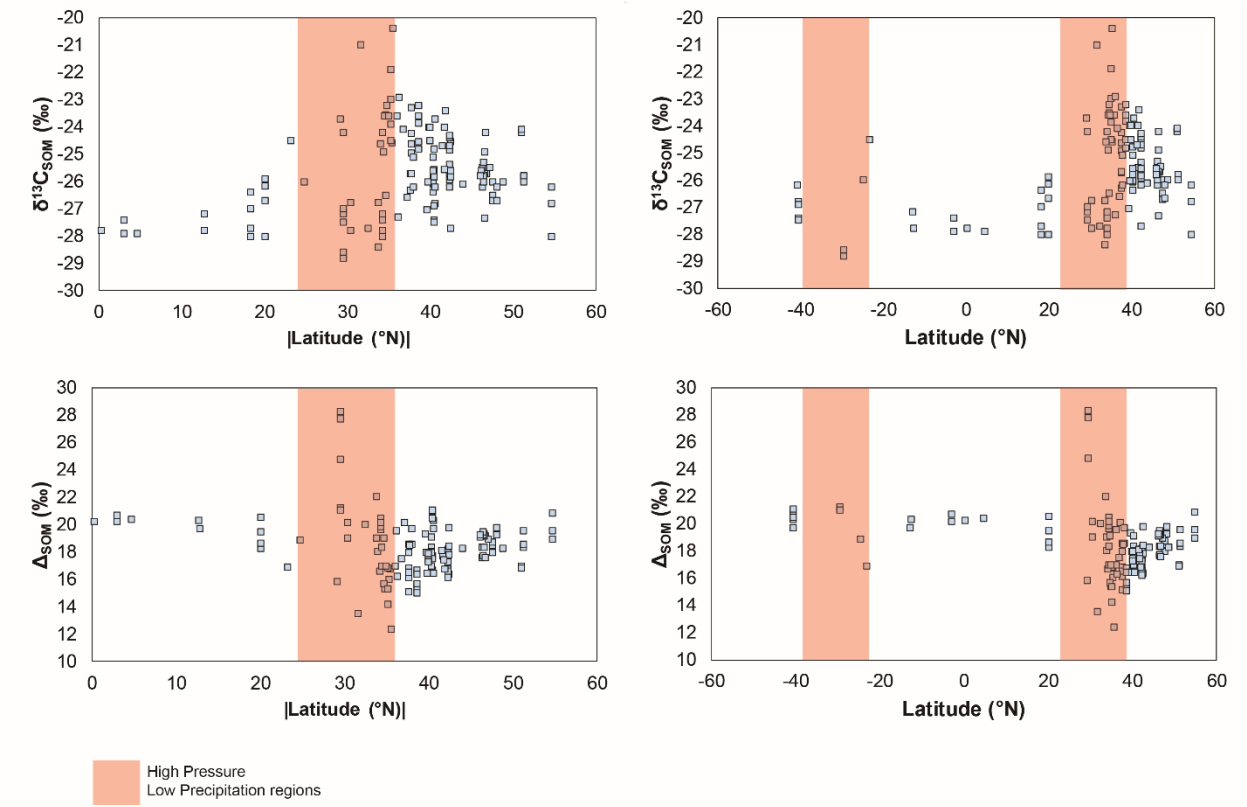

Figure 4.4 The relationship between $\delta^{13}C_{SOM}$, Δ_{SOM} and latitude (both absolute value of latitude, or degrees distance from the equator, and actual latitude). Transparent red areas show desert regions as determined by atmospheric convergent and divergent zones.

Previous workers focused on the relationship between $\delta^{13}C_{leaf}$ and climate variables found that a multivariate logarithmic regression incorporating both MAP and altitude showed the most predictive relationship with $\delta^{13}C$ values (Equation 4.3; $R^2 = 0.59$; Diefendorf et al. 2010; Kohn 2010), so we tested this in soils. Modeled after Diefendorf et al.'s multiple regression (Equation 4.3), we evaluated the relationship between Δ_{SOM}, precipitation, and the square root of elevation and found the multiple linear regression less predictive that the MAP-only regression findings (Equation 4.4; $R^2 = 0.62$, p-value = 4.48×10^{-32}; Supp. Table C2).

$$\Delta_{leaf} = 4.20(\pm 0.26) * \log(\text{MAP}) - 0.06\ (\pm 0.01) * \sqrt{elevation} + 9.35(\pm 0.90) \text{ (Equation 4.3)}$$

$$\Delta_{SOM} = 5.24(\pm 0.57) * \log(\text{MAP}) - 0.01(\pm 0.01)\sqrt{elevation} + 4.7;\ R^2 = 0.62, \text{p} - \text{value} = 4.48 \times 10^{-32} \text{ (Equation 4.4)}$$

We conducted multivariate analyses looking at the combined factors between MAP and any variable with a demonstrated single-variable relationship with Δ_{SOM} and $\delta^{13}C_{SOM}$ (specific

criteria: p-value < 0.001, $R^2 \geq 0.10$; Table 4.1). None of these relationships was more predictive than that between mean annual precipitation and Δ_{SOM} and/or $\delta^{13}C_{SOM}$ alone, but introducing additional variables increases uncertainty, especially with regard to the geologic record (Supp. Table C2).

4.5 Discussion

4.5.1 Overall relationships between climate variables and $\delta^{13}C_{SOM}$

There were neither strong nor predictive relationships between $\delta^{13}C_{SOM}$ and mean annual temperature, maximum summer temperature, vapor pressure deficit, atmospheric partial pressure of CO_2 (pCO_2), or latitude (R^2 value <0.25 for all studied climate and spatial variables, p-values included in Supp. Table C2). Some of the variability in $\delta^{13}C_{SOM}$ values that is not explained by mean annual precipitation can be explained by elevation ($R^2 = 0.25$), but we cannot discount that this relationship is related to topographic controls on precipitation (Duckstein et al. 1973). It is likely that high temperatures and high vapor pressure deficit and their subsequent impacts on evapotranspiration (resulting in increased water demand from soils and soil drying) during the warm (and presumably growing) season, were counteracted by water availability from the non-growing season months. It is also likely that the highest temperatures originate in tropical regions, where precipitation is high as well, which is why we did not see a relationship between $\delta^{13}C_{SOM}$ values and temperature. Complementary multivariate regressions examining the relationship between (MAP + any variable with a statistically significant R^2 value > 0.10; see Table 4.1) and Δ_{SOM} did not improve the relationship between MAP alone and carbon isotope values in soil (Supp. Table C2). The inclusion of additional variables for reconstructive purposes, while adding specificity, also adds uncertainty, thus, we propose solely considering MAP for the new $\delta^{13}C_{SOM}$-precipitation proxy. These findings indicate that it is possible to apply $\delta^{13}C_{SOM}$ values to reconstruct paleo-precipitation without worrying about interference from other tested climate variables. This is especially useful because many of the other tested variables (elevation, latitude, growing season precipitation, and vapor pressure deficit) are difficult to constrain in the geologic record, and reliance on these additional variables being defined adds more uncertainty and limitations to this proxy.

While there was no predictive relationship between latitude and $\delta^{13}C_{SOM}$ or Δ_{SOM} values (Fig. 5; $R^2 < 0.10$), the isotopic variability of soils collected at the horse latitudes (~30°N and 30°S) was wider (-20 to -29‰) as compared to non-horse latitudes (-23 to -28‰). This variability could be linked to precipitation (discussed further below); precipitation and latitude are interdependent, and at these latitudes, converging dry air masses result in deserts and extremely low precipitation values. As a result, plants growing in the horse latitudes are more stressed and more susceptible to variability in the timing of rainfall, rather the average annual precipitation. During extended periods of high precipitation, soils are likely to have depleted $\delta^{13}C_{SOM}$ signatures and high Δ_{SOM} values, but during long droughts, show enriched $\delta^{13}C_{SOM}$ signatures and low Δ_{SOM} values. This variability and wide range of $\delta^{13}C_{SOM}$ values between 20 and 40°N and °S indicate the sensitivity of these regions to drought conditions. The impacts of drought at these latitudes can collapse empires: for example, the end of the Maya Classic Period coincided with a ~200-year period of intense drought as recorded in Lake Chichancanab sediments on the Yucatan Peninsula (~20°N; Hodell et al. 1995; Douglas et al. 2016), so future concentrated work on isotope biogeochemistry in these areas of possible climate stress may allow us to predict humanitarian disasters.

4.5.2 Water availability and $\delta^{13}C_{SOM}$

There is a clear and significant relationship between precipitation (both seasonal and annual) and carbon isotope values of soils (as measures of integrated plant values), comparable to the logarithmic trend between precipitation and $\delta^{13}C_{leaf}$ values in previous leaf-based meta-analyses (Diefendorf et al. 2010; Kohn 2010). The relationship between the actual measured precipitation and reconstructed precipitation using the new $\delta^{13}C_{SOM}$ model was significant (Equation 4.5; Supp. Fig. C3; $R^2 = 0.68$, p-value < 0.001), and most importantly, the slope of the relationship (1.02 ± 0.05) between reconstructed and actual precipitation indicates that our $\delta^{13}C_{SOM}$ model predicts reasonable precipitation values. Similarly, although the intercept indicates a modest positive offset of 44.85 (±60.19) mm yr^{-1} of precipitation between predicted values compared to measured values, this is an insubstantial amount of precipitation when distinguishing between different biomes (Whitaker 1975), and is within error of no offset.

$$\text{Reconstructed MAP} = 1.02(\pm 0.05) * (\text{Actual MAP}) + 44.85\ (\pm 60.19) \quad \text{(Equation 4.5)}$$

While there is a positive logarithmic relationship between Δ_{SOM} and mean annual precipitation (complementary with the negative logarithmic relationship between $\delta^{13}C_{SOM}$ and MAP), it shows slightly weaker predictive value than that seen between $\delta^{13}C_{SOM}$ and MAP (R^2 = 0.64). Assumptions about $\delta^{13}C_{atm}$ values introduce uncertainty in calculating Δ_{SOM} related to age and homogeneity of the atmosphere. First, soil organic matter is hundreds to thousands of years old (e.g., Trumbore 2000) and turns over slowly; this means that $\delta^{13}C_{atm}$ values were not constant throughout the lifetime of soil organic carbon. We used set pre-Industrial values (-6.5‰) as the most widely representative value, but the rapidly changing $\delta^{13}C_{atm}$ values introduce some noise and uncertainty into the data (Sanderman et al. 2017). However, we have no evidence that $\delta^{13}C_{atm}$ values have changed at such an unprecedented rate as today (Tipple et al. 2010), so this noise should not be problematic in the geologic record (Keeling 1979). Secondly, because of micro-environmental variability in $\delta^{13}C_{atm}$ related to differences in topography and regional, $\delta^{13}C_{atm}$ values close to the soil surface are heterogeneous (Francey et al. 1985; Broadmeadow et al. 1992) and can exceed the variability in $\delta^{13}C_{atm}$ on the timescale of soil collection. $\delta^{13}C_{atm}$ is important for reconstructions, but $\delta^{13}C_{atm}$ is not well-constrained in the geologic record at short (<10 ka) timescales, and soil carbon spans hundreds to thousands of years in age. Therefore, during times with dynamic climate atmospheric C changes (e.g. glacial-interglacial periods, Paleocene-Eocene transition, middle Miocene climatic optimum; Tipple et al. 2010), it is recommended to use the $\delta^{13}C_{SOM}$-MAP, but not Δ_{SOM}-MAP, relationship to reconstruct mean annual precipitation (useful adjustments using the independent foraminiferal-derived $\delta^{13}C_{atm}$ proxy that spans the Cenozoic are discussed below).

There is a negative logarithmic relationship between $\delta^{13}C_{SOM}$ values and growing season precipitation (GSP) but this relationship is weaker than that observed between $\delta^{13}C_{SOM}$ and mean annual precipitation ($\delta^{13}C_{SOM}$ = -0.90(GSP) – 20.08; R^2 = 0.24; Supp. Fig. C2a). Some of the relationship can be explained by the high correlation between growing season precipitation and mean annual precipitation (p-value < 0.001, R^2 = 0.57; Supp. Fig. C2b). The muted relationship between GSP and isotopic fractionation compared to mean annual precipitation demonstrates the importance of soil water storage to growth season productivity even when this water is accrued

during plant dormancy (e.g. snowmelt, wintertime precipitation, etc.). Previous workers have demonstrated variability in moisture deficit that does not necessarily correspond to peak growing season or dormancy (Tabor et al. 2013; Gallagher et al. 2016). The new results reaffirm the importance of non-growing season precipitation (e.g. soil water, frozen soil water, snowpack) in providing water ultimately used by plants during the subsequent growing season.

4.5.3 A case study in the geologic record

In order to test the veracity of this paleoprecipitation proxy in the geologic record, we reconstructed paleo-precipitation using the modern $\delta^{13}C_{SOM}$-model for a number of paleosols described in the literature. The applications of this proxy to the geologic record are limited by development and preservation of soil horizons, so we compared $\delta^{13}C_{SOM}$-paleoprecipitation values based on upper (O- and A-; undistinguished) horizons with MAP reconstructed using other paleoprecipitation proxies (Fig. 4.6). The comparative proxies included CIA-K (Sheldon et al. 2002), CALMAG (Nordt & Driese 2010), depth to Bk horizons (Retallack 2005), leaf area index (LAI; Pfeifer et al. 2012) and CLAMP (Spicer et al. 2009), with physiognomic data called "flora" and semi-quantitative methods (e.g. existence of carbonate, types of vegetation) are categorized as "other" (Supp. Fig. C7). Some of the methods used for comparison, like CIA-K and LAI, are thought to under-predict precipitation related to over-representation of clay content and taphonomic bias favoring preservation of small leaves, respectively (Spicer 2000; Stinchcomb et al. 2016). CLAMP, on the other hand, has been shown to overpredict mean annual precipitation in modern forests, due to the approximation of statistical fits associated with this tool (Wilf et al. 1998). The slope of the relationship (1.01) between precipitation reconstructed using other proxies and $\delta^{13}C_{SOM}$ values is very close to 1, indicating that relative changes in precipitation reconstructed using both proxies are approximately equal. Despite these stipulations for other paleoprecipitation proxies, the quality of comparison between $\delta^{13}C_{SOM}$-paleoprecipitation and paleoprecipitation values reconstructed using other established proxies was random, not systematically biased depending on the proxy (Supp. Fig. C7).In this study, the $\delta^{13}C_{SOM}$ -reconstructed values produce higher MAP reconstructions than other proxies by 373 mm yr^{-1}, but this over-prediction is still within the standard error (400 mm yr^{-1}) of an exact 1:1 relationship and it is unclear whether this is systemic based on individual alternate proxy errors

or $\delta^{13}C_{SOM}$ -reconstruction overprediction. When error is introduced for both $\delta^{13}C_{SOM}$ based reconstructions and other paleo-proxies, most of this study's data fall within the realm of a 1:1 relationship between other proxy reconstructions. It is possible that precipitation is conflated with time during weathering, affecting some paleoprecipitation proxies more than others, and making it difficult to compare $\delta^{13}C_{SOM}$ with chemical weathering proxies like CIA-K and CALMAG; in other words, it is not clear which (if either) proxy is necessarily accurate. Systemic over-prediction of precipitation using the $\delta^{13}C_{SOM}$-precipitation proxy could be related to weathering biases, or could relate to selective degradation of compounds with positive isotopic signatures, leaving behind lipids, which are more depleted in ^{13}C (Canuel et al. 2003) in acidic conditions. Systemic under-prediction using the $\delta^{13}C_{SOM}$-precipitation proxy could be related to oxidation of microbial digestion and mobilization of ^{12}C as soil-respired gas, leaving behind more enriched organic matter (e.g. Wynn 2007). The comparison between reconstructed precipitation from each established proxy and the new $\delta^{13}C_{SOM}$-precipitation was randomly distributed, indicating that there was no systematic over- or under-prediction for any given proxy (Supp. Fig. C7). The comparable values reconstructed using the $\delta^{13}C_{SOM}$ proxy and other established proxies demonstrates that this would make an excellent complementary tool to use in paleoclimate reconstructions.

4.5.4 General paleo-limitations and implications

While the relationship between $\delta^{13}C_{SOM}$ and precipitation is geographically robust (in reference to modern calibration; Fig. 2), there are certain limitations to where this relationship can be used. This relationship was tested in C_3-dominated ecosystems only, so this tool will work best before ~30 million years ago (Cerling et al. 1993; Edwards et al. 2010), or in more recent cases where there is an independent constraint on C_3 vs. C_4 plant abundance (e.g. paleobotanical evidence, phytoliths; Germeraad et al. 1968; Royer et al. 2001; Piperno 2006; Stromberg & McInerney 2011; Hyland et al. 2014; Smiley et al. 2018). As shown in Figure 1, this excludes major grass-dominated ecosystems from the Miocene through the modern without additional independent evidence of flora (e.g. savannas), which makes this relationship not currently applicable for large equatorial regions with widespread C_4 plants such as exist in modern and Neogene ecosystems. Pre-Neogene ecosystems can be treated as C_4-free due to the lack of

abundance of C_4 plants in the Paleogene and earlier (Tipple & Pagani 2007). Bookending the oldest time wherein paleosols are comparable to modern day soils due to fundamental ecosystem structure is the Devonian Period; before land plants developed adaptations such as seed habits, arborescence, and deeper rooting systems in the Devonian, pedogenic development was weak and many of the most widespread modern soil orders (Histosols, Alfisols, Ultisols, Mollisols) were not yet in existence (Retallack 2008).

Additional deep-time nuances to consider regarding the oldest practical use of this proxy include the radiation of angiosperms: although paleosols developed similarly to those of today post-Devonian, they did not include angiosperms until sometime in the mid-Jurassic to early Cretaceous (Li et al. 2019; but see Coiro et al. 2019, Sokoloff et al. 2019, Bateman 2020). Angiosperms are the most widespread plant types in modern ecosystems (and ever since their radiation in the mid-Cretaceous; Li et al. 2019), so the past ~144 million years should be directly comparable, but what about for gymnosperm dominated ecosystems of the Paleozoic and earlier Mesozoic? To test the importance of the presence of angiosperms, we compared angiosperm-dominated soils (n = 55) with gymnosperm-dominated soils (n = 23) based on ecosystem-specified (*Populus* (angiosperm)*, Thuja* (gymnosperm)) collections for this study and flora provided in literature (Supp. Fig. C6). T-test results determined that the difference between $\delta^{13}C_{SOM}$ for angiosperm- and gymnosperm- dominated ecosystems was not significant, and that the ranges of these two ecosystems were comparable (Supp. Fig. C6). Thus, the proposed proxy relationship can be used on paleosols prior to the origin and radiation of angiosperms.

When applying this relationship to the geologic record, we must consider that $\delta^{13}C$ values in soils can potentially be altered by chemical, biological, and biological processes (Wynn et al. 2005). Very high precipitation values can result in organic carbon, which is fairly mobile, leaching completely from local soils. Furthermore, even if organic carbon is not completely removed from an ecosystem, dissolved organic carbon (DOC) is more likely to be translated from the upper soil horizons and accumulate in lower, B-horizons, undergoing increased oxidation-related isotopic fractionation with depth in a soil profile (e.g. Rayleigh distillation; Wynn & Byrd 2007). High precipitation can also increase microbial activity and associated diagenesis (Cruz-Martínez et al. 2012). This is further shown by empirical evidence in this study; the three outliers (Fig. 4.3, 4.5, C3), which are from the temperate rainforests on the Olympic

Peninsula of Washington with rainfall >3000 mm yr^{-1}, all appear significantly more isotopically positive than expected at high rainfall. Other than these outliers, the vast majority of the soils compiled for this study were from areas with annual precipitation <2500 mm yr^{-1}, so this paleo-precipitation proxy is only calibrated for use in precipitation regimes <2500 mm yr^{-1} at this time. Above these precipitation levels, most ecosystems are considered "rainforests" (Whitaker 1975) and are typically characterized by Oxisols. Although the proposed proxy is limited at very high precipitation regimes (e.g. >2500 mm yr^{-1}), it is more precise than other precipitation proxies between 1500–2500 mm yr^{-1}. Limitations of the model connecting carbon isotope values and precipitation at high precipitation values coincides with findings by Kohn (2010), who found strong canopy effects above 2500 mm yr^{-1} (Kohn 2010) in his modern plant meta-analysis. Future studies specifically focused on testing the relationship between carbon isotope values of soils and precipitation in rainforests and other high precipitation regimes will constrain the higher end of this relationship for wider applications in the geologic record.

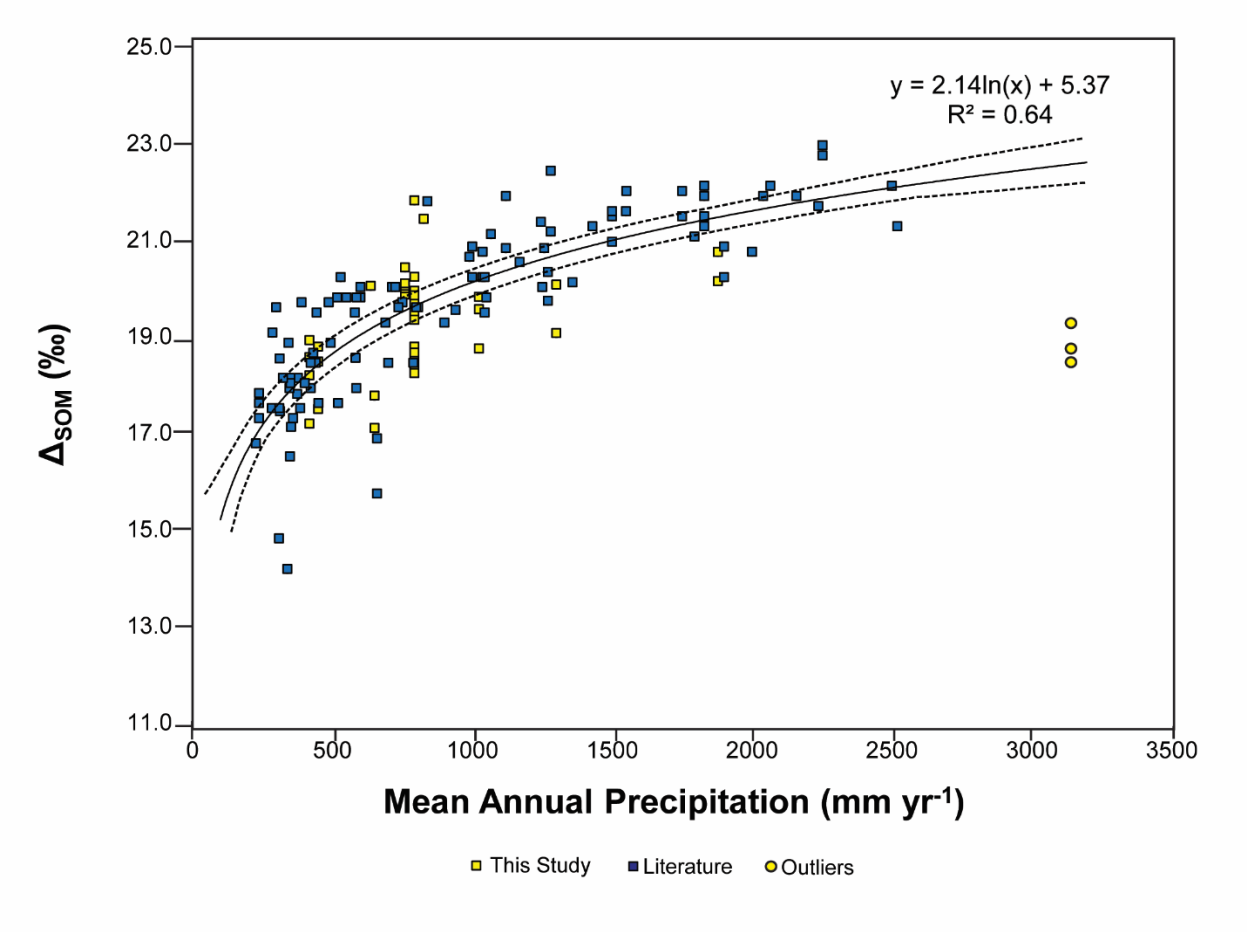

Figure 4.5: $\Delta^{13}C_{SOM}$ values compared to mean annual precipitation for modern soils. Soils from this study are shown in yellow squares, literature data is shown in blue squares, with one standard deviation shown around the best-fit logarithmic relationship model determined in this study, and outliers (from our dataset, measured MAP = 3350 mm yr^{-1}) are shown in yellow circles.

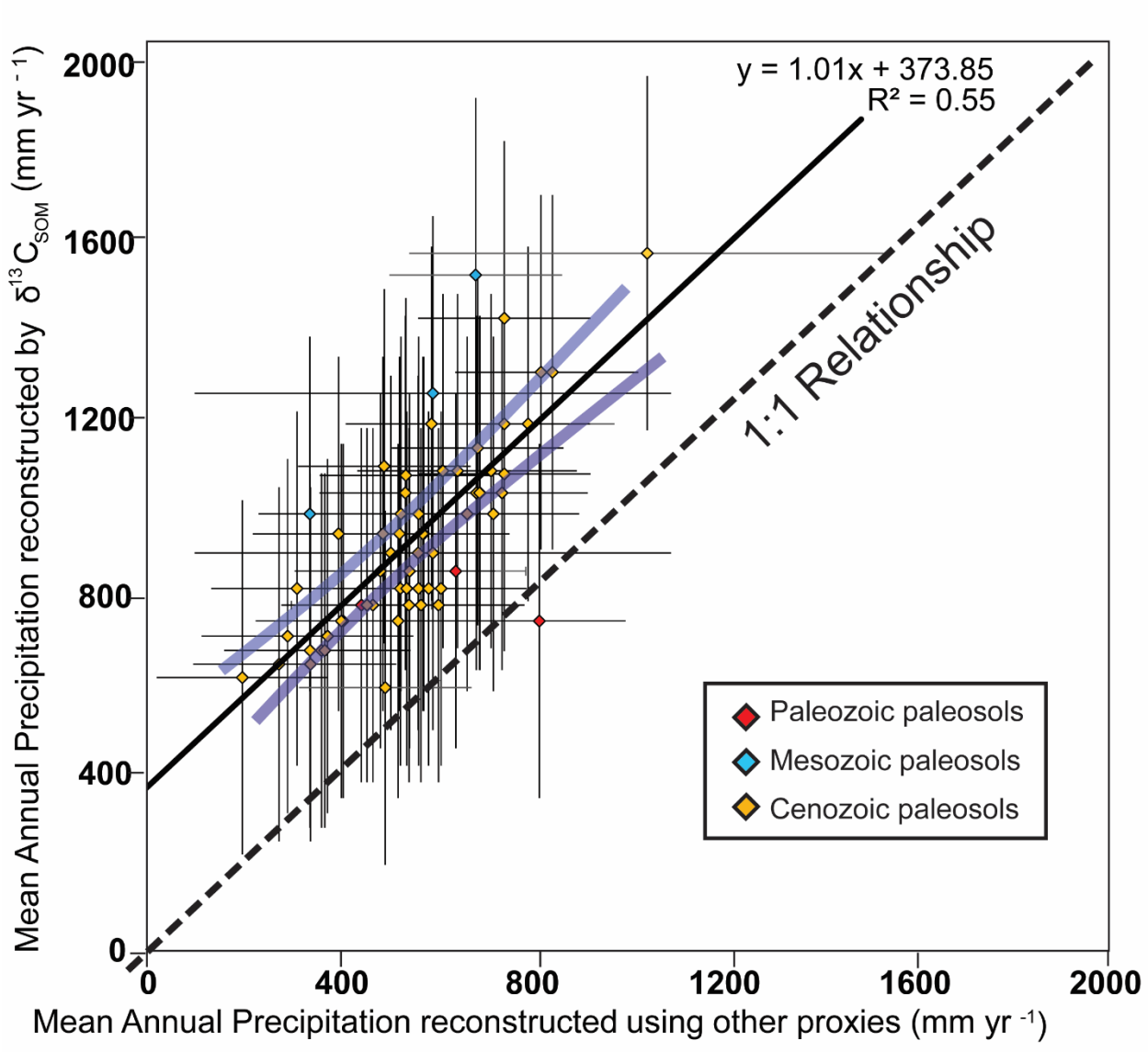

Figure 4.6: Paleosol reconstructed mean annual precipitation values over time as compared to precipitation values reconstructed with different paleoprecipitation proxies. (See Cerling et al. 1992; Mora et al. 1996; Hatte et al. 2001; Nordt et al. 2002; Pustovoytov & Terhorst 2004; Sheldon 2006; Gutierrez & Sheldon 2012; Hyland & Sheldon 2013; Harris et al. 2017; Lukens et al. 2017; Tabor et al. 2017). Shown are average mean annual precipitation values reconstructed with proxy-specific error along the x-axis and $\delta^{13}C_{SOM}$ error along the y-axis (400mm yr^{-1}). Pre-Cenozoic $\delta^{13}C_{atm}$ values (‰) are treated as -6, and Cenozoic $\delta^{13}C_{atm}$ values are calculated using Tipple et al. (2010) values. The 95% confidence intervals, indicating how the confidence in the relationship linking the new calculated values relate to the old calculated values, are shown in blue opaque lines. The 1:1 relationship, which would indicate that previous calculated values are equal to new calculated values, is shown in dashed lines. Red diamonds represent paleosols deposited in the Paleozoic, blue diamonds represent paleosols deposited in the Mesozoic, and gold diamonds represent paleosols deposited in the Cenozoic.

4.5.5 Corrections when applying to the geologic record

The isotopic value of the atmosphere ($\delta^{13}C_{atm}$) has not been constant over geological time (Tipple et al. 2010). For example, the modern atmosphere is more negative compared to most of Earth's history due to anthropogenic causes (geologic fuel combustion, deforestation; Keeling et al. 2001). Because of this, the relationship relating $\delta^{13}C_{SOM}$ and MAP needs to be corrected, using equation 4.6, for differences in $\delta^{13}C_{atm}$ when applied to the geologic record by correcting the $\delta^{13}C_{SOM}$ value of ancient soil.

$$\left(\delta^{13}C_{atm,ancient} - \delta^{13}C_{atm,modern}\right) + \delta^{13}C_{SOM}\ (‰)\right) \text{ (Equation 4.6)}$$

For example, during the early Eocene, when $\delta^{13}C_{atm}$ was approximately -5.5‰, the correction to $\delta^{13}C_{SOM}$ would be +1‰ (Tipple et al. 2010); during the Paleocene-Eocene Thermal Maximum, the correction factor would be closer to +1.5‰; and during the Mid-Miocene, the correction factor would be +0.5‰. At its most sensitive, a difference of 2.5‰ of $\delta^{13}C_{atm}$ would result in a difference between $\delta^{13}C_{SOM}$-reconstructed precipitation values of 222 mm yr^{-1} ($\delta^{13}C_{SOM}$ = -23‰) and 739 mm yr^{-1} ($\delta^{13}C_{SOM}$ = -25.5‰). This is the difference between a desert and a grassland or savannah (Whitaker 1975).

As mentioned, the carbon isotope value of soil organic carbon is not constant through a soil profile (Krull et al. 2002; Wynn et al. 2006; Wynn 2007; Fig. 1). The organic matter at the top of the soil profile (e.g. O- horizon) is most reflective of average aboveground biomass, and should be exclusively used in applications of this model. The $\delta^{13}C_{SOM}$ down-profile becomes more enriched in ^{13}C (see Fig. 1). However, this section of soil is also not always preserved (Mack et al. 1993), or is eroded and unidentifiable (Marriott et al. 2006), and the pattern of Rayleigh fractionation down-profile is contingent on factors such as soil texture and slope (Krull et al. 2002; Wynn 2007; Fig. 1). To address this constraint, when possible, carbon isotope values for the entire soil profile should be collected, such that the carbon isotope value of the topsoil can be back-calculated based on carbon isotope values and the fraction of soil organic carbon remaining for each of these samples (Wynn 2007).

4.6 Conclusions

Overall, there is a strong relationship between organic $\delta^{13}C$ values in soil and mean annual precipitation. This substantiates past work linking $\delta^{13}C$ values of aboveground plant biomass to precipitation. This $\delta^{13}C_{SOM}$-precipitation model provides a new method for reconstructing precipitation in organic-rich sediments, particularly those without clearly preserved soil development (e.g. alluvial floodplains, wetlands), as well as more precision at precipitation levels between 1500 and 2500 mm yr^{-1}. Prior to this proxy, organic-based terrestrial precipitation proxies largely relied on taxonomy or full preservation, and paleosol-based precipitation proxies relied on full-profile development. This new tool will be especially useful in areas with poor pedogenic development, which are often found in areas near to lakes and rivers (e.g. high resolution, high preservation regions) that are vulnerable to flooding, but also especially prevalent in the fossil record. In tandem with identifiable organic material, this organic-based proxy could allow us to investigate the direct link between precipitation and organic carbon and characterize the water limitations of localized ecosystems. Future projects could use pre-determined knowledge of Rayleigh distillation isotope enrichment down-profile in soils to back-calculate topsoil $\delta^{13}C_{SOM}$ values from A- and B- horizons, which will provide a way to connect the use of B- and O- horizons of soils for paleoprecipitation reconstruction.

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4.8 References

Andrews, E., White, T., & del Papa, C. (2017). Paleosol-based paleoclimate reconstruction of the Paleocene-Eocene Thermal Maximum, northern Argentina. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *471*, 181-195.

Balesdent, J., Mariotti, A., & Guillet, B. (1987). Natural ^{13}C abundance as a tracer for studies of soil organic matter dynamics. *Soil Biology and Biochemistry*, *19*(1), 25-30.

Bateman, R. M. (2020). Hunting the Snark: the flawed search for mythical Jurassic angiosperms. *Journal of Experimental Botany*, *71*(1), 22-35.

Beverly, E. J., Lukens, W. E., & Stinchcomb, G. E. (2018). Paleopedology as a tool for reconstructing paleoenvironments and paleoecology. In *Methods in paleoecology* (pp. 151-183). Springer, Cham.

Billings, S. A., & Richter, D. D. (2006). Changes in stable isotopic signatures of soil nitrogen and carbon during 40 years of forest development. *Oecologia*, *148*(2), 325-333.

Bol, R. A., Harkness, D. D., Huang, Y., & Howard, D. M. (1999). The influence of soil processes on carbon isotope distribution and turnover in the British uplands. *European Journal of Soil Science*, *50*(1), 41-51.

Breecker, D. O., Sharp, Z. D., & McFadden, L. D. (2009). Seasonal bias in the formation and stable isotopic composition of pedogenic carbonate in modern soils from central New Mexico, USA. *Geological Society of America Bulletin*, *121*(3-4), 630-640.

Broadmeadow, M. S. J., Griffiths, H., Maxwell, C., & Borland, A. M. (1992). The carbon isotope ratio of plant organic material reflects temporal and spatial variations in CO_2 within tropical forest formations in Trinidad. *Oecologia*, *89*(3), 435-441.

Canuel, E. A., Freeman, K. H., & Wakeham, S. G. (1997). Isotopic compositions of lipid biomarker compounds in estuarine plants and surface sediments. *Limnology and Oceanography*, *42*(7), 1570-1583.

Cerling, T. E., Solomon, D. K., Quade, J. A. Y., & Bowman, J. R. (1991). On the isotopic composition of carbon in soil carbon dioxide. *Geochimica et Cosmochimica Acta*, *55*(11), 3403-3405.

Cerling, T. E. (1992). Use of carbon isotopes in paleosols as an indicator of the P (CO_2) of the paleoatmosphere. *Global Biogeochemical Cycles*, *6*(3), 307-314.

Cerling, T. E., & Quade, J. (1993). Climate change in continental isotopic records. *Geophysical Monograph*, *78*, 217-231.

Cerling, T. E., Wang, Y., & Quade, J. (1993). Expansion of C_4 ecosystems as an indicator of global ecological change in the late Miocene. *Nature*, *361*(6410), 344-345.

Chabbi, A., Kögel-Knabner, I., & Rumpel, C. (2009). Stabilised carbon in subsoil horizons is located in spatially distinct parts of the soil profile. *Soil Biology and Biochemistry*, *41*(2), 256-261.

Coiro, M., Doyle, J. A., & Hilton, J. (2019). How deep is the conflict between molecular and fossil evidence on the age of angiosperms? *New Phytologist*, *223*(1), 83-99.

Cotton, J. M., Jeffery, M. L., & Sheldon, N. D. (2013). Climate controls on soil respired CO_2 in the United States: implications for 21st century chemical weathering rates in temperate and arid ecosystems. *Chemical Geology*, *358*, 37-45.

Cruz-Martínez, K., Rosling, A., Zhang, Y., Song, M., Andersen, G. L., & Banfield, J. F. (2012). Effect of rainfall-induced soil geochemistry dynamics on grassland soil microbial communities. *Applied and environmental microbiology*, *78*(21), 7587-7595.

Dai, A. (2006). Precipitation characteristics in eighteen coupled climate models. *Journal of climate*, *19*(18), 4605-4630.

De Camargo, P. B., Trumbore, S. E., Martinelli, L. A., Davidson, E. A., Nepstad, D. C., & Victoria, R. L. (1999). Soil carbon dynamics in regrowing forest of eastern Amazonia. *Global Change Biology*, *5*(6), 693-702.

Diefendorf, A. F., Mueller, K. E., Wing, S. L., Koch, P. L., & Freeman, K. H. (2010). Global patterns in leaf ^{13}C discrimination and implications for studies of past and future climate. *Proceedings of the National Academy of Sciences*, *107*(13), 5738-5743.

Dijkstra, P., Ishizu, A., Doucett, R., Hart, S. C., Schwartz, E., Menyailo, O. V., & Hungate, B. A. (2006). ^{13}C and ^{15}N natural abundance of the soil microbial biomass. *Soil Biology and Biochemistry*, *38*(11), 3257-3266.

Douglas, P. M., Demarest, A. A., Brenner, M., & Canuto, M. A. (2016). Impacts of climate change on the collapse of lowland Maya civilization. *Annual Review of Earth and Planetary Sciences*, *44*, 613-645.

Dümig, A., Schad, P., Rumpel, C., Dignac, M. F., & Kögel-Knabner, I. (2008). Araucaria forest expansion on grassland in the southern Brazilian highlands as revealed by ^{14}C and $\delta^{13}C$ studies. *Geoderma*, *145*(1-2), 143-157.

Du, B., Liu, C., Kang, H., Zhu, P., Yin, S., Shen, G., Hou, J. & Ilvesniemi, H. (2014). Climatic control on plant and soil $\delta^{13}C$ along an altitudinal transect of Lushan Mountain in Subtropical China: Characteristics and interpretation of soil carbon dynamics. *PloS one*, *9*(1).

Duckstein, L., Fogel, M. M., & Thames, J. L. (1973). Elevation effects on rainfall: A stochastic model. *Journal of Hydrology*, *18*(1), 21-35.

Edwards, E. J., Osborne, C. P., Strömberg, C. A., Smith, S. A., & C4 Grasses Consortium. (2010). The origins of C_4 grasslands: integrating evolutionary and ecosystem science. *science*, *328*(5978), 587-591.

Ekart, D. D., Cerling, T. E., Montanez, I. P., & Tabor, N. J. (1999). A 400 million year carbon isotope record of pedogenic carbonate: implications for paleoatmospheric carbon dioxide. *American Journal of Science*, *299*(10), 805-827.

Etheridge, D. M., Steele, L. P., Langenfelds, R. L., Francey, R. J., Barnola, J. M., & Morgan, V. I. (1998). Historical CO_2 records from the Law Dome DE08, DE08-2, and DSS ice cores. *Trends: a compendium of data on global change*, 351-364.

Farquhar, G. D., Ehleringer, J. R., & Hubick, K. T. (1989). Carbon isotope discrimination and photosynthesis. *Annual review of plant biology*, *40*(1), 503-537.

Francey, R. J., Gifford, R. M., Sharkey, T. D., & Weir, B. (1985). Physiological influences on carbon isotope discrimination in huon pine (*Lagarostrobos franklinii*). *Oecologia*, *66*(2), 211-218.

Gallagher, T. M., & Sheldon, N. D. (2016). Combining soil water balance and clumped isotopes to understand the nature and timing of pedogenic carbonate formation. *Chemical Geology*, *435*, 79-91.

Gallagher, T. M., Hren, M., & Sheldon, N. D. (2019). The effect of soil temperature seasonality on climate reconstructions from paleosols. *American Journal of Science*, *319*(7), 549-581.

Germeraad, J. H., Hopping, C. A., & Muller, J. (1968). Palynology of Tertiary sediments from tropical areas. *Review of palaeobotany and palynology*, *6*(3-4), 189-348.

Givnish, T. J. (1984). Leaf and canopy adaptations in tropical forests. In *Physiological ecology of plants of the wet tropics* (pp. 51-84). Springer, Dordrecht.

Goh, K. M., Rafter, T. A., Stout, J. D., & Walker, T. W. (1976). The accumulation of soil organic matter and its carbon isotope content in a chronosequence of soils developed on aeolian sand in New Zealand. *Journal of Soil Science*, *27*(1), 89-100.

Grant, K. E., Galy, V. V., Chadwick, O. A., & Derry, L. A. (2019). Thermal oxidation of carbon in organic matter rich volcanic soils: insights into SOC age differentiation and mineral stabilization. *Biogeochemistry*, *144*(3), 291-304.

Gutierrez, K., & Sheldon, N. D. (2012). Paleoenvironmental reconstruction of Jurassic dinosaur habitats of the Vega Formation, Asturias, Spain. *Bulletin*, *124*(3-4), 596-610.

Harrington, G., Kemp, S., & Koch, P. (2004). Palaeocene–Eocene paratropical floral change in North America: responses to climate change and plant immigration. *Journal of the Geological Society*, *161*(2), 173-184.

Harris, E. B., Strömberg, C. A., Sheldon, N. D., Smith, S. Y., & Vilhena, D. A. (2017). Vegetation response during the lead-up to the middle Miocene warming event in the Northern Rocky Mountains, USA. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *485*, 401-415.

Hatté, C., Antoine, P., Fontugne, M., Lang, A., Rousseau, D. D., & Zöller, L. (2001). $\delta^{13}C$ of loess organic matter as a potential proxy for paleoprecipitation. *Quaternary Research*, *55*(1), 33-38.

Hodell, D. A., Curtis, J. H., & Brenner, M. (1995). Possible role of climate in the collapse of Classic Maya civilization. *Nature*, *375*(6530), 391-394.

Hren, M. T., Sheldon, N. D. (2012). Temporal variations in lake water temperature: Paleoenvironmental implications of lake carbonate $\delta^{18}O$ and temperature records. *Earth and Planetary Science Letters, 337-338,* 77-84.

Hyland, E. G., & Sheldon, N. D. (2013). Coupled CO_2-climate response during the early Eocene climatic optimum. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *369*, 125-135.

Hyland, E. G., Sheldon, N. D., Smith, S. Y., Cotton, J. M., & Strömberg, C. A. (2014). Dynamics of the Rise of C_4 Grasslands in Southwestern Montana. *The Paleontological Society Special Publications*, *13*, 115-116.

iNaturalist. Available from https://www.inaturalist.org. Accessed [May 1, 2018]

IPCC, T. (2007). Climate change 2007: synthesis report. *Contribution of working groups I, II and III to the fourth assessment report of the intergovernmental panel on climate change*, 95-212.

Jacobs, B. F. (1999). Estimation of rainfall variables from leaf characters in tropical Africa. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *145*(1-3), 231-250.

Jenny, H., & Leonard, C. D. (1934). Functional relationships between soil properties and rainfall. *Soil Science*, *38*(5), 363-382.

Keeling, C. D., Piper, S. C., Bacastow, R. B., Wahlen, M., Whorf, T. P., Heimann, M., & Meijer, H. A. (2001). Exchanges of atmospheric CO_2 and $^{13}CO_2$ with the terrestrial biosphere and oceans from 1978 to 2000. I. Global aspects.

Keeling, C. D., & Whorf, T. P. (2004). Atmospheric CO_2 concentrations derived from flask air samples at sites in the SIO network. *Trends: a compendium of data on Global Change*.

Kleber, M. (2010). What is recalcitrant soil organic matter? *Environmental Chemistry*, *7*(4), 320-332.

Kohn, M. J. (2010). Carbon isotope compositions of terrestrial C_3 plants as indicators of (paleo) ecology and (paleo) climate. *Proceedings of the National Academy of Sciences*, *107*(46), 19691-19695.

Krull, E. S., Skjemstad, J. O., Burrows, W. H., Bray, S. G., Wynn, J. G., Bol, R., Spouncer, L. & Harms, B. (2005). Recent vegetation changes in central Queensland, Australia: Evidence from $\delta^{13}C$ and 14C analyses of soil organic matter. *Geoderma*, *126*(3-4), 241-259.

Li, H. T., Yi, T. S., Gao, L. M., Ma, P. F., Zhang, T., Yang, J. B., Gitzendanner, M. A., Fritsch, P. W., Cai, J., Luo, Y. & Wang, H. (2019). Origin of angiosperms and the puzzle of the Jurassic gap. *Nature Plants*, *5*(5), 461.

Livingston, N. J., & Spittlehouse, D. L. (1996). Carbon isotope fractionation in tree ring early and late wood in relation to intra-growing season water balance. *Plant, Cell & Environment*, *19*(6), 768-774.

Looy, C., Kerp, H., Duijnstee, I., & DiMichele, B. (2014). The late Paleozoic ecological-evolutionary laboratory, a land-plant geologic record perspective. *The Sedimentary Record*, *12*(4), 4-18.

Lorenz, K., Lal, R., Preston, C. M., & Nierop, K. G. (2007). Strengthening the soil organic carbon pool by increasing contributions from recalcitrant aliphatic bio (macro) molecules. *Geoderma*, *142*(1-2), 1-10.

Mack, G. H., James, W. C., & Monger, H. C. (1993). Classification of paleosols. *Geological Society of America Bulletin*, *105*(2), 129-136.

Marriott, S. B., Wright, V. P., Alonso-Zarza, A. M., & Tanner, L. H. (2006). Investigating paleosol completeness and preservation in mid-Paleozoic alluvial paleosols: A case study in paleosol taphonomy from the Lower Old Red Sandstone. *SPECIAL PAPERS-GEOLOGICAL SOCIETY OF AMERICA*, *416*, 43.

McPherson, G. R., Boutton, T. W., & Midwood, A. J. (1993). Stable carbon isotope analysis of soil organic matter illustrates vegetation change at the grassland/woodland boundary in southeastern Arizona, USA. *Oecologia*, *93*(1), 95-101.

Mintz, J. S., Driese, S. G., Breecker, D. O., & Ludvigson, G. A. (2011). Influence of changing hydrology on pedogenic calcite precipitation in Vertisols, Dance Bayou, Brazoria County, Texas, USA: implications for estimating paleoatmospheric pCO_2. *Journal of Sedimentary Research*, *81*(6), 394-400.

Mora, C. I., Sheldon, B. T., Elliott, W. C., & Driese, S. G. (1998). An oxygen isotope study of illite and calcite in three Appalachian Paleozoic vertic paleosols. *Journal of Sedimentary Research*, *68*(3), 456-464.

Nesbitt, H., & Young, G. M. (1982). Early Proterozoic climates and plate motions inferred from major element chemistry of lutites. *Nature*, *299*(5885), 715-717.

Nordt, L., Atchley, S., & Dworkin, S. I. (2002). Paleosol barometer indicates extreme fluctuations in atmospheric CO2 across the Cretaceous-Tertiary boundary. *Geology*, *30*(8), 703-706.

Nordt, L. C., & Driese, S. D. (2010). New weathering index improves paleorainfall estimates from Vertisols. *Geology*, *38*(5), 407-410.

Olen, S. M., Ehlers, T. A., & Densmore, M. S. (2012). Limits to reconstructing paleotopography from thermochronometer data. *Journal of Geophysical Research: Earth Surface*, *117*(F1).

Osher, L. J., Matson, P. A., & Amundson, R. (2003). Effect of land use change on soil carbon in Hawaii. *Biogeochemistry*, *65*(2), 213-232.

Passey, B. H. (2012). Reconstructing terrestrial environments using stable isotopes in geologic teeth and paleosol carbonates. *The Paleontological Society Papers*, *18*, 167-194.

Pfeifer, M., Gonsamo, A., Disney, M., Pellikka, P., & Marchant, R. (2012). Leaf area index for biomes of the Eastern Arc Mountains: Landsat and SPOT observations along precipitation and altitude gradients. *Remote Sensing of Environment*, *118*, 103-115.

Piperno, D. R. (2006). *Phytoliths: a comprehensive guide for archaeologists and paleoecologists*. Rowman Altamira.

Powell, R. L., Yoo, E. H., & Still, C. J. (2012). Vegetation and soil carbon-13 isoscapes for South America: integrating remote sensing and ecosystem isotope measurements. *Ecosphere*, *3*(11), 1-25.

Quade, J., Cerling, T. E., Andrews, P., & Alpagut, B. (1995). Paleodietary reconstruction of Miocene faunas from Paşalar, Turkey using stable carbon and oxygen isotopes of geologic tooth enamel. *Journal of Human Evolution*, *28*(4), 373-384.

Retallack, G. J. (1994). The environmental factor approach to the interpretation of paleosols. *Factors of soil formation: A fiftieth anniversary retrospective*, *33*, 31-64.

Retallack, G. J. (2008). *Soils of the past: an introduction to paleopedology*. John Wiley & Sons.

Rothstein, D. E., Toosi, E. R., Schaetzl, R. J., & Grandy, A. S. (2018). Translocation of carbon from surface organic horizons to the subsoil in coarse-textured Spodosols: implications for deep soil C dynamics. *Soil Science Society of America Journal*, *82*(4), 969-982.

Royer, D. L., Wing, S. L., Beerling, D. J., Jolley, D. W., Koch, P. L., Hickey, L. J., & Berner, R. A. (2001). Paleobotanical evidence for near present-day levels of atmospheric CO_2 during part of the Tertiary. *Science*, *292*(5525), 2310-2313.

Sanderman, J., Creamer, C., Baisden, W. T., Farrell, M., & Fallon, S. (2017). Greater soil carbon stocks and faster turnover rates with increasing agricultural productivity, Soil, 1-16.

Schermerhorn, V. P. (1967). Relations between topography and annual precipitation in western Oregon and Washington. *Water Resources Research*, *3*(3), 707-711.

Sheldon, N. D. (2006). Abrupt chemical weathering increase across the Permian–Triassic boundary. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *231*(3-4), 315-321.

Sheldon, N. D., Smith, S. Y., Stein, R., & Ng, M. (2020). Carbon isotope ecology of gymnosperms and implications for paleoclimatic and paleoecological studies. *Global and Planetary Change*, 103060.

Shucheng, X., & Evershed, R. P. (2001). Peat molecular geologics recording paleoclimatic change and organism replacement. *Chinese Science Bulletin*, *46*(20), 1749.

Smiley, T. M., Hyland, E. G., Cotton, J. M., & Reynolds, R. E. (2018). Evidence of early C_4 grasses, habitat heterogeneity, and faunal response during the Miocene Climatic Optimum in the Mojave Region. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *490*, 415-430.

Sokoloff, D. D., Remizowa, M. V., El, E. S., Rudall, P. J., & Bateman, R. M. (2019). Supposed Jurassic angiosperms lack pentamery, an important angiosperm-specific feature. *New Phytologist*.

Spicer, R. A. (2000). Leaf physiognomy and climate change. *Biotic response to global change: the last*, *145*, 244-264.

Spicer, R. A., Herman, A. B., & Wolfe, J. A. (2008). Clamp. *Encyclopedia of Paleoclimatology and Ancient Environments*, 156-158.

Spicer, R. A., Valdes, P. J., Spicer, T. E. V., Craggs, H. J., Srivastava, G., Mehrotra, R. C., & Yang, J. (2009). New developments in CLAMP: calibration using global gridded meteorological data. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *283*(1-2), 91-98.

Stein, R. A., Sheldon, N. D., & Smith, S. (2019). Rapid response to anthropogenic climate change by Thuja occidentalis: implications for past climate reconstructions and future climate predictions. *PeerJ*, *7*, e7378.

Stein, R. A., Sheldon, N. D., & Smith S. (in press). C_3 plant carbon isotope discrimination does not respond to CO_2 concentration on decadal to centennial timescales. *New Phytologist.* doi: 10.1111/nph.17030

Stevenson, B. A., Kelly, E. F., McDonald, E. V., & Busacca, A. J. (2005). The stable carbon isotope composition of soil organic carbon and pedogenic carbonates along a bioclimatic gradient in the Palouse region, Washington State, USA. *Geoderma*, *124*(1-2), 37-47.

Stewart, B. W., Capo, R. C., & Chadwick, O. A. (2001). Effects of rainfall on weathering rate, base cation provenance, and Sr isotope composition of Hawaiian soils. *Geochimica et Cosmochimica Acta*, *65*(7), 1087-1099.

Stinchcomb, G. E., Nordt, L. C., Driese, S. G., Lukens, W. E., Williamson, F. C., & Tubbs, J. D. (2016). A data-driven spline model designed to predict paleoclimate using paleosol geochemistry. *American Journal of Science*, *316*(8), 746-777.

Stromberg, C. A., & McInerney, F. A. (2011). The Neogene transition from C_3 to C_4 grasslands in North America: assemblage analysis of fossil phytoliths. *Paleobiology*, *37*(1), 50-71.

Tabor, N. J., Myers, T. S., Gulbranson, E., Rasmussen, C., Sheldon, N. D., Driese, S. G., ... & McCarthy, P. J. (2013). Carbon stable isotope composition of modern calcareous soil profiles in California: implications for CO2 reconstructions from calcareous paleosols. In *New Frontiers in Paleopedology and Terrestrial Paleoclimatology* (Vol. 104, pp. 17-34). SEPM (Society for Sedimentary Geology).

Tabor, N. J., Sidor, C. A., Smith, R. M., Nesbitt, S. J., & Angielczyk, K. D. (2017). Paleosols of the Permian-Triassic: proxies for rainfall, climate change and major changes in terrestrial tetrapod diversity. *Journal of Vertebrate Paleontology*, *37*(sup1), 240-253.

Tipple, B. J., & Pagani, M. (2007). The early origins of terrestrial C4 photosynthesis. *Annu. Rev. Earth Planet. Sci.*, *35*, 435-461.

Tipple, B. J., Meyers, S. R., & Pagani, M. (2010). Carbon isotope ratio of Cenozoic CO_2: A comparative evaluation of available geochemical proxies. *Paleoceanography*, *25*(3).

Thompson, R. S., Anderson, K. H., & Bartlein, P. J. (1999). *Quantitative paleoclimatic reconstructions from late Pleistocene plant macrogeologics of the Yucca Mountain region* (p. 39). US Department of the Interior, US Geological Survey.

Torn, M. S., Lapenis, A. G., Timofeev, A., Fischer, M. L., Babikov, B. V., & Harden, J. W. (2002). Organic carbon and carbon isotopes in modern and 100-year-old-soil archives of the Russian steppe. *Global Change Biology*, *8*(10), 941-953. Townsend, A. R., Vitousek,

P. M., Desmarais, D. J., & Tharpe, A. (1997). Soil carbon pool structure and temperature sensitivity inferred using CO_2 and $^{13}CO_2$ incubation fluxes from five Hawaiian soils. *Biogeochemistry*, *38*(1), 1-17.

Trumbore, S. (2000). Age of soil organic matter and soil respiration: radiocarbon constraints on belowground C dynamics. *Ecological Applications*, *10*(2), 399-411.

Volkoff, B., & Cerri, C. C. (1987). Carbon isotopic fractionation in subtropical Brazilian grassland soils. Comparison with tropical forest soils. *Plant and soil*, *102*(1), 27-31.

von Fischer, J. C., & Tieszen, L. L. (1995). Carbon isotope characterization of vegetation and soil organic matter in subtropical forests in Luquillo, Puerto Rico. *Biotropica*, 138-148.

Wang, G., Li, J., Liu, X., & Li, X. (2013). Variations in carbon isotope ratios of plants across a temperature gradient along the 400 mm isoline of mean annual precipitation in north China and their relevance to paleovegetation reconstruction. *Quaternary Science Reviews*, *63*, 83-90.

Wang, Y., Kromhout, E., Zhang, C., Xu, Y., Parker, W., Deng, T., & Qiu, Z. (2008). Stable isotopic variations in modern herbivore tooth enamel, plants and water on the Tibetan Plateau: Implications for paleoclimate and paleoelevation reconstructions. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *260*(3-4), 359-374.

Ward, J. K., Tissue, D. T., Thomas, R. B., & Strain, B. R. (1999). Comparative responses of model C_3 and C_4 plants to drought in low and elevated CO2. *Global Change Biology*, *5*(8), 857-867.

Weiguo, L., Xiahong, F., Youfeng, N., Qingle, Z., Yunning, C., & Zhisheng, A. N. (2005). δ13C variation of C3 and C4 plants across an Asian monsoon rainfall gradient in arid northwestern China. *Global Change Biology*, *11*(7), 1094-1100.

Weltzin, J. F., & McPherson, G. R. (Eds.). (2003). *Changing precipitation regimes and terrestrial ecosystems: A North American perspective*. University of Arizona Press.

White, J. W. C., Vaughn, B. H., & Michel, S. E. (2015). University of Colorado, Institute of Arctic and Alpine Research (INSTAAR), Stable Isotopic Composition of Atmospheric Carbon Dioxide (13C and 18O) from the NOAA ESRL Carbon Cycle Cooperative Global Air Sampling Network, 1990–2014, Version: 2015-10-26. *Path: ftp://aftp. cmdl. noaa. gov/data/trace_gases/co2c13/flask*.

Whittaker, R. (1975). Whittaker Biome Diagram.

Wilf, P., Wing, S. L., Greenwood, D. R., & Greenwood, C. L. (1998). Using geologic leaves as paleoprecipitation indicators: an Eocene example. *Geology*, *26*(3), 203-206.

Wilf, P. (2000). Late Paleocene–early Eocene climate changes in southwestern Wyoming: Paleobotanical analysis. *Geological Society of America Bulletin*, *112*(2), 292-307.

Wynn, J. G., Bird, M. I., & Wong, V. N. (2005). Rayleigh distillation and the depth profile of $^{13}C/^{12}C$ ratios of soil organic carbon from soils of disparate texture in Iron Range

National Park, Far North Queensland, Australia. *Geochimica et cosmochimica acta*, *69*(8), 1961-1973.

Wynn, J. G. (2007). Carbon isotope fractionation during decomposition of organic matter in soils and paleosols: implications for paleoecological interpretations of paleosols. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *251*(3-4), 437-448.

Wynn, J. G., & Bird, M. I. (2007). C_4-derived soil organic carbon decomposes faster than its C_3 counterpart in mixed C_3/C_4 soils. *Global Change Biology*, *13*(10), 2206-2217.

Youfeng, N., Weiguo, L., & Zhisheng, A. (2008). A 130-ka reconstruction of precipitation on the Chinese Loess Plateau from organic carbon isotopes. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *270*(1-2), 59-63.

CHAPTER V

Using Multiple Proxies to Characterize a Post-Early Eocene Climatic Optimum Ecosystem in the Rocky Mountain Interior[4]

5.1 Abstract

The early Eocene climatic optimum (EECO), a warm period ~50 million years ago, is often referred to as an analog for warm-world conditions in a high-emissions anthropogenic modern climate change scenario. Thus, understanding hydroclimate at this time, particularly in areas stressed by modern climate change, is imperative to mitigating future water stress and drought. The Greater Green River Basin (GGRB), which accumulated sediment from the surrounding dynamic topography in a highly evaporative, hypersaline lake (Lake Gosiute) is known for its high resolution, well-preserved records of the EECO. In the middle of this basin, marking approximately the center of Lake Gosiute's maximum extent, the Bridger Formation and Blue Rim escarpment host pristinely preserved, well-documented floral assemblages in alluvial and fluvial sediments. Previous age constraints based on biostratigraphy estimated ages ~50–45.5 million years ago, but here absolute ages of 49.29 and 48.29 Ma are reported based on $^{40}Ar/^{39}Ar$ geochronology, placing the Blue Rim escarpment shortly after the peak warming associated with the EECO. Due to the basin's proximity to multiple potential sources of moisture and transported sediment to the west, northeast and south, there is concern that inconsistent hydrological inputs may interfere with interpretations of climate and depositional signals in the region. Using multiple geochemical proxies and fossil evidence, we demonstrate that moisture and sediment sources in the basin throughout the >1 million years of post-EECO uplift of the Rocky Mountains stayed constant, and that variability in biogeochemistry and floral preservation is related to changes in climate and biota. Our multiproxy approach using floral, organic, and inorganic proxies (CIA-K, PWI, bulk geochemical ratios to determine provenance, carbon isotope ecology, floral humidity province, Holdridge Life Zones) demonstrate that the rim of Lake Gosiute was an ephemeral wet forest ecosystem with warm temperatures (10.4–12.0 °C), medium to high precipitation (608–1167 mm yr^{-1}), moderate weathering, and sediments coming

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from consistent provenance. This systemic approach to a high-resolution record of late, central Lake Gosiute indicates that the region was mostly littoral and floodplain, demonstrating the overall regression of Lake Gosiute just after the EECO. The constant provenance, parent material, temperature, and precipitation imply that the development of the Laramide orogeny had largely finished in this region by the time of deposition.

5.2 Introduction

5.2.1 The Eocene Period

The anthropogenic release of fossil fuels drives a rapid and sustained increase in atmospheric carbon dioxide (CO_2) coupled with subsequent climate change (IPCC 2007). To understand the effects of elevated CO_2 on the Earth, we seek out geological periods with high temperatures and high atmospheric CO_2 for comparison (Cotton et al. 2013). Recently, the early Eocene climatic optimum (EECO) has been invoked as a climate analog for our projected future (Zhu et al. 2019). This peak warming of the EECO occurred 51.5–50.9 million years ago (Ma) and consisted of long-term global temperature maxima and high CO_2 levels but was tectonically comparable to today (Hyland & Sheldon 2013; West et al. 2020). Throughout the early Cenozoic, from the Paleocene to early Eocene, it has been inferred that much of North America was warm and wet, with extensive temperate forests (Smith et al. 2012; Breedlovestrout et al. 2014; Greenwood et al. 2016; West et al. 2020) up to high latitudes 65 °N (Dillhoff et al. 2013). As the planet warms, we are increasingly worried about water availability and dry climates getting drier (Cheeseman 2016). An example of this is the continental interior of North America: currently the North American Southwest is high-elevation desert and experiences severe droughts. It is assumed that with imminent climate change, this drought may be exacerbated (Poore et al. 2005); therefore, we are especially interested in the paleoclimate of the North American interior.

5.2.2 Continental interior and foreland basins in the Rocky Mountains

During the early Eocene, the thick-skinned Sevier orogeny transitioned into the thin-skinned Laramide orogeny mountain building events, resulting in the formation of these uplifting

mountains and basins close to sea level (Dickinson et al. 1988; Snoke et al. 1993). Subsequently, sedimentation rates increased, creating extensive sedimentary basin deposits (Dickinson et al. 1988; Snoke et al. 1993). These high sedimentation rate intracontinental lake basins are typically well-preserved in the fossil record, allowing us to study deep time in high resolution (Looy et al. 2014). One of these, Eocene Lake Gosiute, a basin east of the fold and thrust belt (Figure 5.1), is represented by lacustrine deposits of the Green River Formation (Lyman Tongue, Wilkins Peak, Laney Members; Smith et al. 2003) as well as the inter-fingering paleosols and alluvial mudstones of the Wasatch and Bridger formations (Carroll et al. 2008).

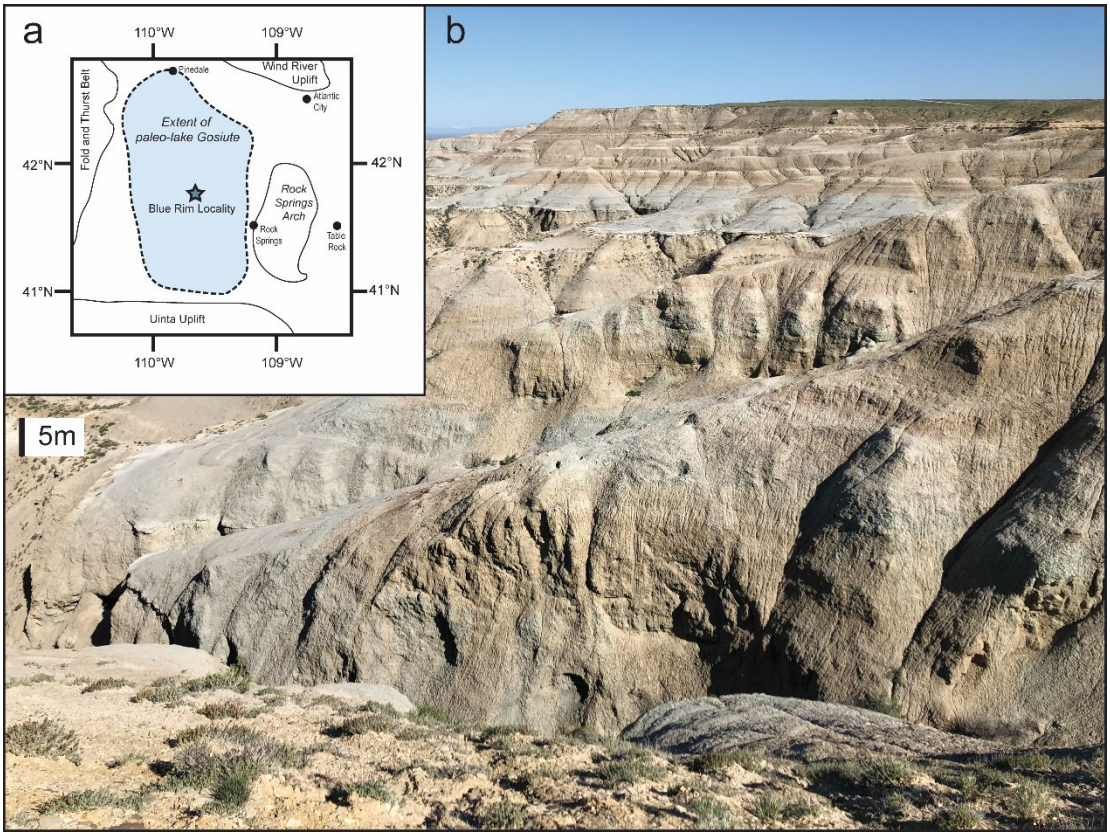

Figure 5.1: Map and profile of Blue Rim escarpment. (a) Map and location of Blue Rim escarpment (41.7985 °N, -109.5856 °E) and surrounding Eocene topography. (b) Landscape image of the escarpment from the uppermost strata.

Lake Gosiute was surrounded by the Wind River range (north), Uinta range (south), Rock Springs uplift (south, east), and Wyoming fold-and-thrust belt (west; Fig. 5.1), and as a result received water inputs from each of these sources (Murphey et al. 2011). The array of surrounding mountain ranges with high sediment input around a highly evaporative, shallow

alkaline lake has resulted in superb preservation in sediments from the EECO of paleo-lake Gosiute in the GGRB (Surdam & Stanley 1979). However, due to the multiple potential inputs, the patterns driving the local hydroclimate can interfere with climate and geochronological interpretations (Carroll et al. 2008). Previous work has speculated that our perception and interpretation of the climate and environment of the GGRB could be driven by changes in hydrological inputs related to tectonic uplift in the region. Specifically, significantly shifting geochemical data ($\delta^{18}O$ values) within calcitic mudstone spanning 100,000 years in the Green River Formation (49 Ma) was interpreted as potential changes in river and stream inputs associated with relief or lengthy distances, rather than changing temperatures or rainfall (Carroll et al. 2008). This could impact our understandings of paleoecosystems, because interpretations of environments could be influenced by allochthonous organic material, as can paleoclimate reconstructions, and even age (if geochronology is performed on grains from external sites; Smith et al. 2003; Malone et al. 2014). The origin and amplitude of hydrological inputs to Lake Gosiute is pertinent to our understanding about water availability in the region post-EECO. Better constraints on fluvial and alluvial inputs to Lake Gosiute will allow us to determine whether our interpretations of the environment are a result of inconsistent sources, or changing climate. The proximity of these lacustrine records to active tectonics in westward mountain building also results in high-frequency tephra, which allow us to constrain the age of Lake Gosiute with anomalous precision. The paleolatitude of southwestern Wyoming in the early Eocene is thought to be moderately comparable to its position today (41–41.82 °N; Wolfe et al. 1998; Hyland & Sheldon 2013), thus this region provides a tectonically constrained, biogeographically similar region to study the early Eocene continental interior.

5.2.3 Using multiple proxies to characterize an environment

There are several terrestrial proxies that can be used to reconstruct paleoclimate and paleoecology (e.g. pedogenic carbonate isotope values, floral assays, stomatal density; Cerling 1992; Royer 1999; Wilf et al. 2000; Spicer et al. 2009). This study seeks to combine these proxies to create a holistic and robust reconstruction of the Greater Green River Basin during the early Eocene. The high degree of preservation of organic and inorganic specimens, due to the tectonic assemblage of the basin currently, makes it such that the Greater Green River Basin is

an excellent location for such an approach. In light of the potential imprint of hydrological changes in climate and ecosystem interpretations, the use of multiple sources of geochemical inorganic in tandem can provide context for many aspects of depositional environment, including characterization of ecosystems, climate, hydroclimate, age and origin of sediments. Organic geochemistry can be used to demonstrate isotopic composition of the atmosphere ($\delta^{13}C_{atm}$; Arens et al. 2000; Stein et al. 2019). The $\delta^{13}C_{atm}$ value is an important environmental variable, as it reflects sources of CO_2 gas to the atmosphere, because potential C sources have different isotopic signatures (e.g. mantle CO_2 = ~-5.5‰; Keeling 1979; Boutton 1991; Deines 1992). These values are also important parameters in models that reconstruct additional environmental variables, such as the concentration of atmospheric [CO_2] using paleosol carbonates (Cerling et al. 1991; Cerling 1992) or using stomatal parameters (Franks et al. 2014).

The Blue Rim locality of the Bridger Formation is a well-characterized stratigraphic section (Kistner 1973) with well-studied floral assemblages (Kistner 1973; Allen 2017), and provides an opportunity to aggregate bulk and isotope geochemical proxies within sedimentary rocks, paleosols, and organic matter in a single location (Buchheim et al. 2000). The geolocation of Blue Rim escarpment was at one time the center of Lake Gosiute during its maximal extent, though the sediments deposited represent an environment littoral to the receding lake. This is a low energy environment with high accumulation rates, and thus promises high preservation and high resolution geochemical data for ecosystem and deposition analyses. In addition to new isotope and bulk geochemistry results on newly collected fossils and mudstone samples, we provide an updated age of this formation using $^{40}Ar/^{39}Ar$ geochronology.

5.3 Methods

5.3.1 Description of locality

The Bridger Formation is an 842m thick series of tuffaceous lacustrine and deltaic-alluvial sedimentary rocks (Koenig 1960). Previously, workers estimated that the Bridger Formation spanned 3.5 million years, from 49.09–45.57 Ma (Murphey & Evanoff 2001). Other estimates place the start of the Bridger Formation prior to 50 million years, spanning through to 45.6 million years, and, although there are no previous reconstructions from the oldest portion of the

Bridger Formation (Bridger A; Allen 2017), it is thought that Bridger A could be older than 48.27 Ma based on previous geochronological estimates of Bridger C and E (47.22 Ma, 46.16 Ma respectively; Murphey and Evanoff 2001; Murphey et al. 2011). The depositional context for the Bridger Formation assumes that limestones and mudstones in the Bridger formation represent wide, shallow lakes that merged with meandering streams to Lake Gosiute as it transgressed (Kistner 1973; Groll & Steidtmann 1987; Clyde et al. 2001). There are six potential sediment sources to the Bridger Formation including Absaroka Range volcaniclastics, Uinta mountain physical weathering, Wyoming Overthrust Belt physical weathering, volcanic ashfall from Challis volcanism in Idaho, and autochthonous lacustrine carbonates (Murphey & Evanoff 2001). Where the older, and in places, co-eval Green River formation (Laney Shale; Allen 2017) is composed primarily of lacustrine sediments, the Bridger formation transitions into fluvial sediments (Buchheim et al. 2000; Allen 2017). Sedimentation within the Bridger Formation is relatively continuous, with high sedimentation rates during fluvial deposition and slightly lower sedimentation rates during lacustrine sedimentation (Murphey & Evanoff 2001). Because of this, it is known for its pristine faunal and floral preservation, making it an excellent candidate for understanding ecosystem function (Stull et al. 2014; Allen 2017).

The Blue Rim escarpment of the Bridger Formation is exposed laterally over 12km, approximately 100m tall in places (Kistner 1973). The flora at this locality have been quarried and described in great depth, and are known for their preservation of multiple plant organs like leaves, flowers, fruits, seeds, wood, pollen, and spores, all from the same localities (Allen 2017). Floral assemblages at Blue Rim occupy warm, subtropical, wet biomes; examples include palms (up to 28m tall; Allen 2017). Of the two major plant quarries, the lower horizon (older) floral assemblage consists of climbing taxa such as the abundant fern *Lygodium kaulfussi* (fern, Lygodiaceae), *Asplenium* sp. (fern, Aspleniaceae), *Acrostichum* sp. (fern, Pteridaceae), *Thelypteris iddingsi* (fern, Thelypteridaceae), dicots like *Serjana rara* (soapberry, Sapindaceae), *Populus cinnamomoides* (poplar, Salicaceae) and extinct sapindalean *Landeenia arailiodes* (Sapindaceae), *Goweria bluerimensis* (Icanicaceae), and *Phoenix windmillis* (palm; Arecaceae; Wilf et al. 2000; Allen 2017). The upper horizon hosts flora like *Macginitea wyomingensis* (sycamore; Plantanaceae), *Populus cinnamomoides* (poplar, Salicaceae), *Cedrelospermum nervosum* (elm; Ulmaceae), *Serjania rara* (soapberry, Sapindaceae), and many more (Allen 2017).

5.3.2 Age constraints

Reworked volcaniclastic ashes were sampled from the charismatic blue-green marker unit approximately halfway up the section as well as two sand beds near the top of the Blue Rim escarpment (Bridger Formation) for $^{40}Ar/^{39}Ar$ geochronological dating. To prepare sanidine phenocrysts for analysis, samples were crushed, leached in dilute hydrochloric acid (HCl) and hydrofluoric acid (HF) prior to hand-picking of sanidine in refractive index oils using a petrographic microscope, and then ultrasonic cleaning in acetone and ethanol. Sanidine phenocrysts from sampled ash beds were irradiated adjacent to standard sanidine crystals from Fish Canyon tuff (FCs) in cadmium shielding within the TRIGA (Training, Research, Isotopes, General Atomics) water-cooled, low-enriched uranium/zirconium fuel reactor at Oregon State University. Single sanidine crystals were fused using a 25W CO_2 laser and then analyzed for $^{40}Ar/^{39}Ar$ composition using a MAP 215-50 mass spectrometer attached to a metal ultra-high vacuum (UHV) gas extraction and cleanup line at the University of Wisconsin Madison WiscAr laboratory. A known 28.201 Ma age for Fish Canyon sanidine standard (FCs; Kuiper et al. 2008) was used to calculate apparent ages for each laser fusion, and weighted mean ages were calculated for the youngest coherent population of sanidine grains from each sample.

5.3.3 Physical Measurements

5.3.3.1 Stratigraphy and fossils

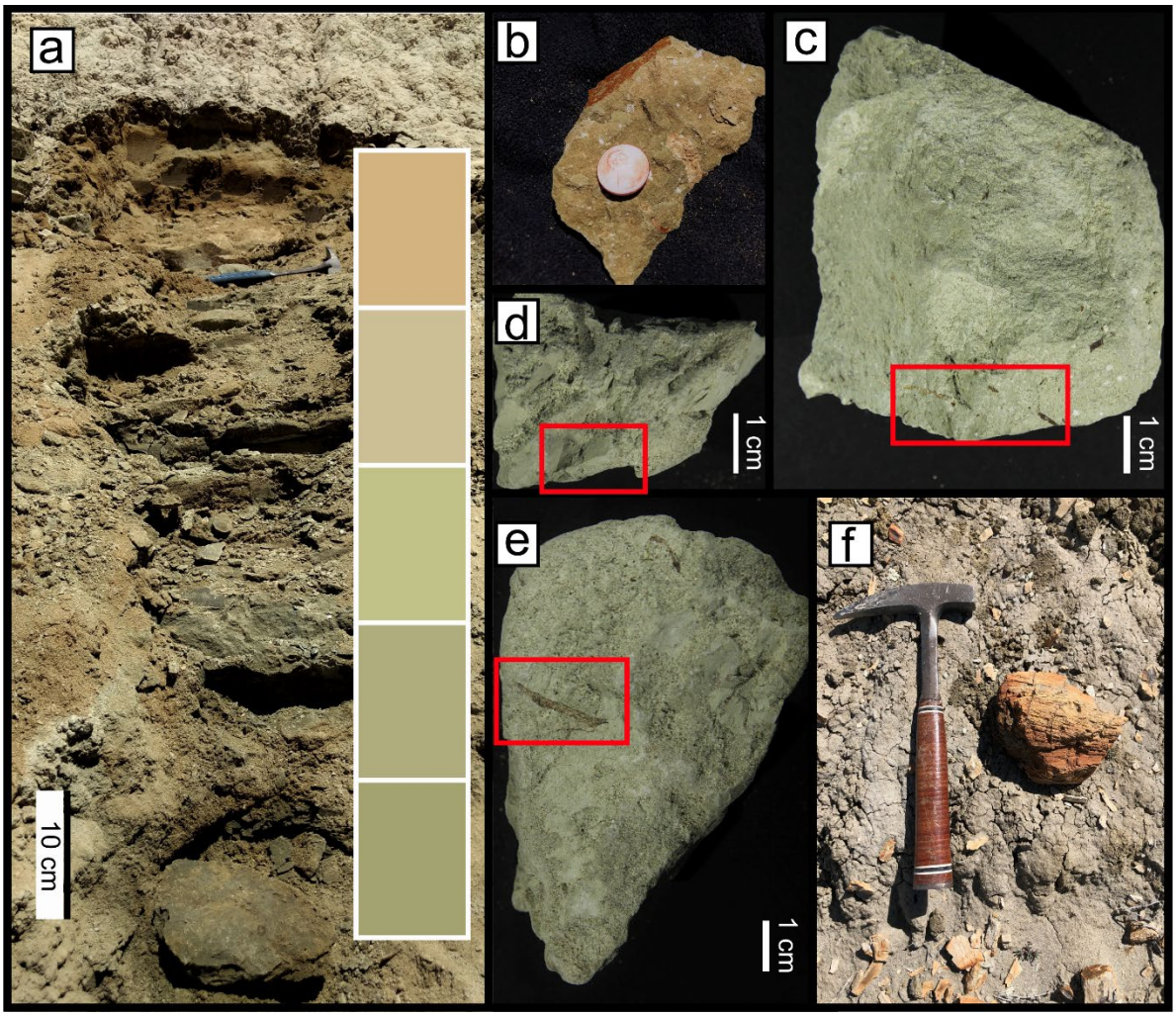

Figure 5.2 Paleosol images and features. (a) Full profile of 19BRWY3 with rock hammer for scale, (b) shows drab-haloed root trace from 19BRWY-2UB, (c) A-horizon fine organic rootlets in red box from 19BRWY2UA, (d) slickensides on 19BRWY1UA, (e) rhizoliths from 19BRWY1UA, and (f) charcoalified wood with rock hammer for scale, excavated ~3m above 19BRWY1.

Starting at the base of the Blue Rim escarpment, adjacent to the first sampled paleosol (Fig. 5.2; 5.6), an updated stratigraphic column was measured (41.7985 °N, -109.5856 °E) in September 2019 (Fig. 5.3, 5.4, 5.5). This 67m stratigraphic column traced the flanks of the escarpment to the top of the badlands. This stratigraphic column was sampled every 3m (approximately the height of one Jacob-staff) or at every interval of visual change (color, texture). In addition, plant fossils and plant hash were quarried at two locations approximately halfway (26m, 33m) and close to the top of the stratigraphic section (51.5m, 52m) for organic-rich fossil samples for isotope and bulk chemistry analysis.

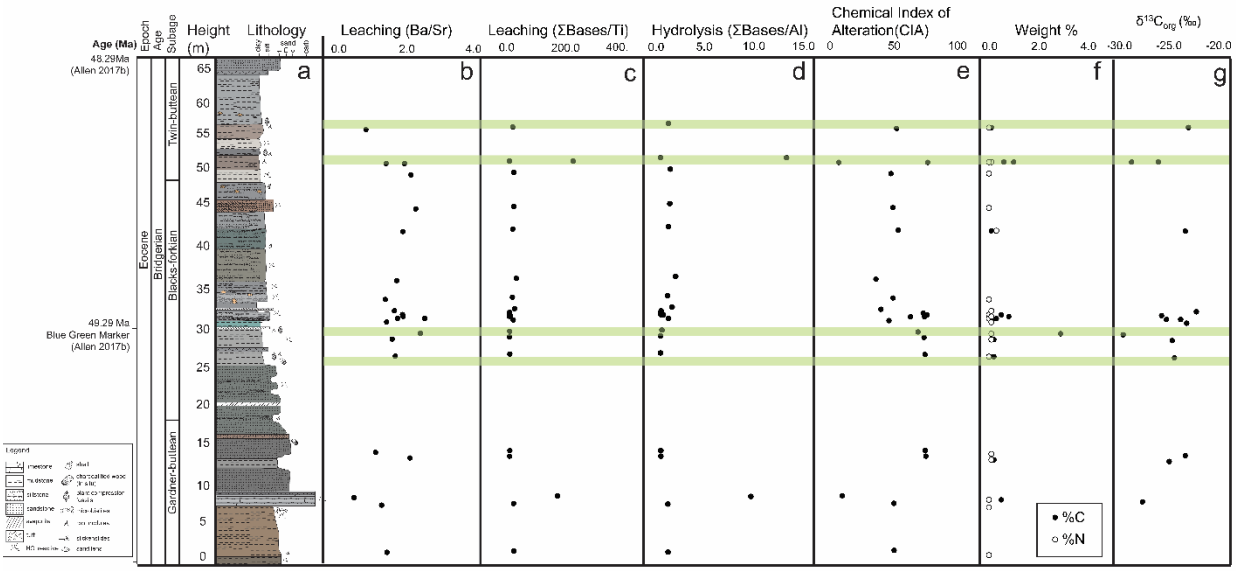

Figure 5.3 Stratigraphy with sedimentary geochemistry. (a) Stratigraphic column at the Blue Rim escarpment of the Bridger Formation. Geochemistry including (b) leaching, calculated using molar ratios of Ba:Sr, (c) leaching, calculated using the ratio of the sum of bases to Titanium, (d) hydrolysis, calculated using the ratio of the sum of bases to Aluminum, (e) chemical index of alteration to measure weathering (Equation 5.1), (f) weight % Carbon (black circles) and % Nitrogen (white circles), (g) $\delta^{13}C_{org}$ values. Light green transparent areas show stratigraphic levels containing plant fossils.

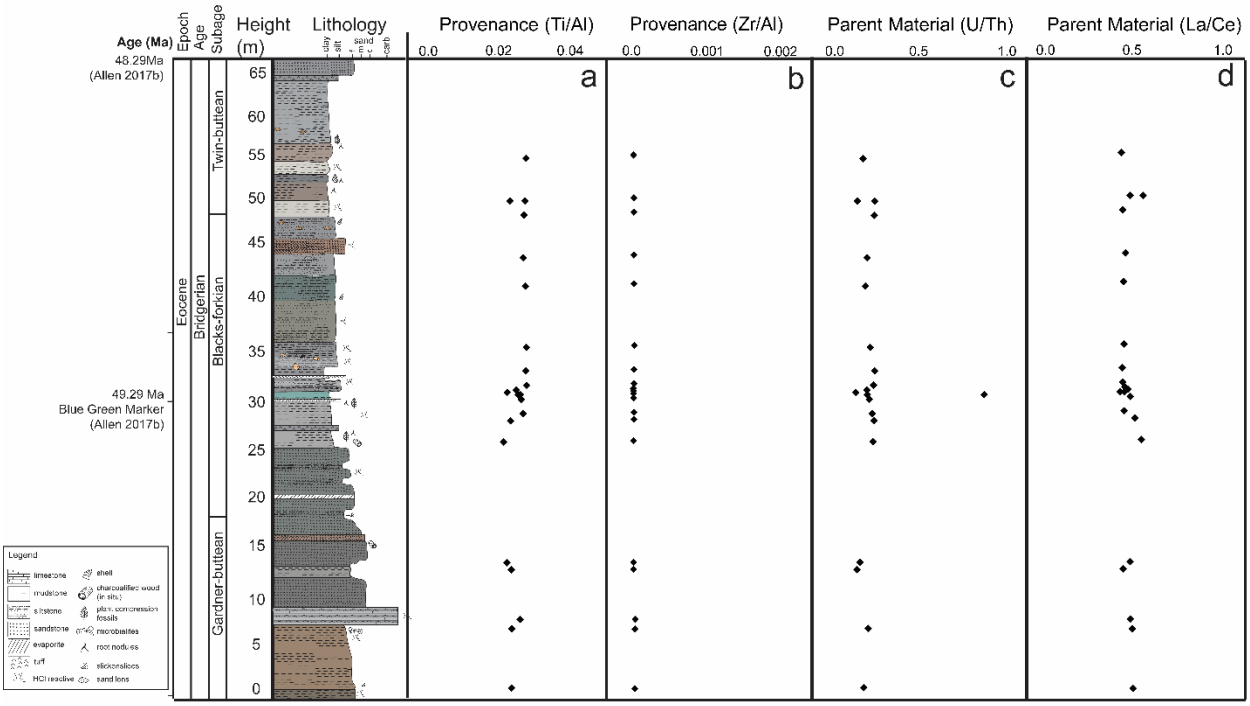

Figure 5.4 Stratigraphy with parent material and provenance proxies. (a) Provenance using molar ratios of Ti:Al, (b) provenance using molar ratios of Zr:Al, (c) parent material using molar ratios of U:Th, (d) parent material using molar ratios of La:Ce.

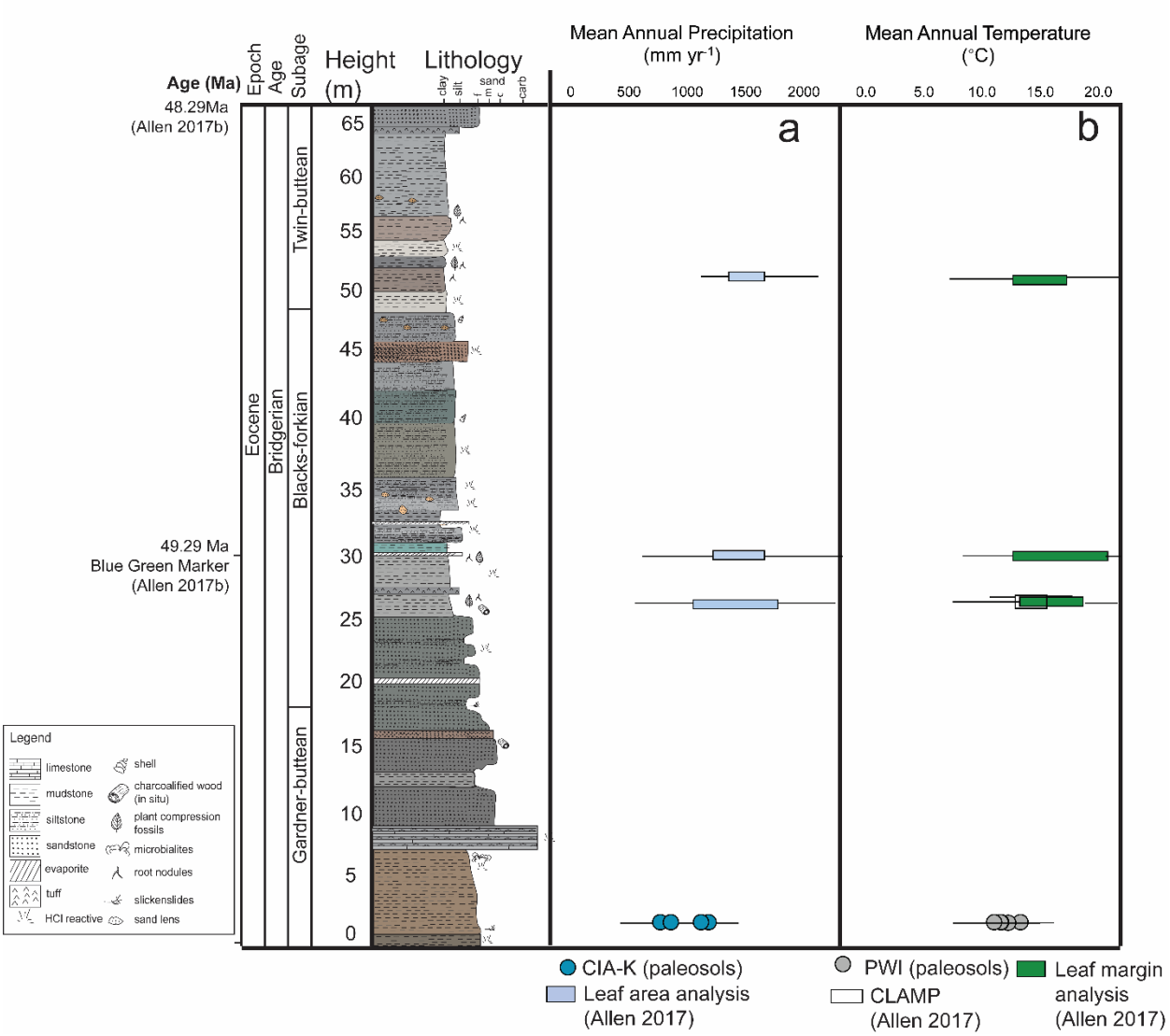

Figure 5.5 Stratigraphic column with climate proxies. (a) Reconstructed mean annual precipitation (mm yr^{-1}), and (b) mean annual temperature (°C).

5.3.3.2 Paleosol sampling

Six profiles of the same paleosol were identified and excavated along a lateral transect at the base of the Blue Rim escarpment (41.79892625, -109.58362614 (19BRWY1); Fig. 5.6). Paleosols sampled by horizon based on pedogenic features including root traces, burrows, drab-haloed and kerogenized roots, and horizonation (Fig. D1a, Table D1). Fresh rock material was excavated by digging at least 20 cm into the surface, avoiding all traces of modern pedogenesis

or surficial climate influence (i.e., modern roots or carbonate nodules). One distinctive, laterally continuous paleosol at the base of the section was sampled in five individual profiles over 440m (Fig. 5.2; Fig. 5.6; Fig. D1, D2, 19BRWY2-6). Samples were collected from each horizon present, with no fewer than three samples per paleosol profile. At each location, every present horizon (O, A, B, C) was sampled. For horizons that had color, texture, and/or other physical intra-horizonal changes, multiple samples were collected.

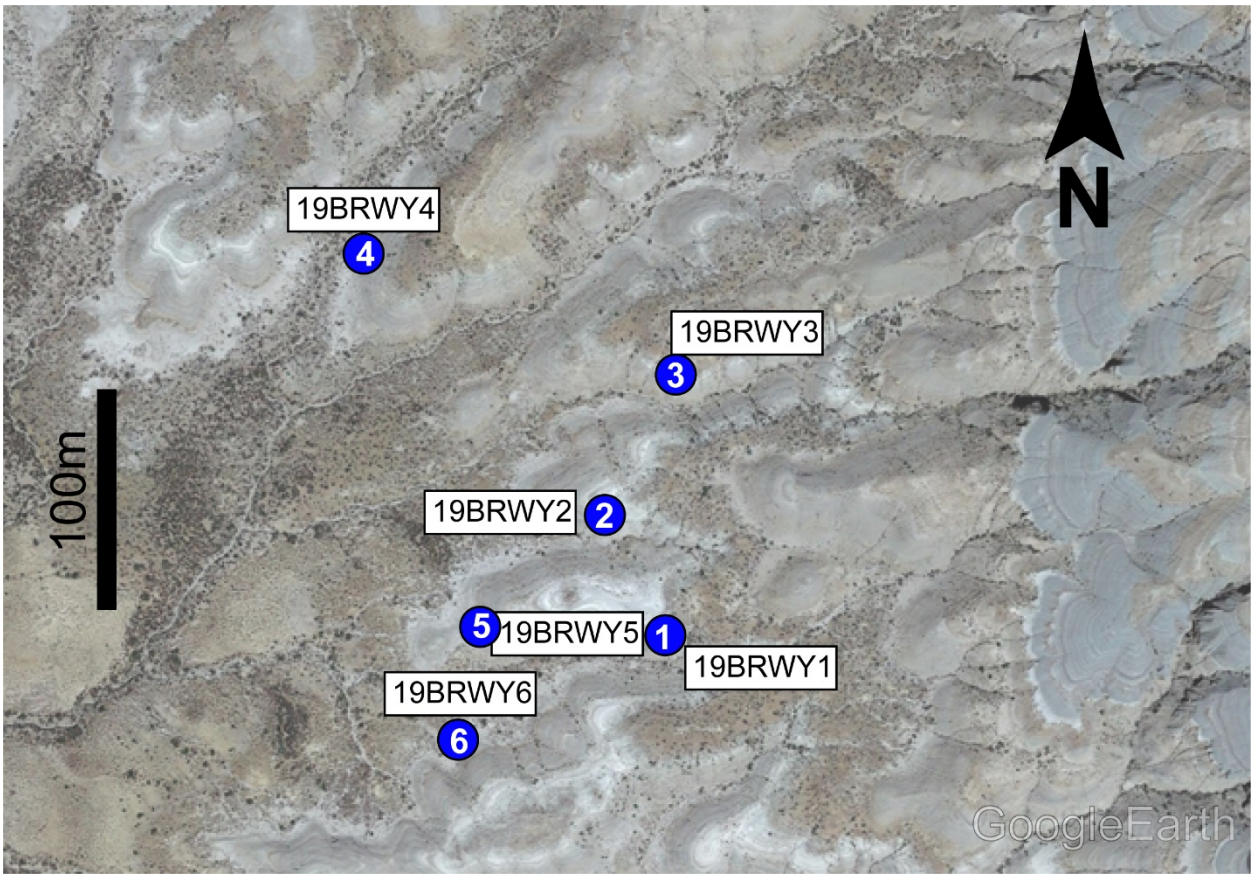

Figure 5.6 Lateral extent of paleosols. Included are paleosols 19BRWY1-6, atop image of Blue Rim escarpment topography, with a 100m scalebar. Paleosol numbers are noted in white text on blue circles. Image taken in Google earth V 9.123.0.2 (July 2019). Wyoming, USA. 41°48'02"N, 109° 35'36"W, eye altitude 8611 ft.

5.3.3.3 Isotope analysis

Paleosol samples were ground to 70μm in a shatterbox. Approximately 10g aliquots of samples were measured then acidified in 5% hydrochloric acid (HCl) for 30 minutes to remove

carbonate and leave behind total organic carbon of bulk sample. After 30 minutes, these samples were decanted, then re-acidified for a total of three times (and/or until solution stopped bubbling). After these acid washes, they were rinsed with deionized water three times (or more, if given >3 acid washes). Samples were then dried in an oven at 50 °C for 72 hours.

Between 20–25mg of each sample was loaded into tin capsules and run on a Costech Elemental Analyzer to determine weight %C and %N in University of Michigan's Earth Systems Lab with acetanilide (71.09 %C, 10.36 %N) for elemental composition calibration and acetanilide and atropine (70.56 %C, 4.18 %N) standards. The %C was used to calculate idealized loading size for isotope analysis; these samples were then run on the Picarro Cavity Ring-Down Spectroscopy (CRDS) on low carbon (Mode 9) for organic carbon isotope values ($\delta^{13}C_{org}$), with external precision better than ±0.3‰ for low-carbon samples.

5.3.3.4 Bulk Geochemistry

Approximately 10g aliquots of crushed paleosols, mudstone, and siltstone were measured and sent to ALS Laboratories in Vancouver, British Columbia, Canada for bulk elemental analysis. At ALS, samples were digested with perchloric ($HClO_4$), hydrofluoric (HF), nitric (HNO_3) and hydrochloric (HCl) acids, and concentrations were determined by inductively coupled plasma (ICP) optical emission spectrometry and ICP-mass spectrometry. The ICP-OES and ICP-MS were calibrated using internal standards, with major element precision better than 0.2 weight %.

5.3.3.5 Calculations

a. Weathering indices and leaching

Weathering was quantified using Chemical Index of Alteration of B horizons (CIA; Equation 5.1; Nesbitt & Young 1982), a feldspar weathering index based on the discrepancy in ion mobility during weathering.

$$CIA = \frac{Al_2O_3}{Al_2O_3+Na_2O+CaO+K_2O} * 100 \qquad \text{(Equation 5.1)}$$

To test for alteration and expected pedogenic elemental trends, changes in individual element mobility and strain were explored using tau and epsilon (Equations 5.2–5.3; Chadwick et al., 1990), where epsilon represents the strain on an immobile element like Ti or Zr and tau represents the relative gain or loss of a mobile element relative to the paleosol's parent material. Average values of 2.7 g cm^{-3} and 1.5 g cm^{-3} were used for reworked ash and soil density, respectively (e.g., Sheldon & Tabor, 2009).

$$\tau_{j,w} = \frac{(\rho_w C_{j,w})}{(\rho_p C_{j,p})} * [\varepsilon_{i,w} + 1] - 1 \qquad \text{(Equation 5.2)}$$

$$\varepsilon_{i,w} = \frac{(\rho_p C_{j,p})}{(\rho_w C_{j,w})} - 1 \qquad \text{(Equation 5.3)}$$

The Paleosol Weathering Index (PWI; Equation 5.4; Gallagher & Sheldon 2013), which is based on differential bond strengths in cation oxides provided additional means for examining weathering. Molar concentrations are used to make calculations in Equations 5.1–5.4, rather than elemental concentrations.

$$PWI = ((4.20 * Na) + (1.66 * Mg) + (5.54 * K) + (2.05 * Ca)) * 100 \qquad \text{(Equation 5.4)}$$

We used several geochemical proxies to examine intensity of leaching, including the ratio of barium to strontium (Ba/Sr), which is higher with more leaching and lower with less leaching (Sheldon 2006; Retallack 2001) due to differential solubility; Sr is more soluble than Ba (Vinogradov 1959). The ratio of the sum of base cations to titanium is another metric for leaching, under the assumption that titanium is immobile, while other bases are mobile (Sheldon & Tabor 2009). The ratio of the sum of base cations to aluminum has been used as a metric for hydrolysis (Retallack 1999; Bestland 2000; Sayyed & Hundekari 2006).

b. Provenance and parent material

The molar ratios of titanium to aluminum (Ti/Al) and zirconium to aluminum (Zr/Al) was used to screen for consistency in sediment source in soils; direction of change in Ti/Al ratios is related to differences in chemical weathering, while Zr/Al ratios is related to changes in physical weathering (Sheldon & Tabor 2009). The molar ratio of uranium to thorium (U/Th), and

lanthanum to cesium (La/Ce) were used to trace potential changes in parent material composition through the stratigraphic unit, where a constant down-profile U/Th and La/Ce ratios reflect single-parent source (Sheldon 2006; Sheldon & Tabor 2009). Absolute parent material values for each of these ratios are not well calibrated, but direction of change observed at any site indicates a change in parent material, U/Th is redox-sensitive so La/Ce ratios are used as a comparative point in case of highly reduced environments.

c. *Paleoclimate reconstructions*

Mean annual precipitation was reconstructed using Chemical Index of Alteration minus potassium (CIA-K; Equation 5.5; 5.6; Sheldon et al. 2002; error ± 182 mm yr^{-1}), modified from CIA to control for potassium metasomatism in paleosols (Maynard 1992; Ennis et al. 2000; Sheldon et al. 2002). Mean annual temperature was calculated using PWI (Equation 5.7; error of ± 2.1°C; Gallagher & Sheldon 2013). We applied the empirical relationship between $\delta^{13}C_{plant}$ and $\delta^{13}C_{atm}$ values found by Arens et al. (2000; Equation 5.8; $R^2 = 0.34$) and used $\delta^{13}C_{plant}$ values of all individual fossils to reconstruct generalized, non-taxon-specific $\delta^{13}C_{atm}$ values. We compared this reconstructed value based on a generalized equation with reconstructed values based on species-specific carbon isotope discrimination values (as measured in Cornwell et al. (2018)). More specifically, we used fossils of *Lygodium* and *Acer* genera (n = 9 identified fossils used for individual measurements) to reconstruct $\delta^{13}C_{atm}$ values based on taxon-specific parameters (e.g. Stein et al. 2019).

$$CIA - K = \frac{Al_2O_3}{Al_2O_3 + Na_2O + CaO} * 100 \qquad \text{(Equation 5.5)}$$

$$MAP = 221e^{0.0197(CIA-K)} \qquad \text{(CIA-K for paleosols; Equation 5.6)}$$

$$T\ (°C)_{PWI} = -2.74 * \ln(PWI) + 21.39 \qquad \text{(Equation 5.7)}$$

$$\delta^{13}C_{leaf} = 1.1\ (\delta^{13}C_{atm}) + 18.67 \qquad \text{(Equation 5.8)}$$

Holdridge life zones are ecoregions classified by water availability and temperature, that can be further subdivided into successional stages reflecting land use, disturbance history, latitude, altitude (Holdridge 1967; Lugo et al. 1999). The parameters for each life zone are calculated based on potential evapotranspiration and humidity provinces (Holdridge 1967; see Appendix D). Similar metrics that use evapotranspiration and precipitation to quantify ecosystems into "floral humidity provinces" based on paleosol measurements, have been established more recently by Gulbranson et al. (2011; see Appendix D). See Appendix D for methodology used to determine Holdridge life zones and Floral Humidity Provinces for paleosols (this study) and previously published floras (Leopold & MacGinitie 1972; Roehler 1993; Wing et al. 2005; Smith et al. 2008; Wing & Currano 2013; Allen 2017).

5.4 Results

5.4.1 Age

Using $^{40}Ar/^{39}Ar$ radiometric dating, weighted mean ages of two younger sanidine crystals in the base and middle of the blue-green marker bed were weighted to place the age at 49.29 ± 0.18 Ma (aligning with Bridger A/1b). These grains were found alongside pumice clasts and biotite grains along with minor detrital components following Challis volcanic field eruptions, indicating juvenile volcanic material deposition. This date was calculated using grains from BR-3, yielding an estimated age of 48.98 ± 0.38 Ma, collected at the base of the main blue layer, just above the UF 15761S plant quarry (elevation 6737 ft; Allen 2017), and grains from Sample BR-4 (collected from the lower main blue-green layer in the 2014/UF 19297 stratigraphic section at 6745 ft; Allen 2017) with a resolved estimated age of 49.43 ± 0.23 Ma. Because these two samples were collected from the same stratigraphic unit but out of stratigraphic order, they were averaged for an age of 49.29 ± 0.18 Ma.

The two sand beds sampled for $^{40}Ar/^{39}Ar$ dating at the top of the escarpment (elevation 6861 ft; Allen 2017) yielded more detrital grains, six young grains gave a weighted mean of 48.29 ± 0.45 Ma, such that the stratigraphy between the blue-green marker bed and sand beds spans Bridger B, landing the uppermost part of the Blue Rim Escarpment time equivalent to Bridger C or D/3 (Fig. 5.3, 5.4, 5.5). This constrains the lower plant horizon as slightly older

than 49.29 Ma (Allen 2017), while the upper plant horizon could be Bridger A1b or younger than 48.29 Ma.

5.4.2 Paleosol descriptions

Six profiles were sampled laterally from a single paleosol at the base of the Blue Rim escarpment (1m in the stratigraphic column; Fig. 5.3, 5.6). Paleosol profiles (Fig. 5.6; Fig. D1) typically consisted of a silty and/or sandy brown, yellow A-horizon over a parent material C-horizon of green-grey silty mudstone anywhere from ~20 to 112 cm below the surface. Paleosol #1 was missing a B-horizon due to erosion, while paleosol #4 was missing an A horizon, likely truncated during burial. Typically, each profile was lighter colored in upper horizons and darker in lower B- and C-horizons. In the paleosol profiles sampled, every A-horizon but one, and several upper B-horizons, had root traces, kerogenized roots, and/or rhizoliths. We observed drab-haloed roots in paleosols #1 and 4. Paleosol #2 had vertical burrows of up to 1cm diameter and ~3 cm length, and paleosol #1 had visible peds (Table D1; Fig. 5.2a). These soils were well-developed Inceptisols based on features, textures, and extrapolation from the local flora (Fig. 5.2a; Fig. D1; D5; Table D1).

5.4.3 Paleosol geochemistry

CIA-K (weathering profiles calculated using Equation 5.5) reference values include 100 for pure kaolinite, and values of 0 demonstrating no Al present at all. Clay-rich materials start with CIA values of 60–70 with even higher values in B-horizons and more weathered surfaces (Sheldon & Tabor 2009), while low CIA-K values occur in soils with low precipitation and high evaporite accumulation (Sheldon et al. 2002). Paleosols with sedimentary, worked parent material like those found at Blue Rim escarpment are expected to have CIA-K values of B-horizon > 60-70. On average, the lateral extent of the paleosol found at the base of the Blue Rim stratigraphic section had A-horizon values of 80 with a minimum of 40–50 in B- and C- horizons (Fig. D1b). Ti/Al values were constant throughout, ranging from 0.040 to 0.045, typical values of mudstones and sandstone parented materials (Sheldon & Tabor 2009), like those seen in sediments throughout the Blue Rim escarpment (Fig. D1c; Table D2).

Tau (used to measure mobile element transport) was calculated following Chadwick et al. (1990; Equations 5.2 and 5.3) and demonstrated in Supplemental Figure D2(a-f). Overall, tau

values for K, Mg and Na all ranged from 0 to -0.5, and tau values for Ca ranged from 0 to -1, except in paleosol #2 (which was extremely high in Ca), as is typical for Inceptisols. Tau for Rb and Fe were generally also between 0 and -0.5, though this was less consistent between profiles. To note, paleosol #1 (19BRWY1; Fig. 5.6) was excluded for paleoclimate reconstructions due to the lack of presence of the B- horizon (we identified this soil as an Entisol, which cannot be used for climate reconstructions; see Fig. 5.6 for location). Paleosol #2 (19BRWY2) was also excluded for climate reconstructions, due to the high % Ca, likely of carbonate origin as this site was reactive to HCl. Based on both field taxonomy and these geochemical results, paleosols #3-#6 are identified as Inceptisols.

5.4.4 Sedimentary geochemistry

Ba/Sr ratios, used to measure leaching intensity, were on average 1.64 (± 0.52 standard deviation) throughout the stratigraphic unit, with outlier values of ~2.54 and 2.42 at 31m and 29m, and 0.47 at 7.25m. Another proxy for leaching (sum bases/Ti) had peaks around 10m (191.19) and 52m (247.76), but otherwise consistent leaching ~ 50, with a range of 9.91 to 247.46 and average of 47.82 (Fig. 5.3b,c). Hydrolysis, as measured by sum bases/Al, peaked at 51.5m (13.69) and troughed at 26m (0.73) but otherwise demonstrated consistent leaking with an average value of 2.20 (Fig. 5.3d).

The mean chemical index of alteration (CIA), a measure of weathering, was 55.61 (± 20.16 standard deviation). CIA was lowest around 51.5m (CIA = 7.14) and highest around at 51.5 (CIA = 76.61) with similarly high values (73–77) at 12.5m, 26, 28.25m, 31m, 31.25m, 31.5m, and 51.5m (Fig. 5.3e). Percent carbon throughout the section was distributed similarly, with peaks at the same locations as CIA: A high of 2.9 wt. %C (29m) and a low of undetected (many places throughout the section). Percent N was highest at 42.5m (0.3%) and lowest at multiple sampling locations throughout the section (0%) (Fig. 5.3f). $\delta^{13}C_{org}$ values were lowest in these sections, with an average of -24.97‰ (± 2.17 standard deviation) and range of -22.13 to -29.49‰ (Fig. 5.3g).

Provenance remained nearly constant (Ti/Al ranged from 0.02 to <0.03), with a high at 32m and low at 26m (Fig. 5.4a). Parent material, likewise, remained constant for all metrics except U/Th; La/Ce ranged from 0.44 to 0.57, Zr/Al ranged from 2.37 x 10^{-5} to 4.83 x 10^{-5} (Fig.

5.4b,d). All U/Th ratios fell between 0.15 and 0.26 except for 31m at the blue-green marker, with a value of 0.87 (Fig. 5.4c).

5.4.5 Flora

At least 69 morphotypes were previously identified from Blue Rim by Allen (2017). The identifiable fossils from this specific field excursion sampled specifically for organic isotope analyses included multiple specimens of *Lygodium kaulfussi* (climbing fern, genus Lygodiaceae) compression fossils, as well as one example of *Asplenium sp.* (fern, family Aspleniaceae; as described in Allen 2017), an example of *Populus cinnamomoides* (poplar, family Salicaceae), one *Cedrela* leaf, (undefined species; mahogany, family Meliaceae; Fig. D5), several dense leaf mats, and assorted twig and branchlet fossils were recovered. These specimens were collected from the same strata as the lower horizon (e.g. UF 15761N, Allen 2017), located 26 m on the stratigraphic column included in this study (Fig. 5.3, 5.4, 5.5). There was evidence of scraps of several unidentified monocots, though no isotope analyses were run on these fossils.

5.4.6 Climate

Mean annual precipitation (MAP) values reconstructed using CIA without potash (CIA-K) on paleosol B-horizons (Equation 5.6) ranged from 608–1167 mm yr^{-1}, with an average of 845 mm yr^{-1} (±181 mm yr^{-1}) (Equation 5.6; Fig. 5.5; D6). The lowest estimated MAP value (288 mm yr^{-1}) was excluded due to high %Ca (10.25%) in the B horizon of paleosol 2. Mean annual temperature values (MAT) reconstructed using PWI on paleosol B-horizons (Equation 5.7) ranged from 10.4 to 12.0 °C (± 0.72 °C standard deviation), with an average of 11.0 °C.

A wide range of $\delta^{13}C_{atm}$ values were reconstructed from $\delta^{13}C_{leaf}$ from the 34 individual leaf fossils used using a generalized relationship (Arens et al. 2000). Reconstructions using the generalized Arens et al. (2000) model were done on all 34 individual leaves, even though some included unidentified fossils. Additional species-specific tests were done on all samples of *Lygodium* or *Acer* using isotope discrimination values from extant plants of these genera. 38% (n = 13) of the 34 $\delta^{13}C_{atm}$ values reconstructed using the generalized Arens et al. (2000) model suggested a $\delta^{13}C_{atm}$ value of between -5.32 and -5.82‰. 56% of all of these reconstructed values were between -5.0 and -6.0‰ (n = 19; Equation 5.8; Fig. 5.7). Limitations on this reconstruction are the species-specific nature of this proxy (Beerling & Royer 2002; Stein et al. 2019), and

values outside the range of most samples (44%) were more extreme potentially preferential diagenesis of certain compounds, driving the isotopic signature away from these values (Beerling & Royer 2002; Tu et al. 2004). Using identified *Lygodium* and *Acer* fossils (n = 9 total), we applied the taxon-specific isotope discrimination principle and reconstructed an average value of -4.82‰ (±0.92‰ standard deviation). These reconstructions were based on isotope discrimination values of 20.56‰ for *Lygodium* and 20.37‰ for *Acer* (as reported in modern isotope analyses by Cornwell et al. 2018).

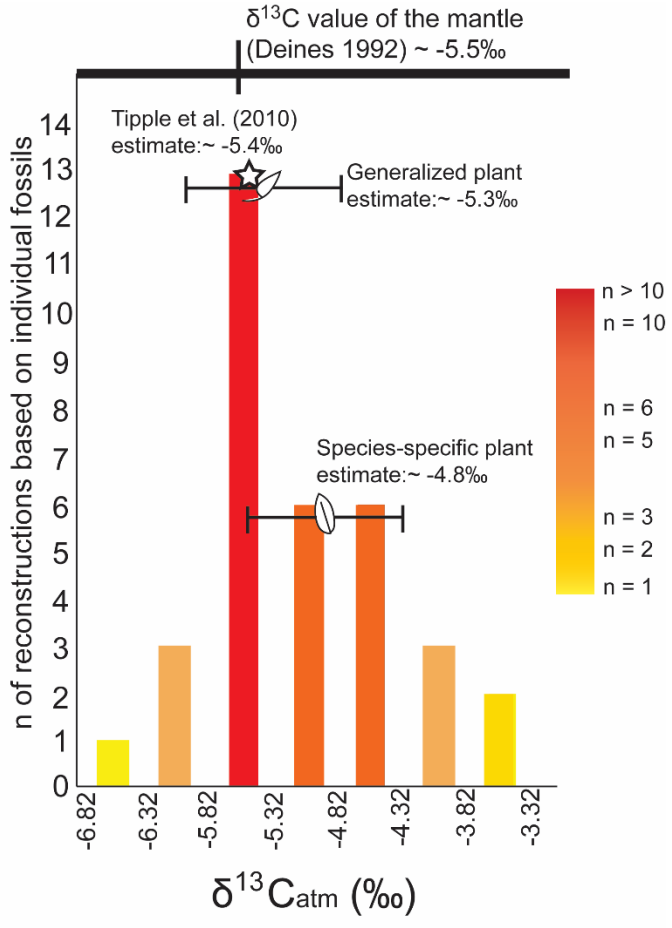

Figure 5.7 $\delta^{13}C_{atm}$ as reconstructed from $\delta^{13}C_{leaf}$ of Blue Rim fossil flora. Reconstructions utilized the generalized relationship between $\delta^{13}C_{atm}$ and $\delta^{13}C_{plant}$ (Arens et al. 2000; n = 34; Equation 5.8). The species-specific mean and standard deviation are shown, as are the generalized plant mean and standard deviation. The Tipple et al. (2010) foraminiferal reconstruction is denoted in a star, and the $\delta^{13}C$ value of the mantle is shown above (Deines 1992).

5.5 Discussion

5.5.1 Age

Original estimates based upon biostratigraphy placed the deposition of the Bridger Formation beginning before 50 Ma (Krishtalka et al. 1987; Alexander & Burger 2001). Early radiometric dates suggested an age between 49.09–45.57 Ma (Murphey et al. 1999). Other estimates bracketed the youngest sediments at 46.16 Ma (Sage Creek Mountain Bridger E tuff; Murphey & Evanoff 2007), or older than 48.27 Ma from a nearby, stratigraphically younger sanidine from the Church Butte tuff, also in the Bridger Basin (Murphey et al. 2011). Bookending older age estimates, the laterally correlative Big Island Tuff within the Wilkins Peak Member of the Green River Formation has been dated to 50.4 Ma ± 1.1 Ma and 40.1 Ma ± 1.2 Ma (Krishtalka et al. 1987; Alexander & Burger 2001; Allen 2017). The new $^{40}Ar/^{39}Ar$ dates presented here for the blue-green marker bed and sand bed above the floral quarries suggest that this section spans 49.29 Ma–48.29 Ma, making it slightly younger than the EECO, with the paleosols at the base of the section >49.29 Ma. Assuming constant sedimentation rates based on a linear interpolation between measurements, which calculates each meter of sedimentation equal to ~28 ka, paleosols are roughly 833,300 years older than the blue-green marker bed, or 50.1 Ma. This age lacks in precision, although it has been demonstrated that sedimentation rates in the Bridger Formation are roughly continuous (Murphey & Evanoff 2001), so the paleosols are unlikely to have been dramatically different in age. However, the shifts between different depositional environments indicate there is likely some variability in sedimentation rate. Future workers could focus on dating the sandstone features at the base of the section to constrain the oldest age of deposition in the Blue Rim escarpment better.

These new, and slightly younger dates on average, demonstrate that post-Eocene, Lake Gosiute was regressing and transgressing, though overall shrinking in size as the region dried. The Blue Rim locality is located approximately in the middle of Lake Gosiute's full extent (Fig. 5.1a), so shallowing and/or ephemeral dry land ecosystems in this region signifies that this lake's disappearance was imminent during the formation of Blue Rim. The new dates and the inferred depositional environment can be used to determine the timing and fate of the lake in conjunction with biostratigraphic evidence: fossils of *Goniobasis/Elimia* (fresh water snails, Pleuroceridae)

are prominent just above this stratigraphic section, affirming the Bridger A/B transition, as there is a biostratigraphic *Goniobasis* marker bed between Bridger A and B documented nearby (Allen 2017). *Goniobasis*' shallow lake dwelling habitats (Hanley 1976) align with the overall regression of Lake Gosiute.

5.5.2 Stratigraphy, provenance and weathering

Provenance was consistent throughout the stratigraphic section and paleosols, which can be interpreted as consistent hydrological inputs to the section. Consistent provenance does not support the idea that there might be inconsistent water sources from disparate mountain ranges causing interference in signals in the region (Doebbert et al. 2012). Parent material analyses agreed with our assumptions about parent rock and indicated that all sources were primarily sedimentary. The consistent Ti/Al, U/Th, and La/Ce ratios correspond to constant parent material throughout the one million years section covered by the Blue Rim stratigraphic column, demonstrating that basin-scale hydrology was likely not reorganized during this time. The one exception to constant parent material and provenance ratios is the anomalously high U/Th ratio in the blue-green marker bed (0.87). This proxy is redox-sensitive, so this anomalously high U/Th ratio is due to the preferential redistribution and accumulation of U in this section, as Th is insoluble and immobile (Pett-Ridge et al. 2007; Sheldon & Tabor 2009). Weathering and leaching were highest in the sections where there was high carbon content; this correlation is likely due to organic acids produced by plants in the ecosystem that contribute to chemical weathering (Fig. D4; $R^2 = 0.20$; p-value = 0.01 Ong et al. 1970; Berner 1992).

5.5.3 Paleosols

The six paleosol profiles sampled from one single paleosol, which was stratigraphically equivalent to 1m up the documented column, were all Inceptisols. This taxonomy was determined including soil features, provenance, leaching, weathering, element transport, and parent material (Fig. D1, D2). This is fitting considering the depositional history of this environment; these soils were likely formed between floods, when there was sufficient time for horizonation to occur, before being cut off by a flooding or minor lake transgression. Paleosol #1 (19BRWY1; 1m in stratigraphy; Fig. 5.3, 5.4, 5.5, 5.6) is an Entisol and was not included in paleoclimate reconstructions because it lacks a B horizon. The soil classification of these soils as

Inceptisols aligns with the interpreted depositional history of an ephemeral shallow, drying lake environment with periods of fluvial-alluvial deposition.

5.5.4 Climate

The early Eocene of North America is reconstructed as populated by generally widespread temperate to subtropical wet forests (Allen 2017). Depending on latitude, other studies indicate slightly warmer conditions than prior Blue Rim-based reconstructions (Allen 2017). Generally, mean annual temperatures reconstructed from other sites between 36 and 80 °N have ranges from 35°C (36 °N) to 8°C (80 °N; Fricke & Wing 2004). For mid-latitude floral assemblages, physiognomic reconstructions had cold month mean temperatures around 10 °C, indicating a relatively frost-free existence for plants living in the bulk of North America at the time (Wing & Greenwood 1993), which aligns very well with the paleosol-based results in this study. Specific examples include Kisinger Lakes, a floodplain deposit in the Wind River Basin (Aycross Formation; NE of the Greater Green River Basin; Berry 1930; MacGinitie 1974), which was thought to have warmer temperatures ranging 19 to 23 °C, with cold month mean temperatures calculated by Climate Leaf Analysis Multivariate Program (CLAMP) virtually frost-free. Precipitation in this region was estimated to be 890–1400 mm yr^{-1}, with most of this precipitation accumulating during the summer. Hyland et al. (2018) used $PPM_{1.0}$, a paleosol-based spline model, to estimate mean annual temperature, nearest living relative bioclimatic analyses to reconstruct cold month mean temperature, and clumped isotope measurements (Δ_{47}) to calculate warm month mean temperature estimates of the nearby, slightly older Wasatch Formation (~52– ~50.5 Ma). These estimates were made roughly 140 kilometers NE of the Blue Rim escarpment. The warm month mean temperatures reconstructed in these earlier nearby deposits were 18 to 34 °C +/- 3 °C (Kelson et al. 2017; Hyland et al. 2018), while cold month mean temperatures from 4.2 to 7.6 °C (Hyland et al. 2018) and mean annual temperature values ranged from 15.2 to 18.2 °C (Hyland et al. 2018). These estimates are warmer than those reconstructed at Blue Rim escarpment, though these estimates are likewise older, and span the EECO; Hyland et al. (2018) note a decreasing trend in younger temperatures reconstructed for their study. The Parachute Creek, Laney, and Fossil Butte Members of the Green River Formation, also thought to be slightly older than the Blue Rim escarpment, roughly the age of the EECO, have also been interpreted as semi-deciduous with seasonally dry subtropical taxa (Wing

1987; Allen 2015). Finally, slightly further away in the Okanagan Highlands, climate reconstructions yield temperature ranges of 10–13.5 °C (Wolfe et al. 1994; Wolfe et al. 1998; Greenwood et al. 2005).

MAP reconstructions from this study, based on inorganic proxies in paleosols ranged from 608–1167 mm yr^{-1} (average: 845 mm yr^{-1} ± 255 mm yr^{-1}, standard deviation). High influence of carbonate in parent material results in a lower CIA-K, and thus lower rainfall estimate (Sheldon et al. 2002). Error on CIA-K proxies is ±181 mm yr^{-1} (Sheldon et al. 2002; Passchier et al. 2013); such that estimates from floral and inorganic geochemical proxies are within error of one another. However, overall, these inorganic-based reconstructions are slightly lower than those estimated using CLAMP and leaf area analysis (LAA). This could be due to the location in the section (lower and likely older, see Figure 5.5). The discrepancy may also be because CLAMP has been cited as often producing overestimates of precipitation (Wilf et al. 1998; Allen 2017), and leaf area analysis methodology using vein scaling also can result in overestimates of leaf size, which translate to excess precipitation values (Merkhofer et al. 2015).

Results based off inorganic geochemistry in paleosols in this study showed slightly lower temperatures than those reconstructed using physiognomy, with PWI-based temperatures from 10.4 to 12.0 °C (average 11.0 °C ± 0.7 °C standard deviation). Like precipitation, the underestimation based on PWI in paleosols could be related to location in the section, as paleosols were significantly lower than plant quarries in the section (see Figure 5.5). The discrepancy could be related to the soil taxonomy; the PWI tool used to reconstruct temperature was calibrated for Inceptisols, Alfisols and Ultisols, however none of the Inceptisols sampled were from temperatures >12 °C (Gallagher & Sheldon 2013). As such, the weathering indices these paleo-Inceptisols are based off of Inceptisols in modern ecosystems, which are typically found in cooler temperatures. Because the early Eocene was significantly warmer, it is possible that early developmental soils like Inceptisols existed at higher temperatures, especially in dynamic ecosystems with frequent flooding events like those preserved at the Blue Rim escarpment.

Despite the modest discrepancy between physiognomic and paleosol-based precipitation and temperature estimates, the life zones and floral humidity provinces calculated using Blue Rim paleosols were the same as those calculated using physiognomic techniques. When

paleosol-based climate reconstructions are plotted in floral humidity space and Holdridge life zones, our results were comparable to flora-only estimates based on Allen (2017) and Wilf et al. (2000)'s reconstructions of the early Eocene, and Wing et al.'s (2005) reconstruction of the Paleocene-Eocene thermal maximum (PETM; Fig. 5.8). This demonstrates the importance of the holistic approach: although individual proxies might not be exactly comparable, the overall ecosystem-level reconstructions, from taxonomic identity of fossils present to paleosol taxonomy to inorganic, organic, and floral climate reconstructions all align.

These fossils collected for organic analysis found at Blue Rim escarpment included charcoalified trunks and *Lygodium kaulfussi* (Lygodiaceae)*, Asplenium* (Aspleniaceae; two ferns), *Populus cinnamomoides* (Salicaceae)*, Cedrela* (Meliaceae; woody angiosperms) as well as dense leaf mats. These collected fossils (sampled at 26 m on the stratigraphic section) are comparable to a smaller set of findings by Allen (2017) and MacGinitie (1969) and characteristic of mesic, forested environment. *Lygodium,* a climbing fern at present and during the Eocene, cannot grow in exceedingly wet conditions (e.g. rain forest), and *Populus* and *Cedrela* trees are found in temperate and tropical-subtropical forests and riparian areas (Hamzeh & Dayanandan 2004; Hamzeh et al. 2006). There was evidence of monocot fossils, likely a part of the herbaceous understory; this is congruent to the palynological evidence of *Phoenix windmillis*, (palm, Arecaceae) found at this site by Allen (2017), though these fossils were not sufficiently preserved to be identifiable.

This compiled, multi-proxy evidence provides confidence that this region was indeed an ephemeral wet forest along the edge of a lake and/or river, experiencing frequent and sporadic flooding from nearby freshwater sources. Floral humidity provinces and Holdridge life zones calculated from paleosol-based MAP and MAT reconstructions were compared to ones calculated from MAP and MAT as provided in published studies. Chronologically, this region went from wettest during the PETM in the proximal Bighorn Basin (rain forest; reconstructed using LMA and LAA; Wing et al. 2005) to drier and cooler (characterized as a wet forest), resulting in less evapotranspiration and less precipitation as time progressed. EECO (Bighorn Basin; Wing & Currano 2013). Blue Rim-era floral humidity provinces are all estimated to also be wet forests, which is further contextualized by fossil evidence as presented in our fossils and Allen's (2017) characterization of the escarpment. Other comparably aged Eocene climate

reconstructions based on palynological data from the Laney Member of the Green River Formation (~48.5 Ma; Smith et al. 2008), located in the same basin as the Blue Rim escarpment, appear to be closer to rainforest floral humidity provinces (Leopold & MacGinitie 1972; Roehler 1993; Smith et al. 2008; Fig. 5.8). Over the late Paleogene into Neogene and more recently, the region has continued drying and is now high desert/dry scrub, with minimal precipitation (195 mm yr^{-1} in 2019, the year sampled; PRISM Climate Group 2004), cold winters (<0 °C from November to March; PRISM Climate Group 2004), and hot, dry summers (Fig. 5.8). The locations of each of these sites is plotted on Figure D7, to demonstrate their proximity.

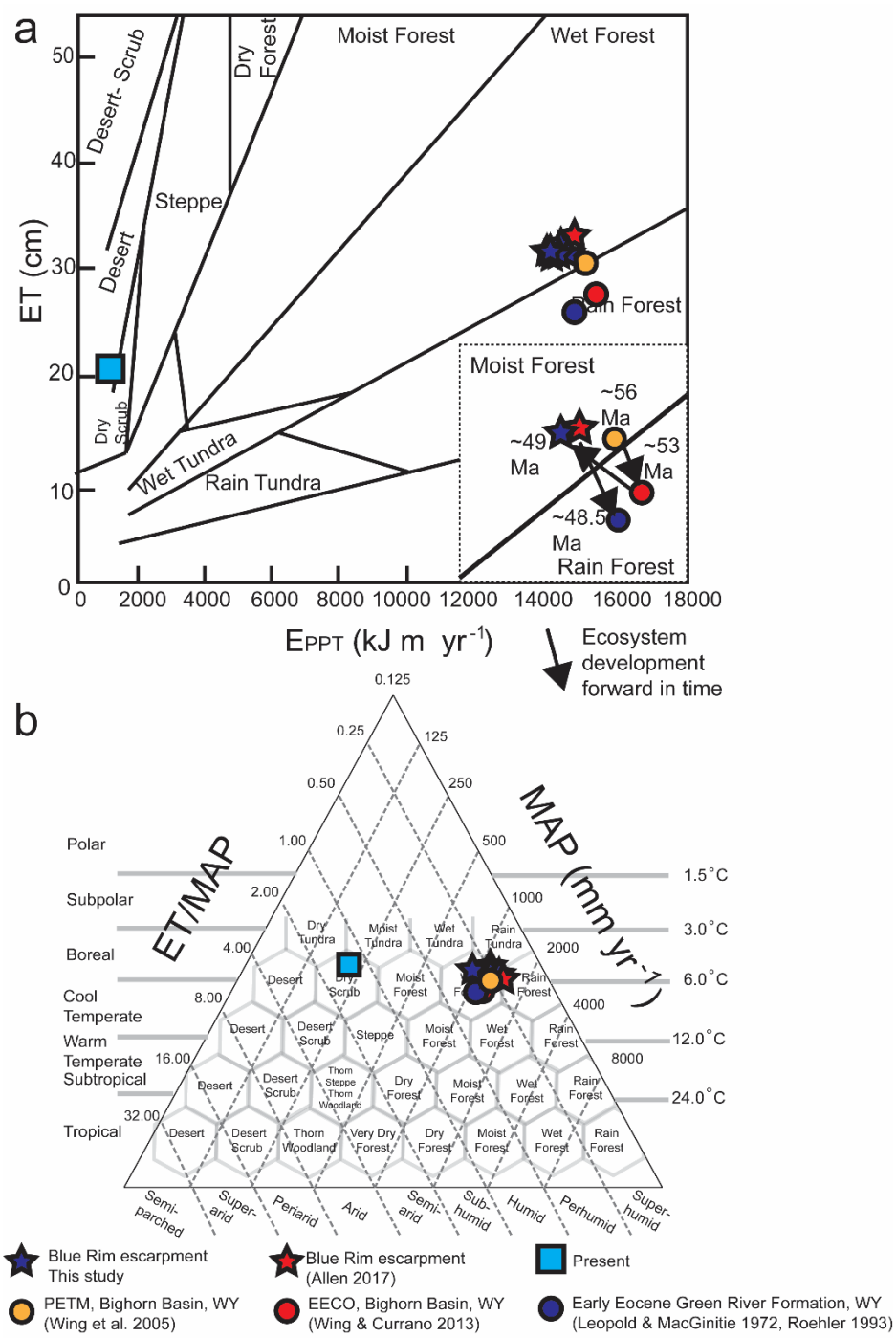

Figure 5.8 Ecosystem level characterization of Blue Rim escarpment and other Cenozoic Wyoming ecosystems. Paleosol-based (a) Floral Humidity Province and (b) Holdridge life zones (Holdridge 1967) in blue stars. (a) includes inset showing climate progression over time, with (1) showing the PETM (Bighorn Basin, ~56Ma), (2) the EECO (Bighorn Basin, ~53Ma), (3) this site (~49 Ma) and (4) the latest stage of Lake Gosiute (Green River Formation, ~48.5Ma; Smith et al. 2008). Comparative studies for this region based on nearby temperature and precipitation reconstructions are shown in yellow, red and blue circles, while the present is shown in light blue squares. Allen (2017) dissertation work using leaf margin analysis to reconstruct MAT and leaf area analysis to reconstruct MAP is shown in red stars.

As mentioned, based on the comparative Arens et al. (2000) model, $\delta^{13}C_{leaf}$ values can be used to infer $\delta^{13}C_{atm}$ values. In previous works, Stein et al. (2019) and others determined that plant carbon isotope discrimination was taxon-specific (Stein et al. 2019; Sheldon et al. 2020; Stein et al. in press). Limitations of the Arens et al. proxy include the lack of taxonomic identity and the assumption that plant water use efficiency (c_i/c_a) remains constant in long and short-term scenarios (Beerling & Royer 2002). Our large sample size of complete leaf fossils from a single horizon (n = 34) allows us to statistically determine the most likely $\delta^{13}C_{atm}$ value based on the assumption that Arens et al.'s (2000) model represents a general relationship between $\delta^{13}C_{atm}$ and $\delta^{13}C_{leaf}$ values. To address limitations related to taxonomic identity, we also conducted analyses with taxon-specific reconstructions using nine total *Lygodium* and *Acer* fossils, using extant members of these genera (as published in Cornwell et al. 2018) to determine isotope discrimination and reconstruct the atmosphere. Taxon-specific reconstructions had an average value of -4.82‰ (±0.92‰ standard deviation), within error of the isotopic value of mantle CO_2 (-5.5‰; Deines 1992)The discrepancy between the mean and the mantle is likely because of the small sample size, and with more targeted sampling, this taxon-specific approach would yield comparable results to the generalized reconstructions and closer to the mantle. Due to our lack of sampling resolution, the higher sampling using assumptions of general C_3 photosynthesis is more appropriate in this case. We compared our reconstructed $\delta^{13}C_{atm}$ values (between -5.32 and -5.82‰) to the value reconstructed for ~49 Ma using benthic and planktonic foraminifera, -5.4‰ (Tipple et al. 2010), and feel confident in our use of this tool to reconstruct $\delta^{13}C_{atm}$ values. This value is aligned with the isotopic composition of the mantle, which is also identified as ~-5.5‰ (Deines 1992); thus, we can assume that the majority of the source of CO_2 gas to the atmosphere at this time was volcanic in origin.

5.6 Conclusions

The age findings contained in this study constrain the time period for the Blue Rim wet forests as younger than previous estimates, with the upper half of the section clearly deposited after the EECO. Based on dating and sedimentation rates, the lower part of the section could overlap with the end of the EECO, but *the climate remains unchanged throughout the section.*

During the EECO, the Blue Rim escarpment received between 608–1167 mm yr^{-1} of precipitation, likely related to different moisture regimes, and was a productive paratropical forest. Though reconstructed temperature and precipitation values using paleosol and sedimentological geochemistry are lower than published values reconstructed from flora, the values all fall within error of one another. Furthermore, the Holdridge life zones and floral humidity provinces calculated for both physiognomic-based and geochemistry-based reconstructions are comparable, pinpointing this region as a warm, wet forest ~49 Ma.

The presented updated age constraints, floral evidence and proxies, and inorganic and organic geochemical proxies at Blue Rim escarpment make it possible to reconstruct the depositional environment of this Lake Gosiute central region in an unprecedented way, including demonstrating the timing of the lake's demise. Geochemical tools allow us to interpret constant climate, hydrology, and provenance in the region; active tectonism was not recorded in this region. While Laramide orogenesis extended from 70 to 40 million years ago, this mountain-building was not continuous at any given location (Dickinson et al. 1988), and indeed, previous works have estimated diachronous termination of Laramide orogeny in Wyoming to be anywhere between 35 and 50 Ma (Dickinson et al. 1988). The multi-proxy results indicate that it is likely that the Blue Rim escarpment was deposited post-Laramide orogeny. The use of multiple proxies to cross-compare sites is under-utilized in paleoclimate reconstructions but affords us more confidence in our understanding of regional and more broad-scale climate regimes. Findings also contextualize the regression of Lake Gosiute, especially given the location of the Blue Rim escarpment; it is clear that at the time, Lake Gosiute was shallowing though still receiving sedimentological inputs from the same, consistent hydrological sources, with ephemeral flourishing forests on the lakeshore. Based on ample floral and geochemical data, ~49.29 to 48.29 million years ago – after the peak of the EECO – southwest Wyoming was a warm, wet forest with little to no frost and mild temperatures, in agreement with previous work.

Previous workers have worried about the interference of multiple hydrological inputs from various topographic sources due to the active tectonism in the region at the time. The consistent Ti/Al, U/Th, and La/Ce ratios to determine provenance and parent material throughout the Blue Rim stratigraphic column demonstrate that the hydrological and sedimentological inputs remained stable for this location throughout the one million years spanned by this section. This multi-proxy approach can be used in roughly contemporaneous, adjacent basins (e.g. Washakie

Basin, Uinta Basin, Sand Wash Basin, Piceance Basin); an in-depth, multi-point study of this region in the early Eocene can further elucidate the North American continental interior climate during hothouse periods, as well provide more information about hydrological inputs and tectonism in the region at this time.

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5.8 References

Allen, S. E. (2017). Reconstructing the local vegetation and seasonality of the Lower Eocene Blue Rim site of southwestern Wyoming using fossil wood. *International Journal of Plant Sciences*, *178*(9), 689-714.

Allen, S. E. (2017). The Uppermost Lower Eocene Blue Rim Flora from the Bridger Formation of Southwestern Wyoming: Floristic Composition, Paleoclimate, and Paleoecology. Doctoral Dissertation, University of Florida.

Arens, N. C., Jahren, A. H., & Amundson, R. (2000). Can C_3 plants faithfully record the carbon isotopic composition of atmospheric carbon dioxide? *Paleobiology*, 137-164.

Beerling, D. J., & Royer, D. L. (2002). Fossil plants as indicators of the Phanerozoic global carbon cycle. *Annual Review of Earth and Planetary Sciences*, *30*(1), 527-556.

Berner, R. A. (1992). Weathering, plants, and the long-term carbon cycle. *Geochimica et Cosmochimica Acta*, *56*(8), 3225-3231.

Berry, E. W. (1930). *Revision of the lower Eocene Wilcox flora of the southeastern states: with descriptions of new species, chiefly from Tennessee and Kentucky* (Vol. 156). US Government Printing Office.

Bestland, E. A. (2000). Weathering flux and CO_2 consumption determined from paleosol sequences across the Eocene–Oligocene transition. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *156*(3-4), 301-326.

Boutton, T. W. (1991). Stable Carbon Isotope Ratios of Natural Materials: I. Sample Preparation and Mass Spectrometric. Carbon isotope techniques, 1, 155.

Brand, L. R. (2002, October). Lacustrine Deposition in the Bridger Formation: Lake Gosiute Extended. In *Geological Society of America Abstracts with Programs* (Vol. 34, No. 6, p. 557).

Breedlovestrout, R. L., Evraets, B. J., and Parrish, J. T. (2013). New Paleogene climate analysis of western Washington using physiognomic characteristics of fossil leaves, *Palaeogeography Palaeoclimatology, Palaeoecology,* 392, 22–40.

Buchheim, H. P., Brand, L. R., & Goodwin, H. T. (2000). Lacustrine to fluvial floodplain deposition in the Eocene Bridger Formation. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *162*(1-2), 191-209.

Buck, B. J., Wolff, K., Merkler, D. J., & McMillan, N. J. (2006). Salt mineralogy of Las Vegas Wash, Nevada: morphology and subsurface evaporation. *Soil Science Society of America Journal*, *70*(5), 1639-1651.

Carroll, A. R., Doebbert, A. C., Booth, A. L., Chamberlain, C. P., Rhodes-Carson, M. K., Smith, M. E., ... & Beard, B. L. (2008). Capture of high-altitude precipitation by a low-altitude Eocene lake, western US. *Geology*, *36*(10), 791-794.

Cerling, T. E., Solomon, D. K., Quade, J. A. Y., & Bowman, J. R. (1991). On the isotopic composition of carbon in soil carbon dioxide. *Geochimica et Cosmochimica Acta*, *55*(11), 3403-3405.

Cerling, T. E. (1992). Use of carbon isotopes in paleosols as an indicator of the $P(CO_2)$ of the paleoatmosphere. *Global Biogeochemical Cycles*, *6*(3), 307-314.

Cheeseman, J. (2016). Food security in the face of salinity, drought, climate change, and population growth. In *Halophytes for food security in dry lands* (pp. 111-123). Academic Press.

Clyde, W. C., Sheldon, N. D., Koch, P. L., Gunnell, G. F., & Bartels, W. S. (2001). Linking the Wasatchian/Bridgerian boundary to the Cenozoic Global Climate Optimum: new magnetostratigraphic and isotopic results from South Pass, Wyoming. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *167*(1-2), 175-199.

Cotton, J. M., Jeffery, M. L., & Sheldon, N. D. (2013). Climate controls on soil respired CO_2 in the United States: implications for 21st century chemical weathering rates in temperate and arid ecosystems. *Chemical Geology*, *358*, 37-45.

Cornwell, W. K., Wright, I. J., Turner, J., Maire, V., Barbour, M. M., Cernusak, L. A., Dawson, T., Ellsworth, D., Farquhar, G. D., Griffiths, H. & Keitel, C. (2018). Climate and soils together regulate photosynthetic carbon isotope discrimination within C_3 plants worldwide. *Global Ecology and Biogeography*, *27*(9), 1056-1067.

Deines, P. (1992). Mantle carbon: concentration, mode of occurrence, and isotopic composition. In *Early Organic Evolution* (pp. 133-146). Springer, Berlin, Heidelberg.

Dickinson, K. A. (1988). Paleolimnology of Lake Tubutulik, an iron-meromictic Eocene lake, eastern Seward peninsula, Alaska. *Sedimentary Geology*, *54*(4), 303-320.

Dickinson, W. R., Klute, M. A., Hayes, M. J., Janecke, S. U., Lundin, E. R., McKittrick, M. A., & Olivares, M. D. (1988). Paleogeographic and paleotectonic setting of Laramide sedimentary basins in the central Rocky Mountain region. *Geological Society of America Bulletin*, *100*(7), 1023-1039.

Dillhoff, R. M., Dillhoff, T. A., Greenwood, D. R., DeVore, M. L., & Pigg, K. B. (2013). The Eocene Thomas Ranch flora, Allenby Formation, Princeton, British Columbia, Canada. *Botany*, *91*(8), 514-529.

Doebbert, A. C., Carroll, A. R., Mulch, A., Chetel, L. M., & Chamberlain, C. P. (2010). Geomorphic controls on lacustrine isotopic compositions: evidence from the Laney Member, Green River Formation, Wyoming. *GSA Bulletin*, *122*(1-2), 236-252.

Dzombak, R. M., Sheldon, N. D., Mohabey, D. M., & Samant, B. (2020). Stable climate in India during Deccan volcanism suggests limited influence on K–Pg extinction. *Gondwana Research*.

Ennis, D. J., Dunbar, N. W., Campbell, A. R., & Chapin, C. E. (2000). The effects of K-metasomatism on the mineralogy and geochemistry of silicic ignimbrites near Socorro, New Mexico. *Chemical Geology*, *167*(3-4), 285-312.

Franks, P. J., Royer, D. L., Beerling, D. J., Van de Water, P. K., Cantrill, D. J., Barbour, M. M., & Berry, J. A. (2014). New constraints on atmospheric CO_2 concentration for the Phanerozoic. *Geophysical Research Letters*, *41*(13), 4685-4694.

Fricke, H. C., & Wing, S. L. (2004). Oxygen isotope and paleobotanical estimates of temperature and $\delta^{18}O$–latitude gradients over North America during the early Eocene. *American Journal of Science*, *304*(7), 612-635.

Gallagher, T. M., & Sheldon, N. D. (2013). A new paleothermometer for forest paleosols and its implications for Cenozoic climate. *Geology*, *41*(6), 647-650.

Greenwood, D. R., Archibald, S. B., Mathewes, R. W., & Moss, P. T. (2005). Fossil biotas from the Okanagan Highlands, southern British Columbia and northeastern Washington State: climates and ecosystems across an Eocene landscape. *Canadian Journal of Earth Sciences*, *42*(2), 167-185.

Greenwood, D. R., Pigg, K. B., Basinger, J. F., and DeVore, M. L. (2016). A review of paleobotanical studies of the Early Eocene Okanagan (Okanogan) Highlands floras of British Columbia, Canada and Washington, USA, *Canadian Journal of Earth Sciences,* 53, 548–564, https://doi.org/10.1139/cjes-2015-0177.

Groll, P. E., & Steidtmann, J. R. (1987). Fluvial response to Eocene tectonism, the Bridger Formation, southern Wind River Range, Wyoming.

Hamzeh, M., & Dayanandan, S. (2004). Phylogeny of Populus (Salicaceae) based on nucleotide sequences of chloroplast TRNT-TRNF region and nuclear rDNA. *American journal of botany*, *91*(9), 1398-1408.

Hamzeh, M., Périnet, P., & Dayanandan, S. (2006). Genetic Relationships among species of Populus (Salicaceae) based on nuclear genomic data1. *The Journal of the Torrey Botanical Society*, *133*(4), 519-527.

Hanley, J. H. (1976). Paleosynecology of nonmarine Mollusca from the Green River and Wasatch formations (Eocene), southwestern Wyoming and northwestern Colorado. In *Structure and classification of paleocommunities* (pp. 235-261). Dowden, Hutchinson and Ross Stroudsburg, PA.

Holdridge, L. R. (1967). Life zone ecology. *Life zone ecology.*, (rev. ed.).

Hyland, E. G., & Sheldon, N. D. (2013). Coupled CO_2-climate response during the early Eocene climatic optimum. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *369*, 125-135.

Hyland, E. G., Huntington, K. W., Sheldon, N. D., & Reichgelt, T. (2018). Temperature seasonality in the North American continental interior during the Early Eocene Climatic Optimum. *Climates of the Past, 14,* 1391-1404.

Keeling, C. D., MOOK, W. G., & Tans, P. P. (1979). Recent trends in the $^{13}C/^{12}C$ ratio of atmospheric carbon dioxide. *Nature*, *277*(5692), 121-123.

Kelson, J. R., Huntington, K. W., Schauer, A. J., Saenger, C., & Lechler, A. R. (2017). Toward a universal carbonate clumped isotope calibration: Diverse synthesis and preparatory methods suggest a single temperature relationship. *Geochimica et Cosmochimica Acta*, *197*, 104-131.

Kistner, F. B. (1973). Stratigraphy of the Bridger Formation in the Big Island-Blue Rim area, Sweetwater County, Wyoming. In *Masters Abstracts International*, *45*(4).

Koenig, K. J. (1960). Bridger Formation in the Bridger Basin, Wyoming. *Overthrust Belt of Southwestern Wyoming and Adjacent Areas; 15th Annual Field Conference Guidebook,* 163-168.

Kuiper, K.F.A., Deino, F.J.K., Hilgen, W., Renne, P.R., Wijbrans, J.R. (2008). Synchonizing rock clocks of Earth history. *Science* 320: 500-504.

Leopold, E. B., & MacGinitie, H. D. (1972). Development and affinities of Tertiary floras in the Rocky Mountains. *Floristics and Paleoflorists of Asia and Eastern North America*.

Looy, C., Kerp, H., Duijnstee, I., & DiMichele, B. (2014). The late Paleozoic ecological-evolutionary laboratory, a land-plant fossil record perspective. *The Sedimentary Record*, *12*(4), 4-18.

Love, J. D. (1961). Definition of Green River, Great Divide, and Washakie basins, Southwestern Wyoming. *AAPG Bulletin*, *45*(10), 1749-1755.

Lugo, A. E., Brown, S. L., Dodson, R., Smith, T. S., & Shugart, H. H. (1999). The Holdridge life zones of the conterminous United States in relation to ecosystem mapping. *Journal of biogeography*, *26*(5), 1025-1038.

MacGinitie, H. D. (1969). *The Eocene green River flora of northwestern Colorado and northeastern Utah*. University of California Press.

MacGinitie, H. D. (1974). An Early Middle Eocene flora from the Yellowstone-Absaroka Volcanic Province, northwestern Wind River Basin, Wyoming, 1-103. University of California Publications in Geological Science, Berkeley, California, USA.

Malone, D. H., Craddock, J. P., & Mathesin, M. G. (2014). Origin of Allochthonous Volcanic Rocks at Squaw Peaks, Wyoming: A Distal Remnant of the Heart Mountain Slide? *The Mountain Geologist, 4,* 321-336.

Maynard, J. B. (1992). Chemistry of modern soils as a guide to interpreting Precambrian paleosols. *The Journal of Geology*, *100*(3), 279-289.

Merkhofer, L., Wilf, P., Haas, M. T., Kooyman, R. M., Sack, L., Scoffoni, C., & Cúneo, N. R. (2015). Resolving Australian analogs for an Eocene Patagonian paleorainforest using leaf size and floristics. *American Journal of Botany*, *102*(7), 1160-1173.

Miller, I. M., Brandon, M. T., & Hickey, L. J. (2006). Using leaf margin analysis to estimate the mid-Cretaceous (Albian) paleolatitude of the Baja BC block. *Earth and Planetary Science Letters*, *245*(1-2), 95-114.

Murphey, P. C., & Evanoff, E. (2001). Stratigraphy, fossil distribution, and depositional environments of the upper Bridger Formation (Middle Eocene), Southwestern Wyoming. *Wyoming State Geological Survey*.

Murphey, P. C., Torick, L. L., Bray, E. S., Chandler, R., & Evanoff, E. (2001). Taphonomy, fauna, and depositional environment of the Omomys Quarry, an unusual accumulation from the Bridger Formation (middle Eocene) of Southwestern Wyoming (USA). In *Eocene Biodiversity* (pp. 361-402). Springer, Boston, MA.

Murphey, P. C., & Evanoff, E. M. M. E. T. T. (2011, April). Paleontology and stratigraphy of the middle Eocene Bridger Formation, southern Green River basin, Wyoming. In *Proceedings of the Ninth Conference on Fossil Resources: Brigham Young University Geology Studies*, *49,* 83-109.

Nesbitt, H., & Young, G. M. (1982). Early Proterozoic climates and plate motions inferred from major element chemistry of lutites. *Nature*, *299*(5885), 715-717.

Ong, H. L., Swanson, V. E., & Bisque, R. E. (1970). Natural organic acids as agents of chemical weathering. *Geological Survey Research, Paper*.

Passchier, S., Bohaty, S. M., Jiménez-Espejo, F., Pross, J., Röhl, U., van de Flierdt, T., Escutia, C., & Brinkhuis, H. (2013). Early Eocene to middle Miocene cooling and aridification of East Antarctica. *Geochemistry, Geophysics, Geosystems*, *14*(5), 1399-1410.

Peppe, D. J., Royer, D. L., Wilf, P., & Kowalski, E. A. (2010). Quantification of large uncertainties in fossil leaf paleoaltimetry. *Tectonics*, *29*(3).

Pett-Ridge, J. C., Monastra, V. M., Derry, L. A., & Chadwick, O. A. (2007). Importance of atmospheric inputs and Fe-oxides in controlling soil uranium budgets and behavior along a Hawaiian chronosequence. *Chemical Geology*, *244*(3-4), 691-707.

Poore, R. Z., Pavich, M. J., & Grissino-Mayer, H. D. (2005). Record of the North American southwest monsoon from Gulf of Mexico sediment cores. *Geology*, *33*(3), 209-212.

Retallack, G. J. (1999). Postapocalyptic greenhouse paleoclimate revealed by earliest Triassic paleosols in the Sydney Basin, Australia. *Geological Society of America Bulletin*, *111*(1), 52-70.

Retallack, G. J. (2001). Soils of the past. An introduction to palaeopedology.

Roehler, H. W. (1993). Eocene climates, depositional environments, and geography, greater Green River Basin, Wyoming, Utah, and Colorado. *United States Geological Survey, Professional Paper*, (1506-F).

Royer, D. L. (1999). Depth to pedogenic carbonate horizon as a paleoprecipitation indicator?. *Geology*, *27*(12), 1123-1126.

Sayyed, M. R. G., & Hundekari, S. M. (2006). Preliminary comparison of ancient bole beds and modern soils developed upon the Deccan volcanic basalts around Pune (India): Potential for palaeoenvironmental reconstruction. *Quaternary International*, *156*, 189-199.

Sheldon, N. D., Retallack, G. J., & Tanaka, S. (2002). Geochemical climofunctions from North American soils and application to paleosols across the Eocene-Oligocene boundary in Oregon. *The Journal of geology*, *110*(6), 687-696.

Sheldon, N. D. (2006). Abrupt chemical weathering increase across the Permian–Triassic boundary. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *231*(3-4), 315-321.

Sheldon, N. D., & Tabor, N. J. (2009). Quantitative paleoenvironmental and paleoclimatic reconstruction using paleosols. *Earth-Science Reviews*, *95*(1-2), 1-52.

Sheldon, N. D., Smith, S. Y., Stein, R., & Ng, M. (2020). Carbon isotope ecology of gymnosperms and implications for paleoclimatic and paleoecological studies. *Global and Planetary Change*, 103060.

Smith, M. E., Singer, B., & Carroll, A. (2003). $^{40}Ar/^{39}Ar$ geochronology of the Eocene Green River Formation, Wyoming. *Geological Society of America Bulletin*, *115*(5), 549-565.

Smith, M. E., Carroll, A. R., & Singer, B. S. (2008). Synoptic reconstruction of a major ancient lake system: Eocene Green River Formation, western United States. *GSA bulletin*, *120*(1-2), 54-84.

Smith, R. Y., Basinger, J. F., and Greenwood, D. R. (2012). Early Eocene plant diversity and dynamics in the Falkland flora, Okanagan Highlands, British Columbia, Canada, *Palaeobiodiversity and Palaeoenvironments, 92*(3)*,* 309–328, https://doi.org/10.1007/s12549-011-0061-5.

Snoke, A. W., Steidtmann, J. R., & Roberts, S. M. (1993). Geologic history of Wyoming within the tectonic framework of the North American Cordillera. *Geology of Wyoming: Geological Survey of Wyoming Memoir*, *5*, 2-56.

Solomon, S. (2007). IPCC (2007): Climate change the physical science basis. *AGUFM*, *2007*, U43D-01.

Spicer, R. A., Valdes, P. J., Spicer, T. E. V., Craggs, H. J., Srivastava, G., Mehrotra, R. C., & Yang, J. (2009). New developments in CLAMP: calibration using global gridded meteorological data. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *283*(1-2), 91-98.

Stein, R. A., Sheldon, N. D., & Smith, S. (2019). Rapid response to anthropogenic climate change by *Thuja occidentalis*: implications for past climate reconstructions and future climate predictions. *PeerJ*, *7*, e7378.

Stein, R. A., Sheldon, N. D., & Smith S. (in press). C_3 plant carbon isotope discrimination does not respond to CO_2 concentration on decadal to centennial timescales. *New Phytologist.* doi: 10.1111/nph.17030

Stull, G. W., Allen, S. E., & Manchester, S. R. (2014). Fossils of *Iodes* (Icacinaceae) from the early Eocene Blue Rim flora (SW Wyoming) and the late Miocene Wenshan flora (SW Yunnan, China). *The Paleontological Society Special Publications*, *13*, 17-18.

Surdam, R. C., & Stanley, K. O. (1979). Lacustrine sedimentation during the culminating phase of Eocene lake Gosiute, Wyoming (Green River Formation). *Geological Society of America Bulletin*, *90*(1), 93-110.

Tipple, B. J., Meyers, S. R., & Pagani, M. (2010). Carbon isotope ratio of Cenozoic CO_2: A comparative evaluation of available geochemical proxies. *Paleoceanography*, *25*(3).

Tu, T. N., Derenne, S., Largeau, C., Bardoux, G., & Mariotti, A. (2004). Diagenesis effects on specific carbon isotope composition of plant n-alkanes. *Organic Geochemistry*, *35*(3), 317-329.

Vinogradov, A. P. (1959). Geochemistry of rare and dispersed chemical elements in soils.

West, C. K., Greenwood, D. R., Reichgelt, T., Lowe, A. J., Vachon, J. M., Basinger, J. F. (2020). Paleobotanical proxies for early Eocene climates and ecosystems in northern North America from middle to high latitudes, *Climate of the Past, 16,* 1387-1410.

Wilf, P., Wing, S. L., Greenwood, D. R., & Greenwood, C. L. (1998). Using fossil leaves as paleoprecipitation indicators: an Eocene example. *Geology*, *26*(3), 203-206.

Wilf, P. (2000). Late Paleocene–early Eocene climate changes in southwestern Wyoming: Paleobotanical analysis. *Geological Society of America Bulletin*, *112*(2), 292-307.

Wing, S. L. (1987). Eocene and Oligocene floras and vegetation of the Rocky Mountains. *Annals of the Missouri Botanical Garden*, 748-784.

Wing, S. L., & Greenwood, D. R. (1993). Fossils and fossil climate: the case for equable continental interiors in the Eocene. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *341*(1297), 243-252.

Wing, S. L., Harrington, G. J., Smith, F. A., Bloch, J. I., Boyer, D. M., & Freeman, K. H. (2005). Transient floral change and rapid global warming at the Paleocene-Eocene boundary. *Science*, *310*(5750), 993-996.

Wing, S. L., & Currano, E. D. (2013). Plant response to a global greenhouse event 56 million years ago. *American Journal of Botany*, *100*(7), 1234-1254.

Wolfe, J. A. (1994). Tertiary climatic changes at middle latitudes of western North America. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *108*(3-4), 195-205.

Wolfe, J. A., Forest, C. E., & Molnar, P. (1998). Paleobotanical evidence of Eocene and Oligocene paleoaltitudes in midlatitude western North America. *Geological Society of America Bulletin*, *110*(5), 664-678.

Zhu, J., Poulsen, C. J., & Tierney, J. E. (2019). Simulation of Eocene extreme warmth and high climate sensitivity through cloud feedbacks. *Science advances*, *5*(9), eaax1874.

CHAPTER VI

Conclusions

This dissertation is a compilation of four chapters that use carbon isotope ecology in plants and soils to examine water and carbon cycle dynamics between land and the atmosphere. Each chapter provides insights into how plants respond to changes in their water and carbon cycles, as recorded, or not, in carbon isotope records in plants and in soil organic matter. This concluding chapter emphasizes important findings and future questions based on my research. Some of these questions contain preliminary data collected over the course of my thesis, presented to emphasize hypotheses and areas for future growth.

6.1 Summary of results and key findings

In **Chapter II,** I explore the relationship between carbon isotope values ($\delta^{13}C_{leaf}$), carbon isotope discrimination ($\Delta^{13}C_{leaf}$) and a number of aspects of climate and the environment (e.g. Körner et al. 1991; Ehleringer & Dawson 1992; O'Leary 1993; Arens et al. 2000; Diefendorf et al. 2010; Schubert & Jahren 2012; Wernerehl & Givnish 2015; Mårtensson et al. 2017; Stein et al. 2019) in one species: *Thuja occidentalis* (northern white cedar, Cupressaceae). This natural experiment relies on collections of leaves from expeditions spanning the early 1800s to the present from museums and herbaria. Stable C isotopes show a relationship with carbon isotope values of the atmosphere ($\delta^{13}C_{atm}$), time, and pCO_2. However, when pCO_2 is corrected for $\delta^{13}C_{atm}$, there is no relationship with $\delta^{13}C_{leaf}$. Carbon isotope discrimination shows no relationship with any other tested climate variable, indicating that there is no clear predictive relationship between climate (tested) and carbon isotope discrimination. This effectively means that $\delta^{13}C_{leaf}$ should reflect $\delta^{13}C_{atm}$ of source gas, provided taxonomic identity is clear. The role that the heterogeneity of $\delta^{13}C_{atm}$ values at ground level plays on $\delta^{13}C_{leaf}$ variability remains unclear across ecosystems; this could be investigated with ecosystem-wide gaseous and solid

measurements (see section 6.2.1). Additional future questions raised include how this can be applied to the fossil record, and the role that taphonomy plays in preservation of leaf carbon isotope values in variable conditions (see section 6.2.2).

Chapter III approaches carbon isotope ecology from a different angle, instead focusing specifically on the Δ_{leaf}-paleobarometric model that has been applied in the fossil record previously (Schubert & Jahren 2012; Cui & Schubert 2017). Using historical specimens from herbaria and museum collections, I examine plant biogeochemical responses to enhancing carbon dioxide in the atmosphere over Industrialization in high resolution. In my findings, using this historical approach in conjunction with a literature review of stable isotope ecology for a wide range of C_3 plants, it is clear that Δ_{leaf} values are not driven by CO_2 enhancement over Industrialization. Furthermore carbon isotope values across a wide range of C_3 taxa are not comparable to those used to develop the Δ_{leaf} -paleobarometric model (*Arabidopsis thaliana*: and *Raphanus sativus*: wild radish, Brassicaceae). This suggests that this paleobarometric model, based upon growth chamber experiments, might not be representative of those plants seen in the fossil record. Previous works have found that the control of atmospheric CO_2 concentration on Δ_{leaf} values is partially mitigated by water availability (Lomax et al. 2019), so the interplay of multiple complex climate variables, as seen in natural ecosystems, leaves room for future investigation (see section 6.2.3). Likewise, the role that individual species' adaptive morphology plays in carbon isotope discrimination remains uncertain, and future work on the relationship between leaf pore and discrimination across multiple species will help to determine why we see species-specific responses to climate (see section 6.2.4).

I expand on findings from Chapter II in **Chapter IV**, with a focus on the role of organic carbon isotopes in the water cycle. Despite Diefendorf et al. (2010) and Kohn's (2010) studies that found carbon isotope discrimination changed logarithmically with increased rainfall, in the single species historical analysis from Chapter II as well as findings from multiple species' historical records presented in Sheldon et al. (2020), this relationship was not replicable. This is likely because the generalized relationship between Δ_{leaf} and precipitation described by Diefendorf et al. (2010) is actually a series of straight lines for individual species living over wide precipitation regimes, stacked to make a curve (e.g. **Figure 6.1**). However, soils aggregate carbon isotope values from aboveground biomass to act as an integrator that behaves similarly to

Diefendorf et al. (2010)'s generalized plant results, minus specific taxonomic identification. In **Chapter IV,** this was tested in both modern soil systems as well as paleosols with independent precipitation estimates from other proxies. In both scenarios, reconstructed precipitation values were predictive of actual or established reconstructions of precipitation. This work would also benefit from future work to understand how different depositional conditions affect taphonomy and whether this impacts carbon isotope values recorded in organic matter (section 6.2.2).

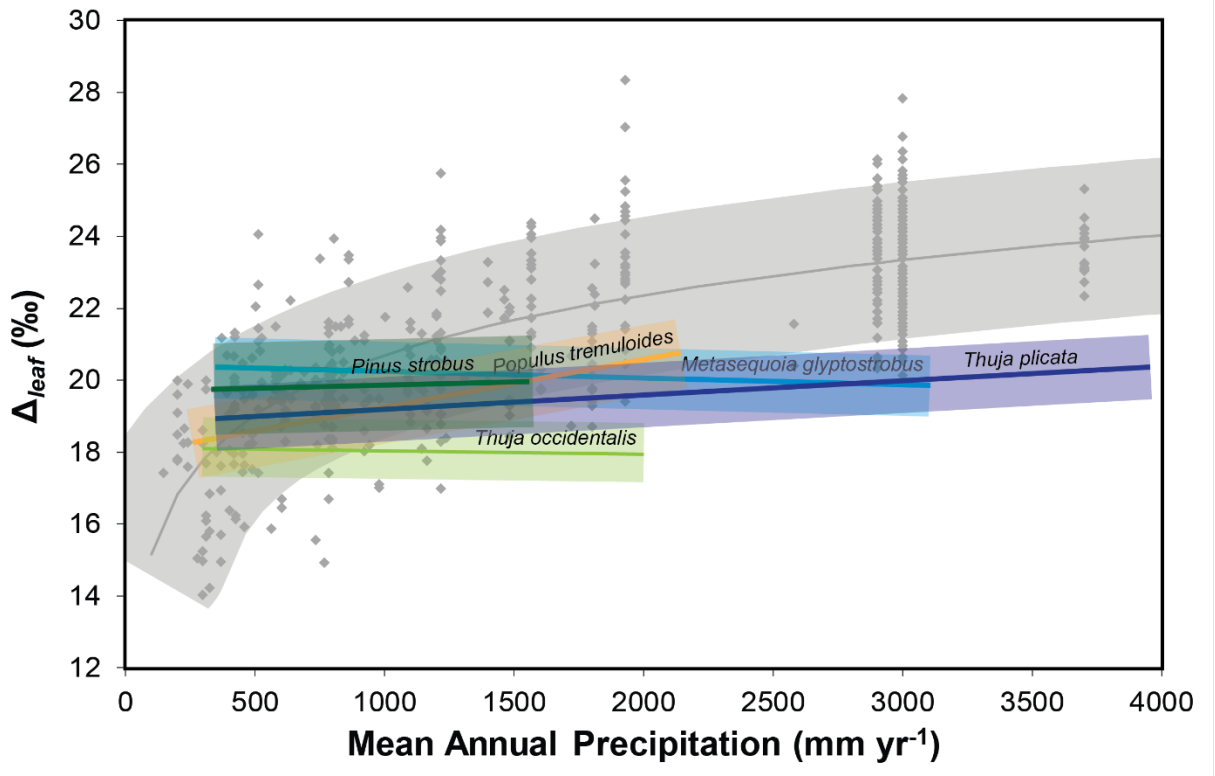

Figure 6.1 Δ_{leaf} values compared to mean annual precipitation, with individual species collected for Sheldon, Smith, Stein & Ng (*Global Planetary Change,* 2020) overlaid on Diefendorf et al.'s (2010) meta-data set.

Finally, **Chapter V** compiles the knowledge garnered from modern and ancient systems in the previous chapters and applies it to a deep time case study: the early Eocene climatic optimum (EECO). This hothouse period is now established to be a potential analog for the highest, "business as usual" scenario for future climate change created by the Intergovernmental Panel on Climate Change (Pachauri & Reisinger 2007; Zhu et al. 2019). Findings from **Chapter V** indicate that the continental interior ancient lake Gosiute, located in present day Wyoming,

Colorado and Utah, was a littoral wet forest by a regressing lake with constant hydrological inputs, medium to high rainfall, medium temperatures (10-14°C) and atmospheric carbon dioxide of mantle origin. This region is currently a high desert, with low mean annual temperature (7.4°C; 2017 value; PRISM Climate Group 2004), and precipitation (308.82 mm yr^{-1}; 2017 value; PRISM Climate Group 2004). During the early Eocene, however, the region was lush with ferns, woody angiosperms, lianas and monocots. The multiple mountain ranges surrounding the region were forming during the deposition of paleo-lake Gosiute, but changing sources did not result in climate signal interference, as provenance and parent material stayed constant throughout the section. This study provides high-resolution, valuable insight about the hydroclimate and paleoclimate of the continental interior during a modern climate analog. Findings from Chapter V, which demonstrate a more stable ecosystem than expected during a time of reconstructed dynamic global climate and dynamic regional tectonics, raise further questions about how multiple climate parameters interact, and how this affects ancient sedimentological records (section 6.2.3).

6.2 Future directions and remaining questions

In this dissertation, I have assessed the relationship between carbon isotope values in plants and soils and climate using carbon isotope values as a tool. Though not directly covered in **Chapters II-V**, this relationship is tied very closely to plant physiology and the mechanism of photosynthesis. As such, a number of outstanding questions about nuances in carbon isotope ecology relate to complexities of the carbon and water cycle. Many of these outstanding questions will address how plant morphology and physiology relate to these large biogeochemical cycles.

The carbon and water cycles are both complex, and intertwined on Earth (Wehrli 2013). As such, many of the questions raised from this work relate to how carbon and water cycle and interdependency might relate to carbon isotope records in leaves. In particular, one question raised regularly throughout this research relates to heterogeneity of the isotopic composition of the atmosphere on an ecosystem scale: the basis of carbon isotope discrimination in plants relies on a known $\delta^{13}C_{atm}$ value. However, even when the global composition is measurable (i.e. White et al. 2015) or constrainable in the fossil record (i.e. Tipple et al. 2010), variability in canopy

density and soil respiration rates cause heterogeneous $\delta^{13}C_{atm}$ values that impact interpretations of $\delta^{13}C$ values in organic matter (**6.2.1**). Other questions relate to the mechanism of carbon isotope discrimination in plants: the aforementioned data presented in this dissertation show empirical relationships between single climate variables and $\delta^{13}C_{leaf}$ and $\delta^{13}C_{SOM}$, but mechanistically, how is this happening? Do soil conditions (**6.2.2**) and/or plant morphology (**6.2.4**) affect the interpretations of our records? Finally, climate cannot be represented by a single parameter, and the findings demonstrated in this dissertation examine single climate variable interactions with carbon isotope discrimination. However, in the natural world, effects of the carbon and water cycle often run interference on one another (for example, increased CO_2 causes increased warming (Houghton et al. 2001), but subsequent increase in plant productivity and transpiration, leading to regional cooling; Tan et al. 2020). As such, carbon isotope discrimination in plants can and should be explored in the context of multivariable climate phenomena (**6.2.3**).

6.2.1 *Carbon cycle:* How do we account for the heterogeneity of $\delta^{13}C_{atm}$?

In **Chapter II, III,** and **IV** we make assumptions about $\delta^{13}C_{atm}$ assuming homogenous mixing in the atmosphere and using global values measured at Mauna Loa Observatory (MLO; White et al. 2015). However, the concentration of CO_2 can vary wildly at the soil surface and below the canopy due to soil-respired CO_2 and eddy circulation (e.g. Stoyan et al. 2000; Dore et al. 2014). This effect is strongest at night, when the forest boundary layer is thickest (e.g. Munger & Hadley 2017). Even during the day, CO_2 near the floor of wet tropical forests can be elevated by tens of ppm, and the isotopic composition of this CO_2 can be depleted by -2 to -3‰ (e.g. Broadmeadow et al. 1992; Lloyd et al. 1996; Buchmann et al. 1997; Holtum & Winter 2001). In temperate forests, these effects are muted but still present (up to 20 ppm and -1‰ depletion; Francey et al. 1985; Munger & Hadley 2017). While the location of each specimen collected in the modern portions of this study was controlled for by height, and accessibility (often related to proximity to road or trail, inherently higher air mixing regions), any shift in $\delta^{13}C_{atm}$ value from the global average measured at Mauna Loa Observatory White et al. 2015) would result in changed carbon isotope discrimination. In these works, $\delta^{13}C_{atm}$ values used were

reasonably well constrained, though we know less about the ecosystems sampled in historical studies.

It is important for us to examine patterns in $\delta^{13}C_{atm}$ heterogeneity across ecosystems. $\delta^{13}C_{atm}$ values are not just used to calculate carbon isotope discrimination; this variable is well utilized in stomatal and pedogenic paleobarometers (Cerling et al. 1991; Cerling et al. 1992; Franks et al. 2014), as well as to provide insight into carbon sources in the atmosphere (e.g. Keeling et al. 1980). Future work could expand on the effects of heterogeneous microenvironmental air and CO_2 flow, incorporating isotopic measurements from ground to canopy. Eddy flux towers across the country at AmeriFlux, National Ecological Observation Network (NEON), Critical Zone Observatory network (CZO) and Long Term Ecological Research network (LTER) sites provide infrastructure to conduct these measurements (e.g. Thompson et al. 2011; Novick et al. 2018). The Picarro Cavity Ring-Down Spectroscope is largely mobile and can be run on continuous flow, so this could be used to measure isotopic variation at locations along the Eddy Flux tower. The AmeriFlux, NEON, CZO and LTER networks, in total encompassing >341 flux sites, 59 of which have >10 years of data, occur across ecosystems (e.g. grasslands, shrublands, evergreen forests, mixed forests, deciduous forests, savannas, lakes, tundra, and more; Turner et al. 2003; Xiao et al. 2010; Novick et al. 2018). Flux towers have already been used to explain ecosystem productivity (e.g. Belmecheri et al. 2014); this could be expanded to examine the isotopic signature of the carbon cycle. Previous works with a Picarro CRDS have examined water isotope variability and flux in a similar way (Aron et al. 2019; Aron et al. 2020). By taking discrete and continuous measurements at different levels of ecosystems (**Figure 6.2**), it would be possible to create isotope-enabled eddy flux models and minimize uncertainty about the isotopic signature of plants' source gas. This would enhance our understanding of plants' roles in the carbon cycle.

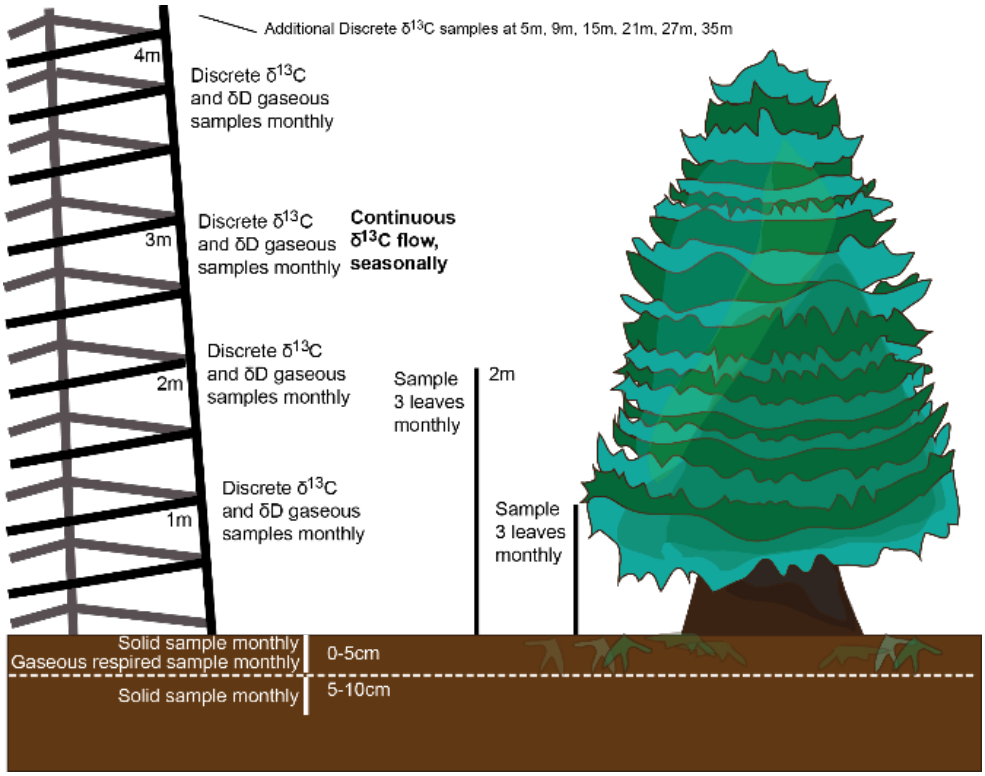

Figure 6.2 Example of potential ecosystem level ^{13}C sampling (including gaseous CO_2 from the atmosphere, leaves, soil-respired CO_2 in gaseous form, and soil organic carbon) that could constrain isotope fluxes in an ecosystem. The tower on the left represents and eddy flux tower, set up in many LTER, AmeriFlux, CZO and NEON sites across the world.

6.2.2 *Water cycle:* High precipitation regimes and carbon isotope values

In **Chapter IV** I explore the relationship between mean annual precipitation and $\delta^{13}C$ values of upper soil horizons. Like many proxies, $\delta^{13}C_{SOM}$-precipitation works well at lower precipitation, and begins to behave erratically >2500 mm yr^{-1} (Stein et al. in prep., see **Chapter IV**). Of note, the range of isotope values seen in Diefendorf et al.'s (2010) dataset of $\delta^{13}C_{leaf}$ values also increased at higher precipitation values (Diefendorf et al. 2010). There is certainly a maximum carbon isotope discrimination value that can happen just based on CO_2 available and light availability, even with unlimited water availability (Farquhar 1989). Plants are not adapted to be conducting C_3 photosynthesis constantly throughout the day and night (Joo et al. 2017). Thus, we do not expect carbon isotope discrimination to increase indefinitely with increased precipitation; it is noteworthy that carbon isotope discrimination becomes unpredictable at high precipitation levels. It is possible that this is because high mean annual precipitation does not inherently mean that all of this water is available to plants; it can be run off quickly (e.g. Royer

1979), and/or moved in downward transport as colloids or in solution (Osher et al. 2003). It may be controlled by microbes present, or, other soil-specific edaphic factors such as soil texture (Dodd & Lauenroth 1997; Zhang et al. 2020). Further assessment of high precipitation ecosystems, in highly measured, resolved soils should be done to determine how and if these soil-based factors drive carbon isotope values in soils. With more effort to determine plant available water, which is more complex than just mean annual precipitation, we can better quantify plant water stress and its relationship to carbon isotope ecology in plants and soils (Zhang et al. 2020).

Furthermore, experiments looking at fractionation effects in soil acidic conditions can allow us to better understand how taphonomy affects carbon isotope values of whole and partial leaves. Carbonic acid in rain, which has a pH of 5.0, and increased weathering and leaching intensity drive soil pH to decrease with increased rainfall (USDA, unk.). The effects of this acidity on organic matter can be tested on plant material. Indeed, this has been tested in natural systems using fresh and sub-fossil leaves in mangrove ecosystems buried in peat in Belize (Wooller et al. 2003). In these experiments, sub-fossil leaf fragments and fresh leaves had comparable isotopic values (-29 to -22 ‰ and -29 to -23 ‰, respectively; Wooller et al. 2003). This can also be simulated in a lab, using set pH acid to emulate soil acidic conditions, and allowing plant fragments and full leaves to sit in acid for extended periods of time. When conducted in a closed lab experiment, using bleached and rinsed *Thuja occidentalis* leaves (to control for microbial growth), capped vials and dilute hydrochloric acid at pH = 6, (Table 6.1), results were mixed, though none were significant. Though it did appear that partial leaves became more isotopically enriched (more + isotopic values with time) and full leaves demonstrated mostly isotopic depletion with time, this experiment should be replicated in longer studies, with more data points.

Table 6.1 Taphonomic changes in $\Delta^{13}C_{leaf}$ for *Thuja occidentalis* samples over 32 weeks (sampled at 0, 2, 4, 8, 16 and 32 weeks). "P" denotes partial leaves (chopped up), "F" denotes full leaves.

Leaf	Species	Slope	Intercept	R^2	p-value
777 (P)	*Thuja occidentalis*	0.05	-29.25	0.3	0.26
778 (P)	*Thuja occidentalis*	0.1	-28.28	0.62	0.06

921 (P)	*Thuja occidentalis*	0.01	-28.92	0.58	0.16
777 (F)	*Thuja occidentalis*	0.03	-28.89	0.04	0.7
778 (F)	*Thuja occidentalis*	-0.02	-28.612	0.02	0.78
921 (F)	*Thuja occidentalis*	-0.02	-28.71	0.69	0.21

6.2.3 *Water and carbon cycles:* What happens to carbon isotope discrimination when you combine multiple climate variables?

This thesis has mentioned the importance of the water and carbon cycles in determining carbon isotope discrimination, fractionation and values countless times. If that is so, the two cycles can feasibly interfere with one another. As of late, most work addressing climate factors on carbon isotope discrimination focuses on one key variable; some works have tested the relationship between $\Delta^{13}C_{leaf}$ and pCO_2 closely in controlled environments (Schubert & Jahren 2012), and others have compared $\delta^{13}C_{leaf}$ and precipitation (Diefendorf et al. 2010) and $\delta^{13}C_{atm}$ (Arens et al. 2000). **Chapters II-IV** all use single and multivariate regressions to assess the relationship between carbon isotopes and climate variables. In **Chapter V,** these relationships are applied to the fossil record in the context of multiple variables, to assist in categorizing the landscape. However, even within controlled experiments, when additional variables are introduced (e.g. water availability, Lomax et al. 2019) idealized modeling relationships begin to fall apart. In modern ecosystems under free-air CO_2 enrichment experiments, water availability still limits stomatal conductance (Norby & Zak 2011). This introduces importance nuance to using $\delta^{13}C$ values in deep time, because never is there only one climate factor impacting a depositional environment.

There are several ways to test this; one of these is, of course, using a priori proxy data to tether climate simulations to findings, and testing what happens in dynamic earth system models (e.g. what was done with water isotopologues; Twining et al. 2006, or using ^{13}C isotope enabled CESM; Lawrence et al. 2019). Another way to do this is to compare complex climate patterns, such as the El Niño Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), North

American Monsoon (NAM), with seasonal and annual patterns in biogeochemistry as compared to these complex teleconnections (Ito 2011; Martens et al. 2018). Previous work looked at tree growth height growth in coastal species *Picea morrisonicola* (Pinaceae; Guan et al. 2012) with measures of PDO anomalies. In preliminary data examining the relationship between $\Delta^{13}C_{leaf}$ values collected in Pacific, western montane, and Great Lakes ecosystems, $\Delta^{13}C_{leaf}$ data could be parsed to occurring on dominant ENSO/PDO timescales (Stein et al. in prep; **Figure 6.3**). The nuanced relationship between plant carbon isotope ecology and complex teleconnections could be explored throughout coastal ecosystems around the world, providing insight about the interplay of multiple climate factors in plant stress.

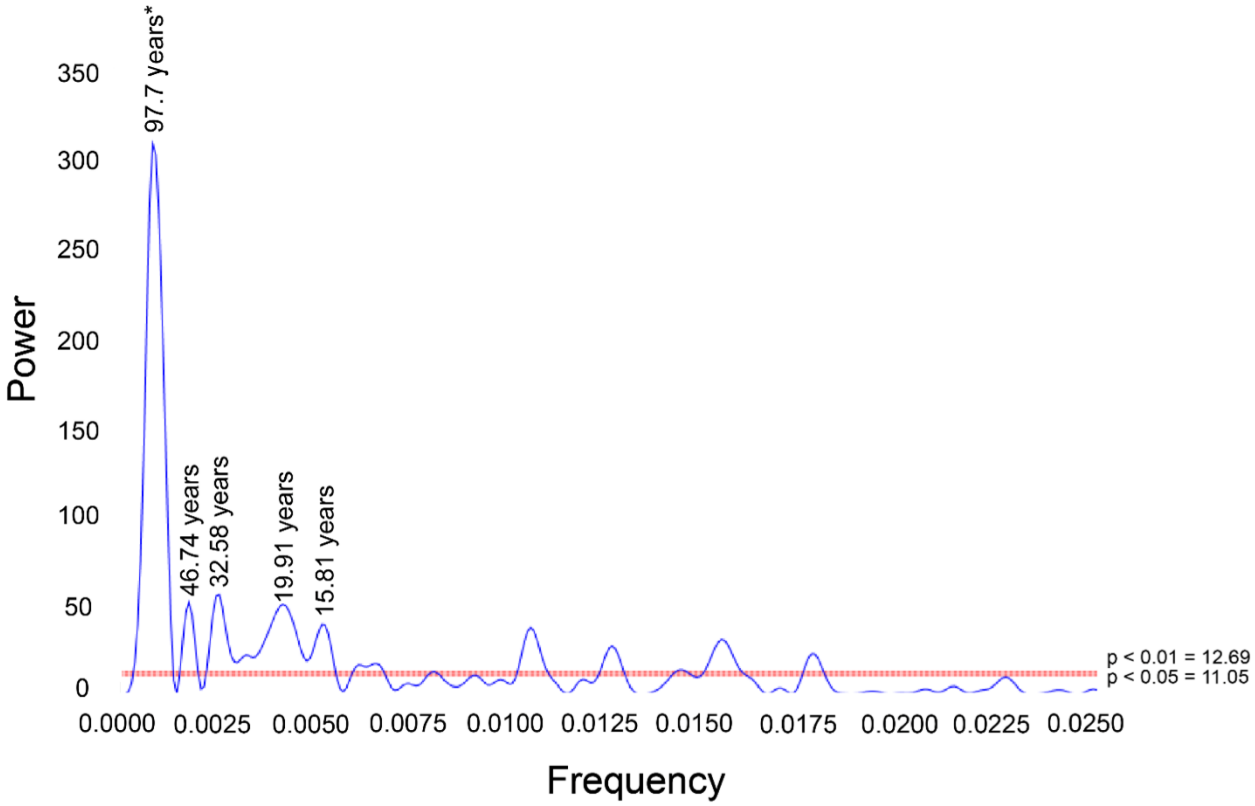

Figure 6.3 Power spectral analysis to determine strongest frequency, interpolated and regularly sampled on month (0.083 year) frequency, of *Thuja plicata* residual $\Delta^{13}C_{leaf}$ (‰) values over time.

6.2.4 Mechanisms for carbon isotope discrimination

$$\Delta_{leaf} = (a) + (b - a)(\frac{C_i}{C_a}) \quad \text{(Equation 6.1)}$$

There have been established generalized equations to describe the mechanism of carbon isotope discrimination in plants (Equation 6.1), the effects that climate has on each of these sub-mechanisms is not fully understood. It has been demonstrated in many studies that stomatal density is inversely related to CO_2 (e.g. Woodward 1987; Woodward & Bazzazz 1988), but how does this factor into carbon isotope discrimination? Franks et al. (2014) designed a model that incorporated the stomatal density and isotope fractionation as a metric for the concentration of CO_2 passing into the cell to solve for pCO_2 of the atmosphere. This model gives us insight into the corresponding effects of stomatal shape and size on $\Delta^{13}C_{leaf}$ – the stomatal density and pores can be compared to isotopic signatures as well, to connect biogeochemistry and plant morphology empirically. While currently developed based on a few case study plants, this metric can be refined with gymnosperms and other non-angiosperm biota to improve the taxon-specific accuracy of this stomatal paleobarometer.

We know that diffusion provides a mechanism for $\Delta^{13}C_{leaf}$ – but to what extent? I conducted preliminary work with help from undergraduate mentees and the guidance of Dr. Dana Royer to look at the relationships between $\Delta^{13}C_{leaf}$ values of *Thuja* and *Populus* specimens collected from the 1800s to present and stomatal morphology (guard cell length and width, pore length, stomatal density and stomatal volume) and found that there was no link between any stomatal parameters and isotope discrimination in these species (**Figure 6.4**). With these preliminary results, it appears that changing the aperture of stomata and density of stomata does not have effects on fractionation via diffusion. This means that changes in carbon isotope discrimination can be blamed on changes in water use efficiency (c_i/c_a ratios) and/or on the function of RuBisCO. Further work to constrain stomatal conductance (by using a porometer) continuously throughout the day and night before conducting these stomatal and isotopic measurements will provide even more insight about the daily patterns of carbon intake.

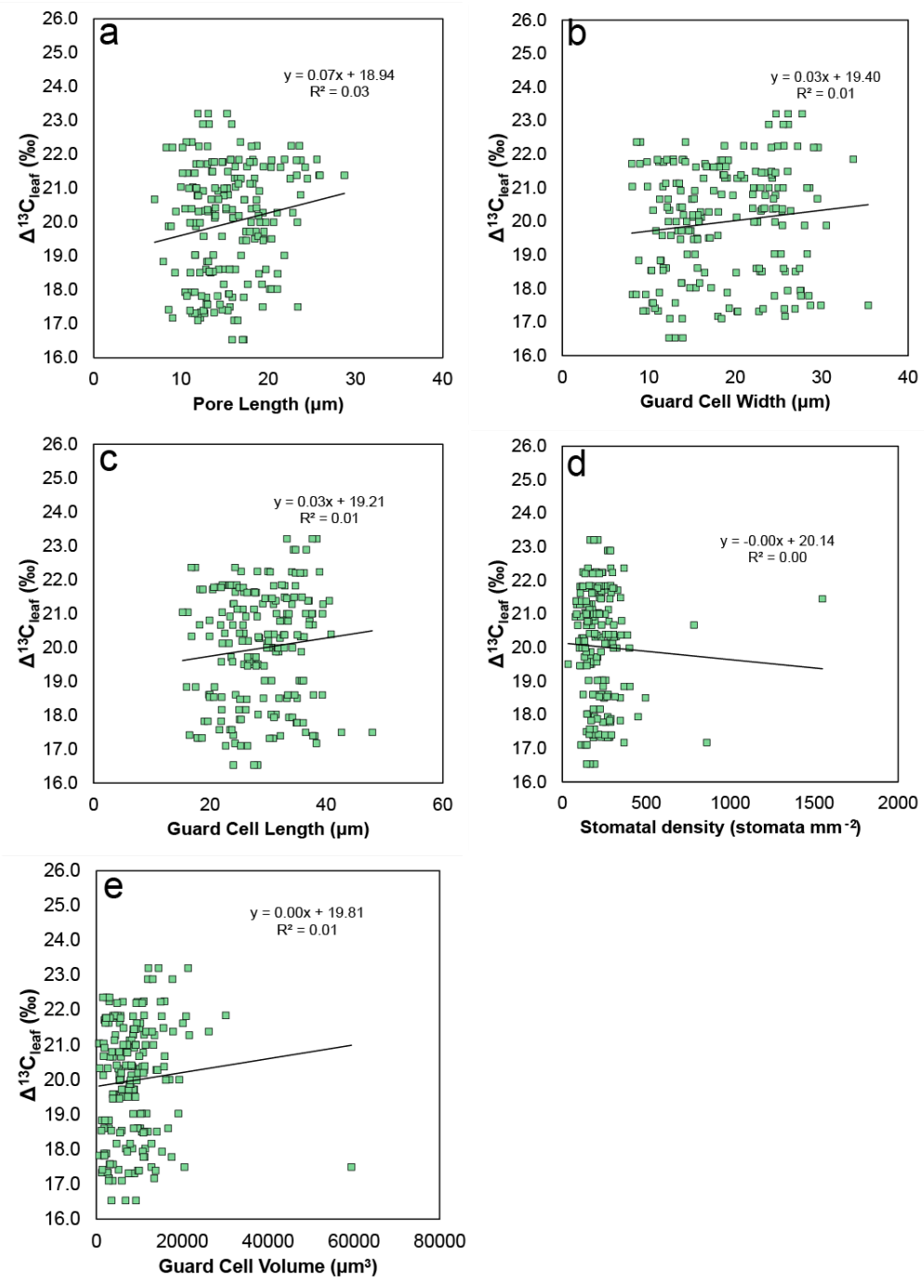

Figure 6.4 $\Delta^{13}C_{leaf}$ values (‰) vs (a) pore length (µm), (b) guard cell width (µm), (c) guard cell length (µm), (d) stomatal density (stomata mm^{-2}) and (e) guard cell volume (μm^3).

6.3 Overall areas for future exploration

Overall, the works presented in this dissertation have contributed to our understanding of carbon isotope ecology within plants and soils, especially as related to the carbon and water cycle individually. Understanding the effects of individual climate variables on plant function is useful for understanding plant carbon isotope discrimination, but leaves many outstanding questions to explore. Because we live on a dynamic planet with many interconnected environmental factors and because plants themselves are complicated, defining empirical relationships between climate and $\delta^{13}C$ values recorded in plants and soils is the tip of the iceberg. It is important that we understand the role that plants play as the carbon *and* water cycles are critically affected by anthropogenic and ancient climate change, because the biosphere plays an instrumental role as a mover of water and carbon. To do this, we must investigate the mechanism of isotope discrimination as it relates to plant adaptations, account for the nuances in each of these cycles, and determine how and when these cycles can interfere with one another in carbon isotope ecological records.

In thinking about how to approach the aforementioned problems, I would like to emphasize the tremendous room for experimental design within the herbarium and museum collections retained in facilities across the world. While there are works that have incorporated herbarium and museum collections, particularly in the biological sciences (e.g. Loiselle et al. 2008; Borchert 1996; Pedicino et al. 2002; Schmidt et al. 2005; Bieker & Martin 2018), there remain so many under-used plant specimens that were collected as early as the 1700's on expeditions by naturalists as well as samples in soil repositories (e.g. the USDA's National Soil Survey Center within the Natural Resources Conservation Service) that include O-, A-, and B-horizons across the country. As climate changes, putting stress on ecosystems and driving changes in plant community composition (Feeley et al. 2020), these facilities provide unique and important materials for us to examine the relationship between the biosphere and anthropogenic climate change (Lang et al. 2019). Though I focus on carbon isotope ecology in my work, there are many other geochemical and morphological experiments possible with these specimens, and enormous room for growth. I hope that future experimenters work to collaborate with curators, so that these resources go to good use. As science, and in particular, sustainability science becomes more interdisciplinary (Porter & Rafols 2009; Nučič 2012), the collaboration between

collections facilities, biologists, geologists, ecologists and chemists will provide new perspectives on important role that plants play in shaping our Earth's climate; I look forward to future works utilizing the natural experiment of human-driven climate change, as recorded in preserved organisms.

6.4 References

Arens, N. C., Jahren, A. H., & Amundson, R. (2000). Can C_3 plants faithfully record the carbon isotopic composition of atmospheric carbon dioxide? *Paleobiology*, 137-164.

Aron, P. G., Poulsen, C. J., Fiorella, R. P., & Matheny, A. M. (2019). Stable Water Isotopes Reveal Effects of Intermediate Disturbance and Canopy Structure on Forest Water Cycling. *Journal of Geophysical Research: Biogeosciences*, *124*(10), 2958-2975.

Aron, P. G., Poulsen, C. J., Fiorella, R. P., Matheny, A. M., & Veverica, T. J. (2020). An isotopic approach to partition evapotranspiration in a mixed deciduous forest. *Ecohydrology*, *13*(6), e2229.

Belmecheri, S., Maxwell, R. S., Taylor, A. H., Davis, K. J., Freeman, K. H., & Munger, W. J. (2014). Tree-ring $\delta^{13}C$ tracks flux tower ecosystem productivity estimates in a NE temperate forest. *Environmental Research Letters*, *9*(7), 074011.

Bieker, V. C., & Martin, M. D. (2018). Implications and future prospects for evolutionary analyses of DNA in historical herbarium collections. *Botany Letters*, *165*(3-4), 409-418.

Borchert, R. (1996). Phenology and flowering periodicity of Neotropical dry forest species: evidence from herbarium collections. *Journal of Tropical Ecology*, 65-80.

Broadmeadow, M., Griffiths, H., Maxwell, C., & Borland, A. (1992). The carbon isotope ratio of plant organic material reflects temporal and spatial variations in CO_2 within tropical forest formations in Trinidad. *Oecologia, 89,* 435-441.

Buchmann, N., Guehl, J.-M., Barigah, T., & Ehleringer, J. R. (1997). Interseasonal comparison of CO_2 concentrations, isotopic composition, and carbon dynamics in an Amazonian rainforest (French Guiana). *Oecologia, 110,* 120-131.

Cerling, T. E., Solomon, D. K., Quade, J. A. Y., & Bowman, J. R. (1991). On the isotopic composition of carbon in soil carbon dioxide. *Geochimica et Cosmochimica Acta*, *55*(11), 3403-3405.

Cerling, T. E. (1992). Use of carbon isotopes in paleosols as an indicator of the $P(CO_2)$ of the paleoatmosphere. *Global Biogeochemical Cycles*, *6*(3), 307-314.

Cui, Y., & Schubert, B. A. (2017). Atmospheric pCO_2 reconstructed across five early Eocene global warming events. *Earth and Planetary Science Letters*, *478*, 225-233.

Diefendorf, A. F., Mueller, K. E., Wing, S. L., Koch, P. L., & Freeman, K. H. (2010). Global patterns in leaf 13C discrimination and implications for studies of past and future climate. *Proceedings of the National Academy of Sciences*, *107*(13), 5738-5743.

Dodd, M. B., & Lauenroth, W. K. (1997). The influence of soil texture on the soil water dynamics and vegetation structure of a shortgrass steppe ecosystem. *Plant Ecology*, *133*(1), 13-28.

Dore, S., Fry, D. L., & Stephens, S. L. (2014). Spatial heterogeneity of soil CO_2 efflux after harvest and prescribed fire in a California mixed conifer forest. *Forest Ecology and Management*, *319*, 150-160.

Ehleringer, J. R., & Dawson, T. E. (1992). Water uptake by plants: perspectives from stable isotope composition. *Plant, cell & environment*, *15*(9), 1073-1082.

Feeley, K. J., Bravo-Avila, C., Fadrique, B., Perez, T. M., & Zuleta, D. (2020). Climate-driven changes in the composition of New World plant communities. *Nature Climate Change*, 1-6.

Francey, R. J., Gifford, R. M., Sharkey, T. D., & Weir, B. (1985). Physiological influences on carbon isotope discrimination in huon pine (*Lagarostrobos franklinii*). *Oecologia*, *66*(2), 211-218.

Franks, P. J., Royer, D. L., Beerling, D. J., Van de Water, P. K., Cantrill, D. J., Barbour, M. M., & Berry, J. A. (2014). New constraints on atmospheric CO_2 concentration for the Phanerozoic. *Geophysical Research Letters*, *41*(13), 4685-4694.

Guan, B. T., Wright, W. E., Chung, C. H., & Chang, S. T. (2012). ENSO and PDO strongly influence Taiwan spruce height growth. *Forest ecology and management*, *267*, 50-57.

Holtum, J. & Winter, K. (2001). Are plants growing close to the floors of tropical forests exposed to markedly elevated concentrations of carbon dioxide? *Australian Journal of Botany,* 49, 629-636.

Houghton, J. T. (2001). Climate Change 2001: The Scientific Basis.

Ito, A. (2011). Decadal variability in the terrestrial carbon budget caused by the Pacific Decadal Oscillation and Atlantic Multidecadal Oscillation. *Journal of the Meteorological Society of Japan. Ser. II*, *89*(5), 441-454.

Joo, Y., Fragoso, V., Yon, F., Baldwin, I. T., & Kim, S. G. (2017). Circadian clock component, LHY, tells a plant when to respond photosynthetically to light in nature. *Journal of integrative plant biology*, *59*(8), 572-587.

Keeling, C. D., Bacastow, R. B., & Tans, P. P. (1980). Predicted shift in the $^{13}C/^{12}C$ ratio of atmospheric carbon dioxide. *Geophysical Research Letters*, *7*(7), 505-508.

Kohn, M. J. (2010). Carbon isotope compositions of terrestrial C3 plants as indicators of (paleo) ecology and (paleo) climate. *Proceedings of the National Academy of Sciences*, *107*(46), 19691-19695.

Körner, C., Farquhar, G. D., & Wong, S. C. (1991). Carbon isotope discrimination by plants follows latitudinal and altitudinal trends. *Oecologia*, *88*(1), 30-40.

Lang, P. L., Willems, F. M., Scheepens, J. F., Burbano, H. A., & Bossdorf, O. (2019). Using herbaria to study global environmental change. *New Phytologist*, *221*(1), 110-122.

Lawrence, D. M., Fisher, R. A., Koven, C. D., Oleson, K. W., Swenson, S. C., Bonan, G., ... & Kluzek, E. (2019). The Community Land Model version 5: Description of new features, benchmarking, and impact of forcing uncertainty. *Journal of Advances in Modeling Earth Systems*, *11*(12), 4245-4287.

Lloyd, J., Kruijt, B., Hollinger, D. Y., Grace, J., Francey, R. J., Wong, S.-C., Kelliher, F. M., Miranda, A. C., Farquhar, G. D., and Gash, J.: Vegetation effects on the isotopic composition of atmospheric CO_2 at local and regional scales: theoretical aspects and a comparison between rain forest in Amazonia and a boreal forest in Siberia. *Australian Journal of Plant Physiology, 23,* 371-399, 1996.

Loiselle, B. A., Jørgensen, P. M., Consiglio, T., Jiménez, I., Blake, J. G., Lohmann, L. G., & Montiel, O. M. (2008). Predicting species distributions from herbarium collections: does climate bias in collection sampling influence model outcomes?. *Journal of Biogeography*, *35*(1), 105-116.

Lomax, B. H., Lake, J. A., Leng, M. J., & Jardine, P. E. (2019). An experimental evaluation of the use of $\Delta^{13}C$ as a proxy for palaeoatmospheric CO_2. *Geochimica et Cosmochimica Acta*, *247*, 162-174.

Mårtensson, L. M., Carlsson, G., Prade, T., Kørup, K., Lærke, P. E., & Jensen, E. S. (2017). Water use efficiency and shoot biomass production under water limitation is negatively correlated to the discrimination against ^{13}C in the C_3 grasses *Dactylis glomerata, Festuca arundinacea* and *Phalaris arundinacea*. *Plant Physiology and Biochemistry*, *113*, 1-5.

Martens, B., Waegeman, W., Dorigo, W. A., Verhoest, N. E., & Miralles, D. G. (2018). Terrestrial evaporation response to modes of climate variability. *NPJ Climate and Atmospheric Science*, *1*(1), 1-7.

Munger, W. & Hadley, J. (2017). CO_2 profile at Harvard Forest HEM and LPH towers since 2009, Harvard Forest Data Archive: HF197, http://harvardforest.fas.harvard.edu:8080/exist/apps/datasets/showData.html?id=hf197.

Norby, R. J., & Zak, D. R. (2011). Ecological lessons from free-air CO_2 enrichment (FACE) experiments. *Annual review of ecology, evolution, and systematics*, *42*.

Novick, K. A., Biederman, J. A., Desai, A. R., Litvak, M. E., Moore, D. J., Scott, R. L., & Torn, M. S. (2018). The AmeriFlux network: A coalition of the willing. *Agricultural and Forest Meteorology*, *249*, 444-456.

Nučič, M. (2012). Is sustainability science becoming more interdisciplinary over time?. *Acta geographica Slovenica*, *52*(1), 215-236.

O'Leary, M. H. (1993). Biochemical basis of carbon isotope fractionation. In *Stable isotopes and plant carbon-water relations* (pp. 19-28). Academic Press.

Pachauri, R. K., & Reisinger, A. (2007). IPCC fourth assessment report. *IPCC, Geneva*, *2007*.

Pedicino, L. C., Leavitt, S. W., Betancourt, J. L., & Van de Water, P. K. (2002). Historical variations in $\delta^{13}C_{leaf}$ of herbarium specimens in the southwestern US. *Western North American Naturalist*, 348-359.

Porter, A. L., & Rafols, I. (2009). Measuring and mapping interdisciplinarity in six research fields over time (1975–2005). *Scientometrics*, *81*(3), 719-745.

PRISM Climate Group. (2004). Oregon State University. *PRISM Climate Data*.

Royer, T. C. (1979). On the effect of precipitation and runoff on coastal circulation in the Gulf of Alaska. *Journal of Physical Oceanography*, *9*(3), 555-563.

Schubert, B. A., & Jahren, A. H. (2012). The effect of atmospheric CO2 concentration on carbon isotope fractionation in C3 land plants. *Geochimica et Cosmochimica Acta*, *96*, 29-43.

Schmidt, M., Kreft, H., Thiombiano, A., & Zizka, G. (2005). Herbarium collections and field data-based plant diversity maps for Burkina Faso. *Diversity and Distributions*, *11*(6), 509-516.

Sheldon, N. D., Smith, S. Y., Stein, R., & Ng, M. (2020). Carbon isotope ecology of gymnosperms and implications for paleoclimatic and paleoecological studies. *Global and Planetary Change*, *184*, 103060.

Stein, R. A., Sheldon, N. D., & Smith, S. (2019). Rapid response to anthropogenic climate change by Thuja occidentalis: implications for past climate reconstructions and future climate predictions. *PeerJ*, *7*, e7378.

Stoyan, H., De-Polli, H., Böhm, S., Robertson, G. P., & Paul, E. A. (2000). Spatial heterogeneity of soil respiration and related properties at the plant scale. *Plant and soil*, *222*(1-2), 203-214.

Tan, P. Y., Wong, N. H., Tan, C. L., Jusuf, S. K., Schmiele, K., & Chiam, Z. Q. (2020). Transpiration and cooling potential of tropical urban trees from different native habitats. *Science of The Total Environment*, *705*, 135764.

Thompson, S. E., Harman, C. J., Konings, A. G., Sivapalan, M., Neal, A., & Troch, P. A. (2011). Comparative hydrology across AmeriFlux sites: The variable roles of climate, vegetation, and groundwater. *Water Resources Research*, *47*(10).

Tipple, B. J., Meyers, S. R., & Pagani, M. (2010). Carbon isotope ratio of Cenozoic CO_2: A comparative evaluation of available geochemical proxies. *Paleoceanography*, *25*(3), PA3202.Turner, M. G., Collins, S. L., Lugo, A. L., Magnuson, J. J., Rupp, T. S., & Swanson, F. J. (2003). Disturbance dynamics and ecological response: the contribution of long-term ecological research. *BioScience*, *53*(1), 46-56.

Twining, J., Stone, D., Tadros, C., Henderson-Sellers, A., & Williams, A. (2006). Moisture Isotopes in the Biosphere and Atmosphere (MIBA) in Australia: A priori estimates and preliminary observations of stable water isotopes in soil, plant and vapour for the Tumbarumba Field Campaign. *Global and Planetary Change*, *51*(1-2), 59-72.

United States Department of Agriculture (unknown). *Soil pH* [Brochure]. Retrieved from: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053293.pdf.

Wehrli, B. (2013). Biogeochemistry: Conduits of the carbon cycle. *Nature*, *503*(7476), 346-347.

Wernerehl, R. W., & Givnish, T. J. (2015). Relative roles of soil moisture, nutrient supply, depth, and mechanical impedance in determining composition and structure of Wisconsin prairies. *PloS one*, *10*(9), e0137963.

White J. W. C., Vaughn B. H., Michel S. E. (2015). University of Colorado, Institute of Arctic and Alpine Research (INSTAAR), stable isotopic composition of atmospheric carbon dioxide (13C and 18O) from the NOAA ESRL carbon cycle cooperative global air sampling network, 1990–2014. Version 2015-10-26 software.

Woodward, F. I. (1987). Stomatal numbers are sensitive to increases in CO_2 from pre-industrial levels. *Nature*, *327*(6123), 617-618.

Woodward, F. I., & Bazzaz, F. A. (1988). The responses of stomatal density to CO_2 partial pressure. *Journal of Experimental Botany*, *39*(12), 1771-1781.

Xiao, J., Zhuang, Q., Law, B. E., Chen, J., Baldocchi, D. D., Cook, D. R., Oren, R., Richardson, A. D., Wharton, S., Ma, S. & Martin, T. A. (2010). A continuous measure of gross primary production for the conterminous United States derived from MODIS and AmeriFlux data. *Remote sensing of environment*, *114*(3), 576-591.

Zhang, C., Wang, Y., Jia, X., & An, Z. (2020). Variations in capacity and storage of plant-available water in deep profiles along a revegetation and precipitation gradient. *Journal of Hydrology*, *581*, 124401.

Zhu, J., Poulsen, C. J., & Tierney, J. E. (2019). Simulation of Eocene extreme warmth and high climate sensitivity through cloud feedbacks. *Science advances*, *5*(9), eaax1874.

APPENDIX A

Supplemental Figures and Tables for Chapter II

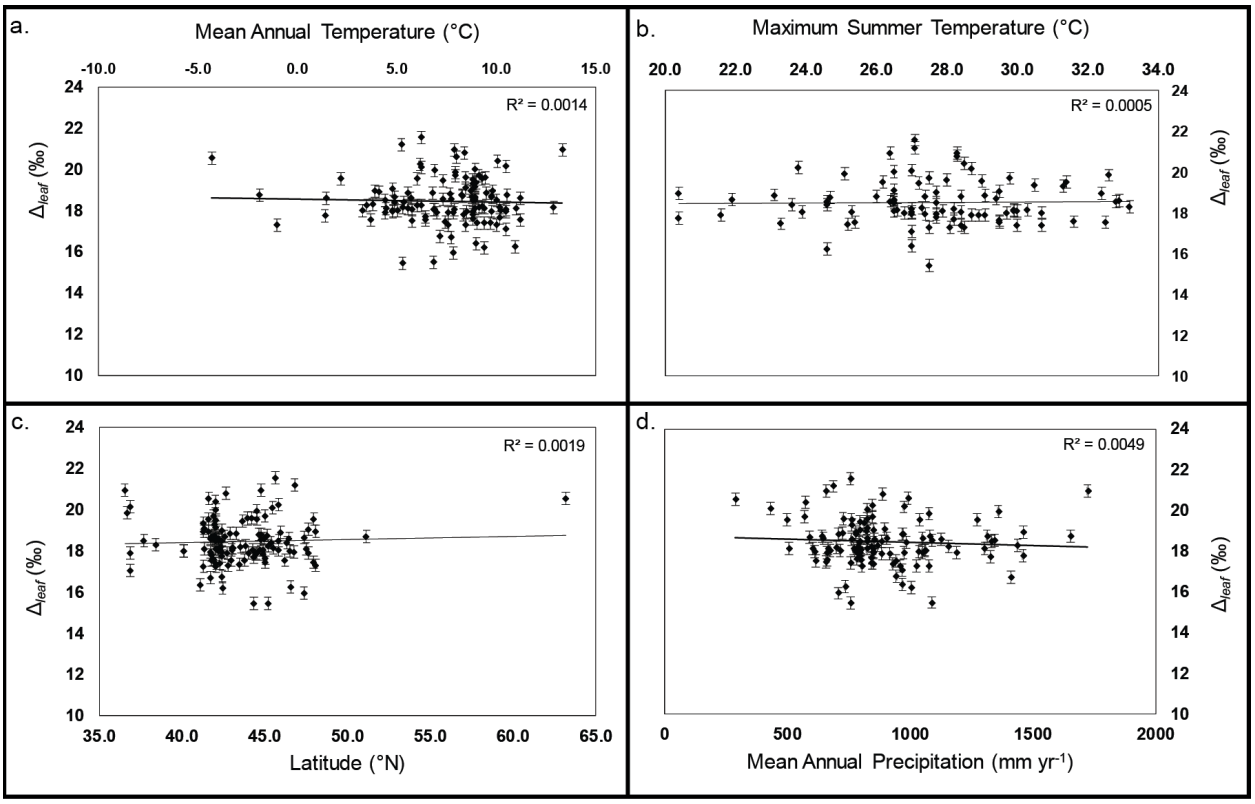

Figure A1 a) Δ_{leaf} values vs. mean annual temperature (−5 to 14°C) for collected specimens (R^2 = 0.0001). b) Δ_{leaf} values vs. maximum summer (growing season) temperature (20 to 33°C) for collected specimens (R^2 = 0.0005). c) Δ_{leaf} values vs. latitude (43 to 63°N) for collected specimens (R^2 = 0.0002). d) Δleaf values vs. mean annual precipitation (288 to 1724 mm yr^{-1}) for collected specimens (R^2 = 0.0005).

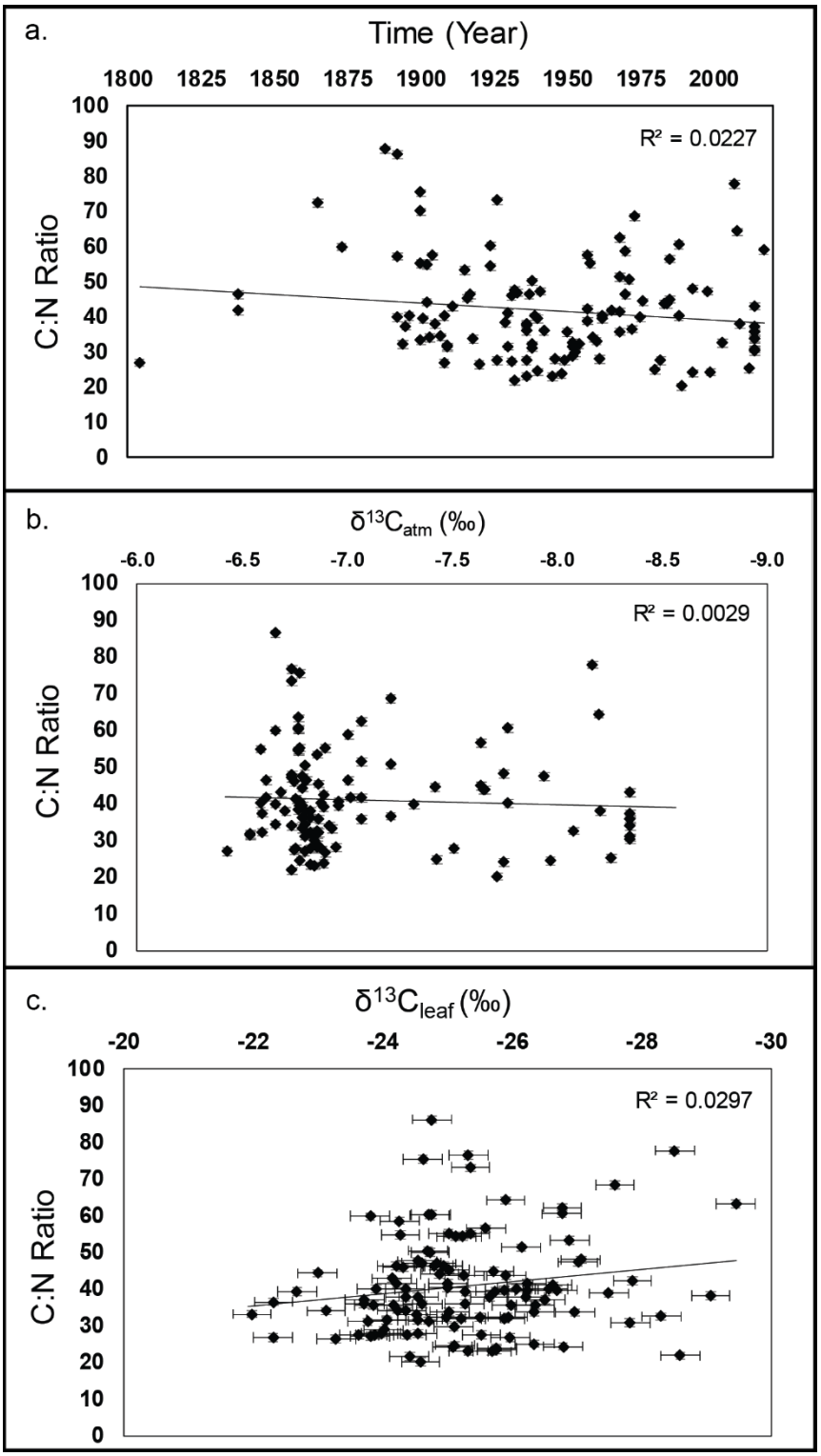

Figure A2 C:N ratios determined by wt. %C and wt. %N measured on a Costech Elemental Analyzer compared to a) time collected (year), b) $\delta^{13}C_{atm}$ values (‰), c) $\delta^{13}C_{leaf}$ values (‰). Error bars on the y-axis are associated with the 0.9% replicate reproducibility of standards. Error bars on the x-axis in c) are associated with the 0.3‰ replicate reproducibility of the Picarro CRDS standards.

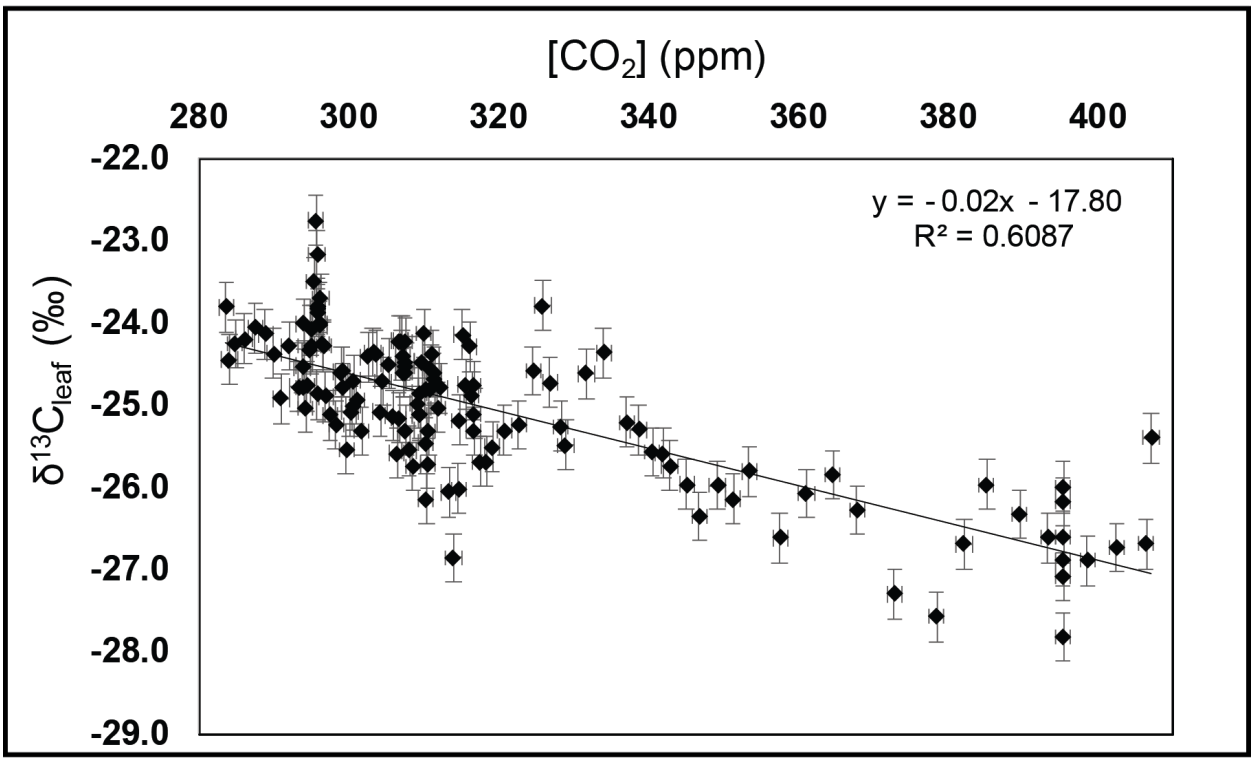

Figure A3 Linear regression between $\delta^{13}C_{leaf}$ values (‰) and [CO_2] (283 to 407 ppm) for collected specimens ($R^2 = 0.61$). Error bars along the y-axis represent the ±0.3‰ replicate reproducibility of standards.

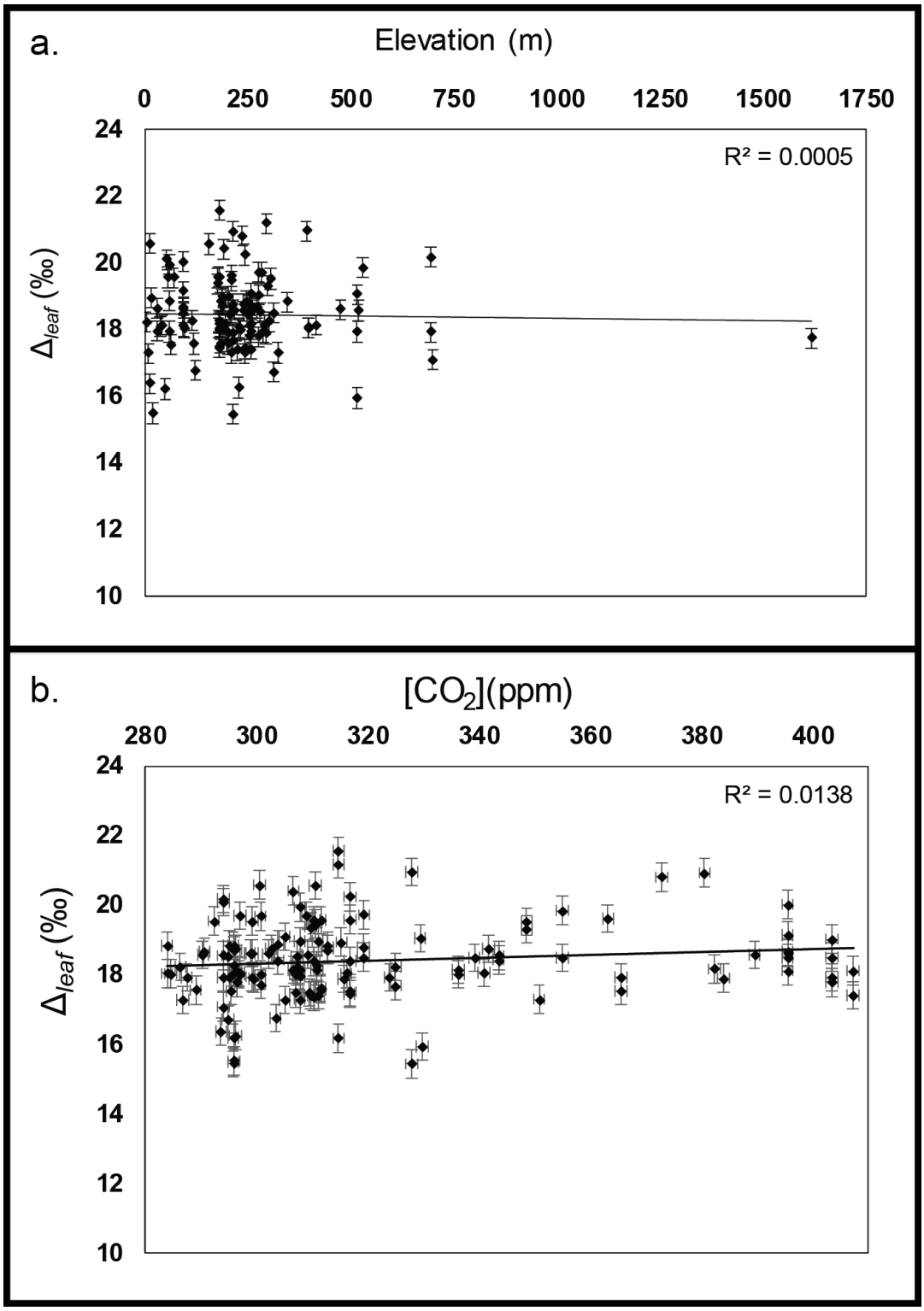

Figure A4 Linear regressions between Δ_{leaf} values and barometric measures. (a) Δ_{leaf} values versus elevation (4 to 1617 m above sea level). Error bars along the y-axis represent the ±0.3‰ replicate reproducibility of standards b) Δ_{leaf} and pCO_2 (283 to 407 ppm) for collected specimens (R^2 = 0.01). Error bars along the y-axis represent the ±0.3‰ replicate reproducibility of standards.

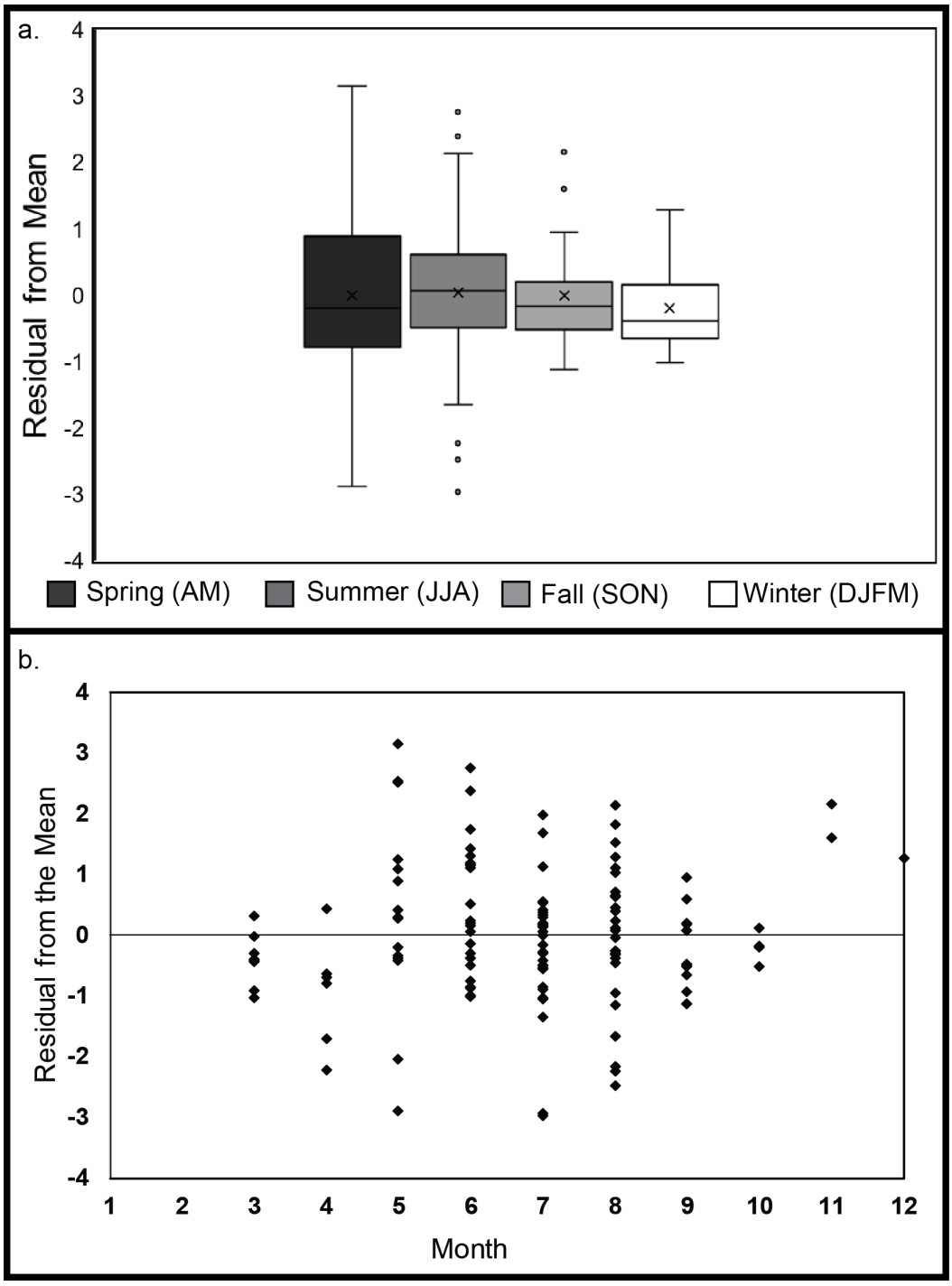

Figure A5 Box and whisker plots for Δ_{leaf} values of sampled months and seasons. a) Box and Whisker plot showing median (lines), mean and range of spring, summer, fall and winter residual values of $\delta^{13}C_{leaf}$. T-tests assuming unequal variance comparing Spring vs. Summer, Fall, Winter, Summer vs. Fall, Winter, and Fall vs. Winter could not prove a null hypothesis; that the mean for all seasonal collections was significantly different. Seasons were categorized by mean monthly temperatures <°2C, from 2–15°C and rising, >15°C, and between

2–15°C and falling in the Great Lakes Region (centralized lower Peninsula Michigan), b) Scatter plot including residual from mean $\delta^{13}C_{leaf}$ values as divided by month.

Table A1 Distribution of herbarium and botanical garden specimen data.

# Specimens	Collection Location	Herbarium Code	Location
70	University of Michigan Herbarium	MICH	Ann Arbor, Mich.
29	Field Museum of Natural History	F	Chicago, Ill.
22	Yale University Peabody Museum	Y	New Haven, Conn.
9	Michigan State Herbarium	MSC	East Lansing, Mich.
8	Hidden Lakes Garden	HLG	Tipton, Mich.
3	Modern Sampling	n/a	MI & OH, see supporting table S3
1	Shanghai Botanical Garden	S	Shanghai, China

Table A2 The range and mean values for measured climate variables in this study. The minimum, maximum, and mean values for climate conditions for each specimen as obtained from NOAA ESRL Global Monitoring Division (2016), White et al. 2015, and PRISM Climate Group, as well as Government of Canada (Ed.). (2018, January 11).

	Minimum	Mean	Maximum
Latitude	36.5	43.5	63.2
$[CO_2]$ (ppm)	283	323	407
$\delta^{13}C_{atm}$ (‰)	-8.7	-7.1	-6.4
$\delta^{13}C_{leaf}$ (‰)	-28.5	-25.0	-21.9
MAP (mm yr^{-1})	288	894	1724
MAT (°C)	-4.3	7.5	13.3
Max T (°C)	20.4	27.7	33.2
Elevation (m)	4	237	1617

Table A3 All collected data.*Direct Mauna Loa measurements (NOAA ESRL Global Monitoring Division (2016) **White et al. (2015)) and Petit et al. (2001) ice core records. ***: for United States Climate Data: PRISM Climate Group Oregon State University. (2017). Data Explorer: Time Series Values for Individual Locations. Retrieved from Northwest Alliance for Computational Science & Engineering database. For Canadian Climate Data: Government of Canada (Ed.). (2018, January 11). All specimens used for isotope analysis are stored in the University of Michigan's Earth Systems Laboratory (Dr. Nathan Sheldon & Dr. Ingrid Hendy) within the University of Michigan Earth and Environmental Science Department.

Supporting Information Table S3: All collected data.*Direct Mauna Loa measurements (NOAA ESRL Global Monitoring Division (2016) **White et al. (2015)) and Petit et al. (2001) ice core records. ***: for United States Climate Data: PRISM Climate Group Oregon State University. (2017). Data Explorer: Time Series Values for Individual Locations. Retrieved from Northwest Alliance for Computational Science & Engineering database. For Canadian Climate Data: Government of Canada (Ed.). (2018, January 11). *All specimens used for isotope analysis are stored in the University of Michigan's Earth Systems Laboratory (Dr. Nathan Sheldon & Dr. Ingrid Hendy) within the University of Michigan Earth and Environmental Science Department.*

RAS ID #	Year	Collector	Original tree location	Source	Accession #	Date collected	$[CO_2]$(ppm) *,**	$\delta 13C_{atm}$ (‰)*,**	Latitude (°N)	Longitude (°W)	MAP (mm yr^{-1}) ***	MAT (°C) ***	Mean Max T (°C) ***	Elevation (m)	%N	%C	C:N (molar)	C:N (weight %)	$\delta^{13}C_{leaf}$ (‰)	Δleaf (‰, calculated using Feng et al. 1999)
18	2014	C. Mervenne	Hidden Lakes Garden	HLG	18	8/25/2014	395.43	-8.35	42.03	-84.11	823.7	8.9	26.5	95	1.43	48.05	39.1	33.7	-26.97	19.14
19	2014	C. Mervenne	Hidden Lakes Garden	HLG	19	8/25/2014	395.43	-8.35	42.03	-84.11	823.7	8.9	26.5	95	1.36	50.59	43.3	37.1	-26.51	18.66
20	2014	C. Mervenne	Hidden Lakes Garden	HLG	20	9/5/2014	395.43	-8.35	42.03	-84.11	823.7	8.9	26.5	95	1.42	48.10	39.5	33.9	-26.34	18.48
64	2014	C. Mervenne	Hidden Lakes Garden	HLG	64	11/1/2014	395.43	-8.35	42.03	-84.11	823.7	8.9	26.5	95	1.66	50.95	35.9	30.8	-27.82	20.03
118	2014	C. Mervenne	Hidden Lakes Garden	HLG	118	9/24/2014	395.43	-8.35	42.03	-84.11	823.7	8.9	26.5		1.65	49.93	35.2	30.2	n/a	n/a
141	2014	C. Mervenne	Hidden Lakes Garden	HLG	141	8/25/2014	395.43	-8.35	42.03	-84.11	823.7	8.9	26.5		1.16	49.87	50.1	43.0	n/a	n/a
163	2014	C. Mervenne	Hidden Lakes Garden	HLG	163	8/25/2014	395.43	-8.35	42.03	-84.11	823.7	8.9	26.5	95	1.39	49.17	41.4	35.5	-25.99	18.11
164	2014	C. Mervenne	Hidden Lakes Garden	HLG	164	8/25/2014	395.43	-8.35	42.03	-84.11	823.7	8.9	26.5	95	1.39	49.71	41.6	35.7	-26.36	18.50
171	1838	Samples, John	Champaign County, Urbana, Ohio	MICH	S.N	3/24/1838	284.60	-6.62	40.11	-83.75	1059.9	10.5	30.7	98	1.05	48.61	54.0	46.3	-24.22	18.03
172	1892	S. R. and D. R. Camp	Topinabee, Michigan	MICH	#576	7/21/1892	294.00	-6.66	45.48	-84.59	432.5	6.3	27.0	55	1.27	50.54	46.4	39.8	-26.24	20.10
173	1894	Mrs. James Buchanan	Lowell, Kent County, Michigan	MICH	#51233	4/03/1894	295.10	-6.60	42.94	-85.35	972.0	9.5	29.1	60	1.59	51.13	37.5	32.2	-24.99	18.86
174	1895	Pyle, Livingston, Shaddick, Skeels	Grand Rapids, Michigan	MICH	#42440	7/21/1895	295.50	-6.60	42.96	-85.66	616.0	6.4	29.5	64	1.49	55.54	43.5	37.3	-23.72	17.54
175	1907	Frank C Gates	Mt. Hope Cemetery, Urbana, Illinois	MICH	#1313	3/23/1907	300.70	-6.66	40.10	-88.23	1036.0	10.2	29.7	231	1.54	52.79	40.0	34.3	-24.22	18.00
176	1908	Bartlett	Mt. Madison, New Hampshire	MICH	#1257	4/24/1908	300.70	-6.59	44.33	-71.28	1327.7	1.4	20.4	1617	1.26	50.48	46.7	40.1	-23.90	17.73
177	1916	E M Umbach	Portage, Michigan	MICH	#8299	7/31/1916	298.80	-6.87	42.23	-85.58	904.5	8.8	32.9	260	1.18	53.46	52.8	45.3	-25.03	18.63
178	1924	Erlanson	Petoskey, Michigan	MICH	#426	7/18/1924	303.90	-6.77	45.37	-84.97	792.0	5.3	23.6	207	0.86	51.84	70.3	60.3	-24.75	18.44
179	1924	Erlanson	Scotty Bay, Clark Township, Mackinac County, Michigan	MICH	#680	8/30/1924	303.90	-6.77	45.98	-84.19	723.9	4.1	23.1	187	0.96	52.06	63.2	54.2	-25.13	18.84
180	1926	Lyon Jr.	Mineral Springs, Indiana	MICH	MICH# 1491323	8/18/1926	305.00	-6.74	41.33	-85.74	896.1	8.4	29.5	258	0.72	52.63	85.2	73.1	-25.36	19.10
181	1929	Unknown	Gulliver Lake, Doyle Township, Michigan	MICH	S.N.	8/24/1929	306.20	-6.77	45.99	-86.03	781.6	3.9	23.2		1.29	49.20	44.5	38.1	n/a	n/a
182	1930	Marcus W Lyon, Jr.	Stevensville, Michigan	MICH	MICH# 1244469	7/17/1930	306.60	-6.76	42.01	-86.52	574.3	10.1	28.5	183	1.24	50.93	47.9	41.1	-26.63	20.41
183	1931	Grassl	Chiene Island, Algoma, Ontario	MICH	MICH# 1491259	7/4/1931	307.00	-6.75	46.50	-84.55	852.0	4.8		183	1.16	53.09	53.4	45.8	-24.31	18.00
184	1931	Carl O. Grassl	Siskiwat Bay Isle Royale, Michigan	MICH	#1161	8/25/1931	307.00	-6.75	47.95	-88.76	656.6	5.8	23.3	183	1.85	50.42	31.8	27.3	-23.81	17.48

185	1932	Sister M. Vincent de Paul McGivney	Harbor Beach, Michigan	MICH	MICH# 1247725	10/1/1932	307.30	-6.74	43.84	-82.65	787.4	3.5	27.3	181	1.15	54.76	55.5	47.6	-24.54	18.25
186	1933	Carl O Grassl	Michigan	MICH	#3062	10/1/1932	307.30	-6.74	n/a	n/a	n/a	n/a	n/a	n/a	1.05	49.22	54.7	46.9	-24.83	18.55
187	1936	Cormack & Baldwin	Ontario	MICH	MICH# 1491290	8/4/1936	307.70	-6.83	n/a	n/a	n/a	n/a	n/a	n/a	1.22	46.35	44.3	38.0	-24.55	18.17
188	1936	Grassl	Pardee Township, Ontario	MICH	#7585	9/16/1936	307.70	-6.83	48.08	-89.63	1025.0	-1.0		323	1.39	49.97	41.9	35.9	-23.72	17.30
189	1937	P J Hermann	Michigan	MICH	#9256	9/13/1937	309.20	-6.81	n/a	n/a	n/a	n/a	n/a	n/a	1.11	51.24	53.8	46.2	-24.94	18.60
190	1938	Chester C Cook	Belgium, Wisconsin	MICH	MICH# 1491303	7/27/1938	310.30	-6.80	43.50	-87.85	928.1	9.1	28.4	224	1.67	51.87	36.2	31.1	-23.77	17.38
191	1938	Chester C Cook	Wisconsin	MICH	#C-142	8/16/1938	310.30	-6.80	n/a	n/a	n/a	n/a	n/a	n/a	0.98	49.07	58.4	50.1	-24.74	18.39
192	1939	Harold Neumann	Menominee Indian Reservation, Keshena, Wisconsin	MICH	#C-1525	12/14/1939	309.00	-6.88	45.00	-88.67	568.7	9.1	29.8	284	1.28	51.38	46.8	40.1	-26.07	19.70
193	1940	Cook	Wilson, Wisconsin	MICH	#K-162	8/12/1940	310.50	-6.78	43.68	-87.77	795.0	7.3	27.2	210	1.29	50.91	46.0	39.5	-25.74	19.47
194	1941	M N Zinck	Goulbourn Township, Ottawa	MICH	MICH# 1491265	7/3/1941	310.80	-6.79	45.24	-75.90	868.0	6.0		115	1.07	50.47	55.0	47.2	-24.60	18.26
195	1942	Harold and Virginia Bailey	Mott Island, Isle Royale National Park	MICH	#4306	7/16/1942	311.00	-6.79	48.09	-88.58	777.2	3.9	20.4	190	1.39	49.94	41.9	35.9	-25.27	18.96
196	1946	H H Bartlett	Waterloo, Jackson County, Michigan	MICH	#21453	7/13/1946	310.80	-6.86	42.18	-84.35	668.0	10.2	29.9	293	1.79	49.90	32.5	27.9	-24.54	18.13
197	1948	Chase	Starved Rock State Park, Illinois	MICH	#I0I67	9/19/1948	309.70	-6.89	41.32	-88.99	812.3	9.0	30.5	176	2.05	48.28	27.5	23.6	-25.76	19.37
198	1950	Yves Desmarais	Quebec	MICH	#1029	7/28/1950	311.20	-6.87							1.46	51.94	41.5	35.6	-23.86	17.41
199	1952	Virginius H Chase	Pentwater, Michigan	MICH	#12669	6/28/1952	311.50	-6.86	43.78	-86.43	801.6	8.8	31.6	184	1.65	47.62	33.7	28.9	-24.02	17.58
200	1952	E G Voss	Hume Township, Michigan	MICH	#1201	6/28/1952	311.50	-6.86	43.98	-83.06	726.9	8.4	29.0	180	1.55	50.39	37.9	32.5	-25.94	19.58
201	1954	Jennie V A Dieterle	Traverse City Michigan	MICH	#1304	8/25/1954	312.80	-6.87	44.76	-85.62	778.0	7.7	26.0	185	1.50	48.07	37.4	32.0	-25.22	18.82
202	1957	E G Voss	Beaver Island, Michigan	MICH	#3872	5/25/1957	314.70	-6.89	45.65	-85.55	756.9	6.2	27.1	183	1.16	48.98	49.2	42.2	-27.86	21.57
203	1957	P A Hyypio	Limestone Mountain, Michigan	MICH	MICH# 1244477	6/13/1957	314.70	-6.89	46.81	-88.70	687.8	5.2	27.1	296	1.25	48.48	45.2	38.8	-27.49	21.18
204	1959	Heidenreich	Lake Simcoe, Ontario	MICH	MICH# 1491296	7/6/1959	315.70	-6.92	44.46	-79.34	885.0	4.4		295	1.40	47.58	39.6	34.0	-24.36	17.88
205	1960	Voss	Cadillac, Michigan	MICH	#9456	5/15/1960	316.10	-6.93	44.25	-85.40	775.2	5.8	25.3	398	1.48	48.89	38.5	33.0	-24.53	18.04
206	1961	E. G. Voss	South Manitou Island, Leelanau County, Michigan	MICH	#9876	6/10/1961	316.70	-6.95	45.02	-86.13	757.2	7.4	25.2	182	1.74	48.65	32.6	28.0	-23.98	17.44
207	1962	Voss	Michigan	MICH	#10998	7/18/1962	319.20	-6.96	n/a	n/a	n/a	n/a	n/a	n/a	1.26	49.46	45.8	39.3	-25.28	18.80
208	1962	A Walther, A Auclair	Otter Lake, Quebec	MICH	#1491269	9/23/1962	319.20	-6.96	45.85	-76.43	885.0	4.4	n/a	210	1.22	49.21	47.0	40.3	-25.01	18.51
209	1965	Brunekt	Michigan	MICH	#578	6/19/1965	319.30	-7.02	n/a	n/a	n/a	n/a	n/a	n/a	1.14	47.48	48.6	41.6	-26.23	19.73
210	1968	D. J. Hagenah	Michigan	MICH	#6720	6/2/1968	316.80	-7.07	n/a	n/a	n/a	n/a	n/a	n/a	0.88	45.18	59.9	51.3	-26.15	19.59
211	1968	T. Reznicek	Ontario	MICH	#134	3/13/1968	316.80	-7.07	n/a	n/a	n/a	n/a	n/a	n/a	1.37	48.84	41.6	35.6	-24.17	17.52
212	1968	Stuckey	Ohio	MICH	#6356	3/31/1968	316.80	-7.07	n/a	n/a	n/a	n/a	n/a	n/a	1.14	47.36	48.4	41.5	-25.01	18.40
213	1968	E. G. Voss	St. Helena Island, Moran, Michigan	MICH	#12816	8/31/1968	316.80	-7.07	45.86	-84.87	845.8	6.2	23.8	242	0.78	48.61	72.7	62.3	-26.78	20.25
214	1970	Merkle	Tom Creek, Clare County Michigan	MICH	#70-432	10/18/1970	325.00	-7.01	43.56	-85.00	843.8	6.2	28.2	302	1.06	49.00	53.9	46.2	-24.79	18.23
215	1970	Voss	Thunder Bay Island, Michigan	MICH	#13224	6/24/1970	325.00	-7.01	45.04	-83.20	843.8	6.4	28.2	215	0.82	48.08	68.4	58.6	-24.26	17.68
216	1971	C. E. Garton	Algoma District, Ontario	MICH	#14627	7/29/1971	323.90	-7.21	47.65	-84.80	852.0	4.8	n/a	516	0.96	48.46	58.9	50.5	-24.70	17.93

217	1972	E. G. Voss	Middle Island, Alpena County, Michigan	MICH	#13980	7/14/1972	327.90	-7.21	45.19	-83.33	759.0	5.3	27.5	215	1.36	49.69	42.6	36.5	-22.32	15.45
218	1973	R. Kral	Pickett State Park, Tennessee	MICH	#49852	5/5/1973	327.90	-7.21	36.55	-84.80	1723.4	13.3	28.3	392	0.68	46.52	79.8	68.4	-27.59	20.96
219	1975	J H Soper and L R Williams	Algoma District, Ontario	MICH	#149129	8/26/1975	329.39	-7.32	47.65	-84.80	852.0	4.8	n/a	516	1.24	49.18	46.3	39.7	-25.88	19.05
220	1976	J K Morton and Joan M Venn	Caribou Island, Lake Superior, Ontario	MICH	#NA 9782	8/29/1976	329.78	-7.42	47.36	-85.81	708.0	7.8	n/a	516	1.08	47.86	51.7	44.3	-23.00	15.94
221	1980	A A Reznicek, P M Catling	Ontario	MICH	#5486	5/25/1980	336.20	-7.43	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-24.99	18.01
222	1983	M J Schepanek, A Dugal	Minnehaha Lake, Ontario	MICH	#5469	8/13/1983	340.84	-7.66	45.84	-78.72	1061.5	6.8	n/a	396	1.16	50.59	50.9	43.6	-25.26	18.06
223	1985	B J Madsen	Shingleton Fed, Schoolcraft County, Michigan	MICH	#MH12 44511	7/21/1985	343.50	-7.64	46.35	-86.47	983.2	4.9	24.6	252	0.86	48.58	65.9	56.5	-25.59	18.42
224	1985	Brian T Hazlett	Otter Creek, Michigan	MICH	#3504	7/22/1985	343.50	-7.64	44.75	-86.06	1090.4	7.3	24.6		1.12	50.23	52.3	44.8	-25.72	18.56
225	1988	Robert W Smith	Rome Township, Michigan	MICH	#2418	5/4/1988	348.50	-7.77	41.95	-84.21	762.0	8.8	31.3	299	1.10	44.07	46.7	40.1	-26.57	19.31
226	1988	Robert W. Smith	Cambridge Township, Michigan	MICH	#2433	5/11/1988	348.50	-7.77	42.03	-84.21	760.5	8.8	31.4	305	0.89	53.84	70.6	60.5	-26.77	19.52
227	1989	W. W. Brodowicz	Byron, Kent Co., Michigan	MICH	#602	9/28/1989	350.80	-7.72	42.80	-85.71	802.6	7.6	28.1	211	1.56	31.40	23.5	20.1	-24.59	17.30
228	1993	Naczi, Reznicek & Wieboldt	Scott County, Virginia	MICH	#3169	6/21/1993	354.90	-7.75	36.68	-82.61	1078.0	7.9	32.6	530	1.02	48.95	56.0	48.0	-27.06	19.85
229	1993	Phyllis J Higman, Thomas D Trana	Michigan	MICH	#181	6/10/1993	354.90	-7.75							1.43	34.35	28.0	24.0	-25.76	18.49
230	1998	Timothy L Walters, John Guidinger	Norman Township, Michigan	MICH	#12444 46	6/3/1998	363.11	-7.94	44.21	-85.89	825.2	9.4	28.0	212	1.00	47.28	55.1	47.3	-27.02	19.61
231	2003	Abbie Gosselink	YMCA Camp Manitou-Lin on Lake Barlow, Grand Rapids	MICH	#84	6/9/2003	372.79	-8.08	42.67	-85.51	888.5	8.4	28.3	238	1.20	39.04	37.9	32.5	-28.30	20.81
232	2007	Timoth L Walters, Joel Schaeffer	Whitewater Township, Grand Traverse County, Michigan	MICH	#11883	5/16/2007	380.49	-8.17	44.77	-85.40	658.9	7.9	26.4	214	0.79	61.44	90.7	77.8	-28.51	20.94
233	2008	Thomas G Lammers	Menominee County, Escanaba River State Forest, Michigan	MICH	#12004	8/11/2008	382.31	-8.20	45.52	-87.40	700.8	5.3	26.6	182	0.90	57.79	74.9	64.2	-25.90	18.17
234	2009	David C Dister	Ludington State Park, Mason County, Michigan	MICH	#291	9/27/2009	383.84	-8.21	44.03	-86.51	917.2	7.0	21.6	204	0.81	30.56	44.0	37.7	-25.65	17.90
235	2012	Thomas G Lammers, Diane L Lammers	Kalamazoo County	MICH	#13782	6/27/2012	389.46	-8.26	42.23	-85.52	760.2	11.2	32.8	261	1.41	35.39	29.3	25.1	-26.35	18.58
296	1804		Castillo et Maldonado lectae, New Spain, Cuba	F		12/8/1804	283.40	-6.43	21.37	-77.85	1333.5	25.0		120	1.81	48.65	31.3	26.9	-22.31	16.24
297	1873	H H Babcock	Thousand Islands, Watersmeet Township, Michigan	F	FM#904 81	7/25/1873	289.10	-6.66	46.22	-89.40	662.5	3.7	25.4	520	0.85	50.87	69.8	59.8	-23.81	17.57
298	1892	Small		F	S.N.	7/23/1892	294.00	-6.66	n/a	n/a	n/a	n/a	n/a	n/a	0.55	47.40	100.5	86.2	-24.76	18.56
299	1896	M C Jensan	Lake Forest, Illinois	F	#56	3/10/1905	296.90	-6.78	42.25	-87.83	715.0	5.1	26.8	n/a	1.21	48.67	46.9	40.2	-24.35	18.01
300	1900	Lansing	Clarke, Indiana	F	#876	6/4/1900	295.90	-6.78	38.41	-84.71	1437.6	3.8	33.2	n/a	0.62	46.71	87.9	75.3	-24.62	18.29

301	1900	C Baenitz	Breslau, Wroclaw, Poland	F	S.N.	5/9/1900	295.90	-6.78	51.14	17.06	590.0	8.3	n/a	n/a	0.87	47.97	64.3	55.1	-25.02	18.71
302	1900	C Baenitz	Germany	F	S.N.	5/16/1900	295.90	-6.79	n/a	n/a	n/a	n/a	n/a	n/a	1.45	48.08	38.7	33.2	-21.98	15.54
303	1902	Chas. J. Brand	Bemidji, Minnesota	F	#679	6/1/1902	296.40	-6.59	47.48	-94.88	603.8	4.4	27.9	417	0.88	48.18	63.8	54.8	-24.27	18.12
304	1908	Smith	Missouri	F	#623	5/25/1908	300.70	-6.80							1.87	50.15	31.3	26.8	-25.97	19.68
305	1918	C F Millspaugh	Ephraim, Wisconsin	F	#4244	7/12/1918	302.60	-6.74	45.15	-87.17	1079.5	-1.9	24.7	213	1.44	48.56	39.3	33.7	-25.03	18.76
306	1926	J Francis Macbride	Trout Park, Elgin, Illinois	F	#703b	8/30/1926	305.00	-6.76	42.06	-88.27	959.9	8.4	28.5	242	1.80	49.58	32.1	27.5	-23.64	17.29
307	1930	F J Hermann	Lebanon Township, Michigan	F	#2315	7/19/1930	306.60	-6.83	43.07	-84.75	506.5	9.1	29.9	196	1.66	52.38	36.8	31.6	-24.54	18.16
308	1936	Tryon, Jr.	Mineral Springs, Porter County, Indiana	F	#3088	7/2/1936	307.70	-6.83	41.63	-87.08	820.7	9.8	32.4	205	2.09	48.22	26.9	23.1	-25.32	18.97
309	1936	Olga Lakela	Duluth, Minnesota	F	#1701	8/12/1936	307.70	-6.83	46.76	-92.13	611.9	3.3	27.0	196	1.75	48.25	32.2	27.6	-24.37	17.98
310	1936	Ray C Fiesner	Waldo County, Maine	F	#10162	8/22/1936	307.70	-6.80	44.51	-69.02	1358.9	6.9	25.1	61	1.29	48.60	43.9	37.7	-26.22	19.95
311	1938	Auray Blain	Sainte-Irene, canton Nemtaye, Matapedia Quebec	F	#185	7/17/1938	310.30	-6.83	47.97	-66.95	1038.0	2.2	n/a	57	1.49	47.67	37.3	32.0	-25.89	19.57
312	1940	Marie-Victorin, Boivin, Raymond, Kucyniak	Riviere la Martre, Fort Smith, Northwest Territories	F	#3825	8/18/1940	310.50	-6.78	63.17	-116.81	288.6	-4.3	n/a	157	1.93	46.99	28.4	24.3	-26.79	20.56
313	1944	Benke	Wisconsin	F	#6364	9/14/1944	309.50	-6.84	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-23.92	17.49
314	1945		Par Valle Teguci, Tegucigalpa, Honduras	F		12/27/1945	309.50	-6.85	14.08	-87.20	1002.0	22.3	n/a	n/a	2.09	48.06	26.8	23.0	-25.69	19.34
315	1949	Julian A Steyermark	Trout Park, Elgin, Illinois	F	#68345	6/29/1949	309.70	-6.88	42.06	-88.27	843.5	9.7	30.7	242	1.76	48.37	32.1	27.5	-23.88	17.41
316	1952	Floyd A Swink	Warren Dunes State Park, Sawyer, Michigan	F	#838	4/26/1952	311.50	-6.86	41.92	-86.59	783.3	10.2	29.5	199	1.61	50.72	36.7	31.5	-24.06	17.63
317	1953	Swink	Kenosha County, Wisconsin	F	#2310	7/26/1953	312.70	-6.85	42.57	-87.84	640.8	9.8	29.4	190	1.61	48.00	34.8	29.8	-25.10	18.72
318	1980	M Nee	Jefferson County, Missouri	F	#19081	7/21/1980	336.20	-7.43	43.03	-88.80	768.6	12.9	30.3	257	1.98	49.03	28.9	24.8	-25.12	18.14
319	1999	Hess, Leidner, Allen, Stoynoff, Bolger	Waldo County, Maine	F	#8818	7/15/1999	365.48	-7.97	44.51	-69.02	1189.2	8.5	27.4	61	n/a	n/a	n/a	n/a	-25.45	17.93
320	1999	Hess, Leidner, Allen, Stoynoff, Bolger	Lisle, IL	F	unk	6/21/1999	365.48	-7.97	41.80	-88.08	943.9	11.2	32.5	204	2.02	49.05	28.3	24.3	-25.08	17.55
321	No date	Unknown	San Jose, Costa Rica	F	S.N.	No date	Unknown	Unknown	9.93	-84.12	1901.0	20.4	n/a	n/a	1.28	51.01	46.5	39.9	-26.70	n/a
322	No date	Unknown	Tres Rios, Costa Rica	F	S.N.	No date	Unknown	Unknown	9.91	-83.98	2031.0	19.2	n/a	n/a	1.50	48.41	37.6	32.3	-25.51	n/a
323	No date	Unknown	Pacayas, Costa Rica	F	S.N.	No date	Unknown	Unknown	9.91	-83.81	3002.0	19.2	n/a	n/a	2.17	47.55	25.6	21.9	-28.50	n/a
324	No date	Unknown	Volcan Irazu, Costa Rica	F	S.N.	No date	Unknown	Unknown	9.98	-83.35	3422.9	16.3	17.2	n/a	1.36	48.78	41.8	35.9	-24.61	n/a
347	1857	Unknown	New Haven, CT	Y	#6B	1857	286.70	-6.53	41.31	-72.92	1078.0	10.0	27.5	10	n/a	n/a	n/a	n/a	-23.41	n/a
348	1879	George H. Leland	Newport, VT	Y	YU#025 477	July 1879	290.30	-6.42	44.94	-72.20	853.3	5.7	26.4	217	n/a	n/a	n/a	n/a	-24.55	18.59
349	1887	J H Schuette	Brown County, Wisconsin	Y	#282	8/2/1887	292.30	-6.42	44.53	-87.99	499.3	6.0	26.2	178	n/a	n/a	n/a	n/a	-25.47	19.54
350	1891	Anna E Carpenter	Norwalk, Connecticut	Y	#652	5/17/1891	293.60	-6.61	41.12	-73.42	968.9	9.0	27.0	13	n/a	n/a	n/a	n/a	-22.62	16.38
351	1892	John K Small	Mouth of Hungry's Mother Creek, Smyth County, W. Virginia	Y	YU#025 487	7/4/1892	294.00	-6.66	36.89	-81.52	968.0	10.5	27.0	699	n/a	n/a	n/a	n/a	-23.34	17.08

352	1899	Emile F Williams	Middlesex Fells Reservation, Massachusetts	Y	#2270	4/9/1899	295.80	-6.77	42.46	-71.09	1005.3	9.4	n/a	51	n/a	n/a	n/a	n/a	-22.61	16.21
353	1899	Emile F Williams	Mt. Desert, Maine	Y	#2269	7/18/1899	295.80	-6.77	44.35	-68.34	1087.6	6.8	n/a	21	n/a	n/a	n/a	n/a	-21.92	15.48
354	1901	Nellie E Flynn	Burlington, Connecticut	Y	S.N.	5/17/1901	296.20	-6.79	41.77	-72.95	1652.8	8.3	n/a	254	n/a	n/a	n/a	n/a	-25.05	18.73
355	1902	Nellie E Flynn	Burlington, Connecticut	Y	YU#025491	4/25/1902	296.40	-6.79	41.77	-72.95	1459.5	8.3	n/a	254	n/a	n/a	n/a	n/a	-24.15	17.79
356	1902	C K Averill	Canaan, Connecticut	Y	#417	8/31/1902	294.80	-6.79	41.97	-73.31	1343.7	7.7	n/a	239	1.10	48.56	51.5	44.1	-24.88	18.55
357	1903	E. H. Thompson	Litchfield, Connecticut	Y	YU#025457	4/25/1903	294.80	-6.80	41.74	-73.19	1410.0	7.7	n/a	313	1.36	46.33	39.7	34.1	-23.13	16.72
358	1905	O W Knight	Orono, Maine	Y	YU#025483	5/10/1905	296.90	-6.71	44.88	-68.69	798.9	5.6	n/a	38	1.20	45.48	44.2	37.9	-24.35	18.08
359	1909	H S Clark	Wethersfield, Connecticut	Y	CBS#02594	6/6/1909	299.20	-6.54	41.70	-72.67	1049.0	9.8	n/a	32	1.53	47.93	36.5	31.3	-24.71	18.63
360	1909	C H Bissell	Wethersfield, Connecticut	Y	YU#025498	9/11/1909	299.20	-6.54	41.70	-72.67	1049.0	9.8	n/a	32	1.53	48.38	36.9	31.6	-24.06	17.95
361	1909	E B Harger	New Milford, Connecticut	Y	#5565	6/17/1909	299.20	-6.54	41.60	-73.42	1272.8	9.3	n/a	70	n/a	n/a	n/a	n/a	-25.58	19.54
362	1915	H C Bigelow	Berlin, Connecticut	Y	#007	11/14/1915	300.50	-6.86	41.63	-72.75	990.9	8.0	n/a	14	0.91	48.47	62.1	53.3	-26.89	20.58
363	1917	Harold St. John and George E. Nichols	St. John Pond Township, Maine	Y	#2103	7/10/1917	302.10	-6.80	46.47	-69.90	1125.7	1.4	n/a	476	1.00	46.24	53.9	46.2	-24.94	18.60
364	1920	H Castle	Ithaca, New York	Y	#023489	1-Aug-20	303.40	-6.90	42.44	-76.50	944.1	7.2	n/a	124	1.77	46.68	30.8	26.4	-23.28	16.77
365	1932	K P Jansson	New London, Connecticut	Y	#13	5-Aug-32	307.30	-6.74	41.36	-72.10	1304.0	11.0	n/a	43	2.28	49.33	25.2	21.6	-24.42	18.12
366	1958	John Ebinger	New Haven, Connecticut	Y	#286	6/24/1958	315.20	-6.90	41.31	-72.93	1461.3	8.7	n/a	17	0.86	47.30	64.1	55.0	-25.36	18.94
367	1982	David B Taylor, Jerome Waller, Ellen Ballard, Cindy Schwind	Madison, Kentucky	Y	#1815	7/14/1982	339.15	-7.51	37.71	-84.27	1333.0	10.0	n/a	313	1.70	46.83	32.1	27.5	-25.53	18.49
368	1984	Leslie J Merhhoff	Canaan, Connecticut	Y	#9536	3/16/1984	341.70	-7.65	41.97	-73.31	1313.2	10.6	n/a	239	1.07	46.65	50.8	43.6	-25.91	18.75
399	1830	Douglass Houghton	Trenton Falls, New York	MICH	MICH #1491325	July 1830	283.90	-6.53	43.26	-75.19	968.3	6.8	27.4	247	n/a	n/a	n/a	n/a	-24.90	18.84
401	1901	Bronson Barlow	Marquette County, Michigan	MICH	MICH #1491320	23-Aug-01	296.20	-6.79	46.55	-87.42	735.3	10.9	24.6	228	1.28	50.34	45.9	39.3	-22.68	16.26
402	1911	H E Sargent	Torch Lake, Antrim County Michigan	MICH	MICH #1244466	15-Jul-11	299.50	-6.69	44.92	-85.28	788.2	7.8	28.9	214	1.11	47.54	49.9	42.8	-24.14	17.88
403	1838	John Wright & George H Bull	St. Clair River, Lake Huron, Michigan	MICH	#42	June 4, 1838	283.90	-6.62	43.01	-82.42	675.7	6.9	27.0	180	1.13	46.99	48.5	41.6	-24.22	18.04
404	1957	Voss		MICH	S.N.	8/20/1957	314.70	-6.89							0.85	48.95	67.2	57.6	-22.71	16.18
407	2017	R. Stein	Ann Arbor, MI, 4th Ave	Ann Arbor	407	3/9/2017	407.18	-8.57	42.28	-83.75	848.7	9.4	30.0	258	0.77	45.31	68.6	58.8	-25.53	17.40
408	2017	R. Stein	Ann Arbor, MI, 4th Ave	Ann Arbor	408	3/9/2017	407.18	-8.57	42.28	-83.75	848.7	9.4	30.0	256	0.66	46.26	81.7	70.1	-26.22	18.12
409	1843	Cooley	Michigan	MSC	#19-15	1843	287.40	-6.54							0.37	49.87	157.2	134.8	-24.04	17.94
410	1865	Beal	Cambridge, Massachusetts	MSC	S.N.	5/24/1865	286.30	-6.54	42.37	-71.12	1156.9	9.3	27.0	4	0.69	49.95	84.4	72.4	-24.32	18.22
411	1888	AA Farwell	Keweenaw Co. Michigan	MSC	S.N.	June 1888	290.63	-6.55	47.39	-88.03	646.9	4.9	21.9	274	0.56	49.03	102.1	87.6	-24.75	18.66
412	1892	John K Small	Hungry's Mother Creek, Four Miles North of Marion Smyth County	MSC	S.N.	6/1/1892	294.00	-6.43	36.89	-81.52	973.7	10.5	28.7	694	0.80	45.75	66.7	57.2	-23.93	17.93
413	1892	John K Small	Smyth County, Virginia	MSC	S.N.	6/8/1892	294.00	-6.66	36.89	-81.52	973.7	10.5	28.7	694	0.31	44.92	169.0	144.9	-26.31	20.18
414	1894	H. C. Skeels	Agricultural College, MSC, East Lansing, Michigan	MSC	S.N.	10/7/1894	295.10	-6.66	42.75	-84.49	660.1	7.6	29.1	260	0.51	49.86	114.0	97.8	-24.15	17.92

415	1899	Unknown	Grayling, Crawford County, Michigan	MSC	S.N.	5/27/1899	295.80	-6.60	44.66	-84.71	707.9	5.6	28.4	347	0.20	45.26	263.9	226.3	-24.96	18.83
416	1900	CFW	Crystal Lake, Montcalm County, Michigan	MSC	#141922	6/25/1900	295.90	-6.77	44.69	-86.17	796.0	7.9	28.4	229	0.67	46.87	81.6	70.0	-24.38	18.05
417	1904	Pepoon	Cass County, Michigan	MSC	#75	Aug-04	297.00	-6.78	41.93	-85.99	846.3	7.9	27.5	277	0.77	44.11	66.8	57.3	-25.98	19.71
423	2017	R. Stein	3650 Kensington Road, Cleveland Ohio	Cleveland	423	3/26/2017	407.18	-8.57	41.50	-81.57	1123.7	10.3	29.3	281	0.63	45.88	84.9	72.8	-24.44	16.27
611	2017	R. Stein	Shanghai Botanical Garden	SG	611	7/14/2017	405.13	-8.50	31.15	121.43	1176.9	16.0	27.9	6	n/a	n/a	n/a	n/a	-28.31	20.39

APPENDIX B

Supplemental Figures, Tables and References for Chapter III

Figure B1 [CO_2] values plotted against $\Delta^{13}C_{plant}$ for species with medium-resolution records of the period of Industrialization. Data are for: (a) *Pinus strobus* (Eastern white pine), (b) *Thuja sutchuenensis* (Sichuan arborvitae), (c) *Thuja koraiensis* (Korean arborvitae), (d) *Thuja standishii* (Japanese arborvitae), and (e) *Platycladus orientalis* (Chinese arborvitae). The outer panel shows change in $\Delta^{13}C_{plant}$ vs. [CO_2] over Industrialization, while the inner panel shows the range and distribution of $\Delta^{13}C_{plant}$ values for this species. Each of the species occupies different geographic ranges and different ranges of climatic variability, but none shows a significant $\Delta^{13}C_{plant}$ response to rising [CO_2] over the period of Industrialization.

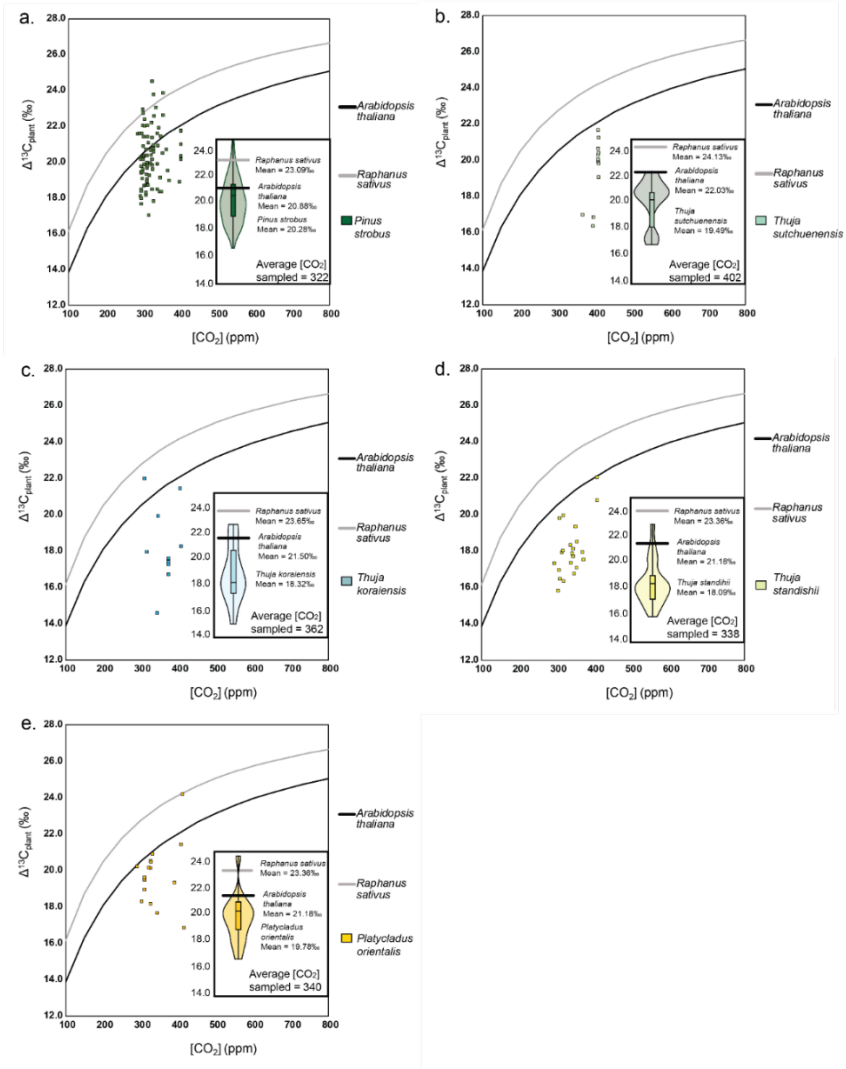

Figure B2 Comparison of $\Delta^{13}C_{plant}$ values of plants as sampled in this study, the Schubert & Jahren (2012) model, and from the literature and sorted by genera. Angiosperms are shown to the left of the diagram, while gymnosperms are shown to the right. Genera for which n<10 samples within the literature, were excluded from this figure. Xs denote mean values for each genus, and lines denote median values for each genus. Each box and whisker in this figure shows a different genus with n ≥ 15 represented isotope values from this study, Sheldon et al. (2020) and literature. Boxes show the 75th percentile of data, while whiskers show the remaining 25th percentile of data. Individual dots show outliers.

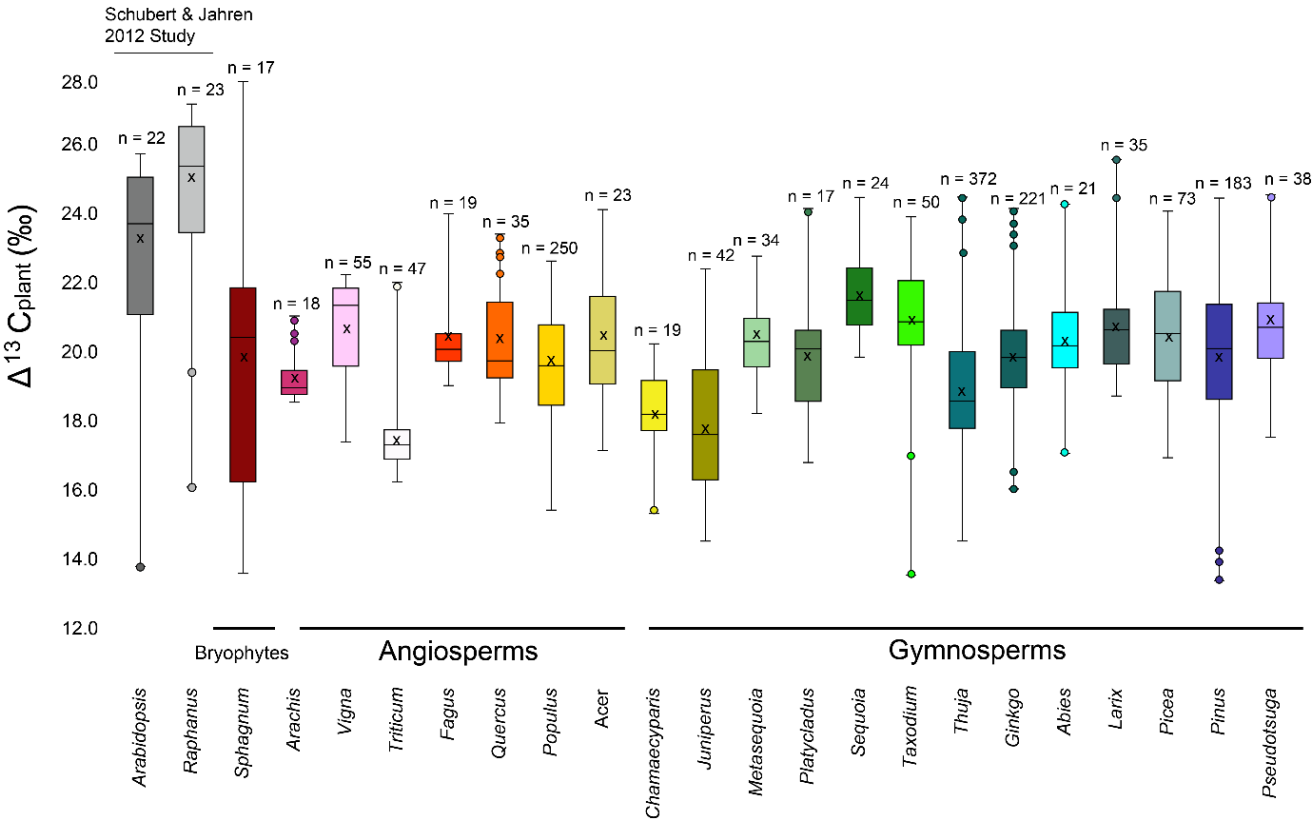

Figure B3 Comparison of $\Delta^{13}C_{plant}$ values of plants as sampled in this study, the Schubert & Jahren (2012) model, and from the literature and sorted by family. Angiosperms are shown to the left of the diagram, while gymnosperms are shown to the right. Families for which n<10 samples within the literature were excluded from this figure, except for "other Brassicaceae" – members of the same family as *Arabidopsis* and *Raphanus*, for comparison. Xs denote mean values for each genus. Each box and whisker in this figure shows a different family with n ≥ 15 represented isotope values from this study, Sheldon et al. (2020) and literature (except for Brassicaceae, which is included to show the discrepancy between model species and other Brassicaceae). Boxes show the 75th percentile of data, while whiskers show the remaining 25th percentile of data.

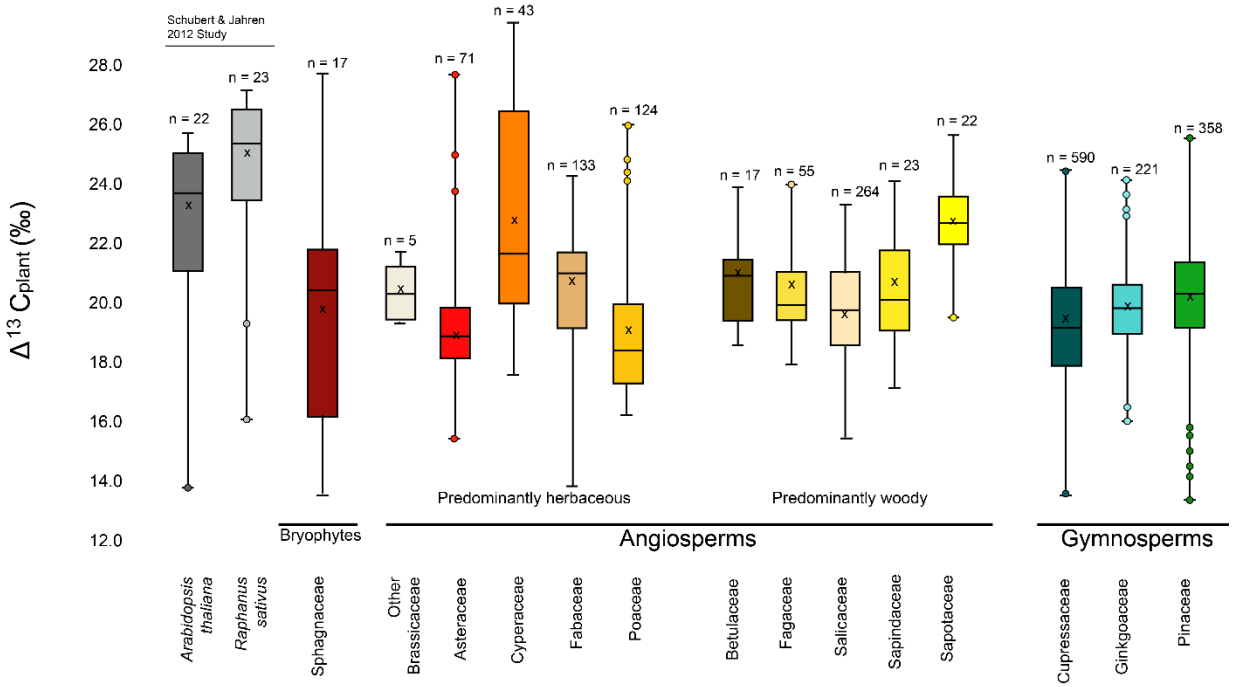

Table B1 Isotope data measurements for specimens collected in the Earth Systems Science Lab (tab labeled *ESS Lab*) and from literature (tab labeled *Literature*). References for literature and ESS data shown in tab labeled *References*. $\delta^{13}C_{plant}$ values and $\Delta^{13}C_{plant}$ values (calculated using Equation 3.2) are listed for ESS Lab and Literature values when known. Climate (PRISM Climate Group 2004) and barometric data (Etheridge et al. 1998; Keeling et al. 2001; White et al. 2015; Eggleston et al. 2016), year, collector, associated publications are listed when known and applicable. N/a denotes information not available. Equation 3.2 (see details in main text):

$$\Delta^{13}C_{plant} = \frac{\delta^{13}C_{CO_2} - \delta^{13}C_{plant}}{1 + \frac{\delta^{13}C_{plant}}{1000}}$$

(for full table, see separate file).

C_3 plant carbon isotope discrimination does not respond to CO_2 concentration on decadal to centennial timescales

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Table S1: Isotope data measurements for specimens collected in the Earth Systems Science Lab (tab labeled ESS Lab) and from literature (tab labeled Literature).
References for literature and ESS data shown in tab labeled References.
$\delta^{13}C_{plant}$ values and $\Delta^{13}C_{plant}$ values (calculated using Eq. 2) are listed for ESS Lab and Literature values when known.
Climate (PRISM Climate Group 2004) and barometric data (Etheridge et al. 1998; Keeling et al. 2001; White et al. 2015; Eggleston et al. 2016), year, collector, associated publications are listed when known and applicable.
N/a denotes information not available.
Eq. 2 (see details in main text):

$$\Delta^{13}C_{plant} = \frac{\delta^{13}C_{CO_2} - \delta^{13}C_{plant}}{1 + \frac{\delta^{13}C_{plant}}{1000}}$$

Study	Secondary	Study ID	RS Sample	Accession	Collector	Higher Pla	Plant Func	Photosynt	Sort	Family	Genus	Species	note	Date	Year	Collection	Latitude (°	Longitude	$[CO_2]$ (ppm	$\delta^{13}C_{CO2}$ (‰)	$\delta^{13}C_{plant}$ (‰	$\Delta^{13}C$ (‰; E	Δ13C (‰; a	MAP (mm y	Mean Annu	Maximum	Elevation (m	%N	%C	C:N (molar	C:N weight %
ESS Lab	et al. 2020	N_TTO201	781	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*		5/15/2018	2018	Trondheim,	63.43238	10.400325	411.3	-8.67	-28.91	20.85		1099	4.8	13.284	10.7	0.87	47.12	63.16	54.16091954
ESS Lab	et al. 2020	BHTP1979	554	#663-H	Helen H No	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		2/18/1979	1979	Hydaburg, A	55.20805	-132.8228	336.76	-7.54	-24.51	17.39		1944	7.4	14.0021	7	1.08	48.76	52.65	45.14815
ESS Lab	et al. 2020	BHTP1982	555	#4716	Mary Clay M	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		3/6/1982	1982	Southeaster	55.47801	-131.7906	342.7	-7.69	-24.10	16.81		2132	6.7	14.4836	150	1.42	50.29	41.30	35.41549296
ESS Lab	et al. 2020	IRE_BCTP2	874	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja plicata*		8/21/2018	2018	Blarney, Ire	51.92939	-8.568599	407.1	-8.42	-26.38	18.45		1065	10.1	15.4233	32.3	1.12	48.15	50.14	42.99107
ESS Lab	et al. 2020	IRE_BCTP2	873	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja plicata*		8/21/2018	2018	Blarney, Ire	51.92873	-8.572279	407.1	-8.42	-27.07	19.17		1065	10.1	15.4233	46	1.68	52.61	36.52	31.31548
ESS Lab	et al. 2020	MHPS1908	252	#1255	H. H. Bartle	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*		4/24/1908	1908	Mt. Madison	44.32818	-71.27788	298.9	-6.85	-25.94	19.60		1328	1.4	15.6	1617	1.51	45.86	35.42	30.37086
ESS Lab	et al. 2020	FMTP1932	328	S.N.	H E Parks	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		7/25/1932	1932	Trinidad, Ca	41.05845	-124.1424	308.2	-6.91	-24.97	18.52		1042	10.0	16	55	0.87	47.97	64.30	55.13793103
ESS Lab	et al. 2020	BHTP1989	557	#136	Brian D Co	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		5/11/1989	1989	Oweekeno \	51.68047	-127.2251	355.67	-7.94	-28.13	20.78		2584	8.8	16.3	13	1.37	49.93	42.50	36.44525547
ESS Lab	et al. 2020	MHTP1952	242	#524	Grayson	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		7/3/1952	1952	Logan Pass	48.6965	-113.7182	311.5	-7.00	-25.27	18.75		2109	0.6	16.9000	2014.0000	0.77	48.91	74.08	63.51948
ESS Lab	et al. 2020	MHTP1952	241	S.N.	H H Bartlett	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		7/3/1952	1952	Lake McDo	47.3867	-113.9174	311.5	-7.00	-25.16	18.63		1370	-0.3	17.2000	1089.0000	0.70	49.24	82.03	70.34286
ESS Lab	et al. 2020	MHTP1974	245	S.N.	J W Bunce	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		9/6/1974	1974	Point Grey,	49.2547	-123.1975	327.43	-7.48	-25.64	18.63		870	9.9	17.2000	75.0000	0.81	51.18	73.69	63.18519
ESS Lab	et al. 2020	MHTP1960	244	#18895	T G Yuncke	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		7/21/1960	1960	Olympic Pe	47.4565	-123.8400	318.18	-7.04	-25.10	18.52		3492	10.0	17.2000	302.0000	0.67	51.33	89.34	76.61194
ESS Lab	et al. 2020	FMTP1980	330	#5163	Hess	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		7/15/1980	1980	Wenatchee	48.38365	-121.0194	339.56	-7.59	-24.68	17.53		2253	2.3	17.9	1620	1.12	49.21	51.24	43.9375
ESS Lab	et al. 2020	FMPS1971	343	#42053	R Kral	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*		4/17/1971	1971	Clear Creek	39.68595	-105.7066	327.79	-7.35	-30.41	23.79		500	0.5	18.3	3049	1.22	50.10	47.89	41.06557
ESS Lab	et al. 2020	CA_CSUTD	910	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thujopsis*	*Thujopsis d*	(Chamaecy	5/23/2018	2018	Arcata, Cali	40.70245	-124.2028	411.3	-8.67	-25.14	16.89		1320	11.9	18.5		1.02	51.23	58.57	50.2254902
ESS Lab	et al. 2020	CA_CSUAC	891	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Austrocedr*	*Austrocedrus chilensis*		5/23/2018	2018	California S	40.70245	-124.2028	411.3	-8.67	-26.14	17.94		1320	11.9	18.5	52	1.22	49.84	47.64	40.85246
ESS Lab	et al. 2020	CA_CSUTA	908	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Tetraclinis*	*Tetraclinis articulata*		5/23/2018	2018		40.70245	-124.2028	411.3	-8.67	-26.54	18.35		1320	11.9	18.5	52	1.96	46.47	27.65	23.70918
ESS Lab	et al. 2020	CA_CSUTP	909	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja plicata*		5/23/2018	2018	Eureka, Cal	40.70245	-124.2028	411.3	-8.67	-26.94	18.77		1320	11.9	18.5		1.00	49.63	57.88	49.63
ESS Lab	et al. 2020	CA_CSUCL	894	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Hesperocyp*	*Cunninghai*	Hesperocyp	5/23/2018	2018	California S	40.70245	-124.2028	411.3	-8.67	-27.16	19.01		1320	11.9	18.5	52	0.67	47.15	82.07	70.37313
ESS Lab	et al. 2020	CA_CSUW	911	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Widdringtor*	*Widdringtor*	(Chamaecy	5/23/2018	2018	Arcata, Cali	40.70245	-124.2028	411.3	-8.67	-27.46	19.32		1320	11.9	18.5		1.21	50.54	48.71	41.76859504
ESS Lab	et al. 2020	CA_CSUPU	902	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Pilgerodenc*	*Pilgerodendron uviferur*		5/23/2018	2018	California S	40.70245	-124.2028	411.3	-8.67	-27.54	19.41		1320	11.9	18.5	52	0.90	49.29	63.87	54.76667
ESS Lab	et al. 2020	CA_CSUAC	890	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Athrotaxis*	*Athrotaxis cupressoides*		5/23/2018	2018	California S	40.70245	-124.2028	411.3	-8.67	-27.64	19.51		1320	11.9	18.5	52	1.33	51.15	44.85	38.45865
ESS Lab	et al. 2020	CA_CSUFC	897	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Fitzroya*	*Fitzroya cupressoides*		5/23/2018	2018	California S	40.70245	-124.2028	411.3	-8.67	-27.99	19.88		1320	11.9	18.5	52	0.91	50.41	64.60	55.3956
ESS Lab	et al. 2020	CA_CSUFH	898	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Fokienia*	*Fokienia hodginsii*		5/23/2018	2018	California S	40.70245	-124.2028	411.3	-8.67	-28.27	20.17		1320	11.9	18.5	52	0.95	47.59	58.42	50.09474
ESS Lab	et al. 2020	CA_CSUMI	901	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Microbiota*	*Microbiota decussata*		5/23/2018	2018	California S	40.70245	-124.2028	411.3	-8.67	-28.31	20.22		1320	11.9	18.5	52	1.23	50.29	47.68	40.88618
ESS Lab	et al. 2020	CA_CSUTC	907	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Taiwania*	*Taiwania cryptomerioid*		5/23/2018	2018	Arcata, Cali	40.70245	-124.2028	411.3	-8.67	-28.47	20.38		1320	11.9	18.5	52	1.02	45.55	52.08	44.65686
ESS Lab	et al. 2020	CA_CSUAA	889	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Xanthocypa*	*Actinostrob*	Xanthocypa	5/23/2018	2018	California S	40.70245	-124.2028	411.3	-8.67	-28.55	20.47		1320	11.9	18.5	52	1.15	50.43	51.14	43.85217
ESS Lab	et al. 2020	CA_CSULF	900	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Libocedrus*	*Libocedrus plumosa*		5/23/2018	2018	California S	40.70245	-124.2028	411.3	-8.67	-28.87	20.80		1320	11.9	18.5	52	0.57	49.77	101.83	87.31579
ESS Lab	et al. 2020	CA_CSUCD	893	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Calocedrus*	*Calocedrus decurrens*		5/23/2018	2018	California S	40.70245	-124.2028	411.3	-8.67	-28.95	20.88		1320	11.9	18.5	52	1.16	49.75	50.02	42.88793
ESS Lab	et al. 2020	CA_CSUDA	896	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Diselma*	*Diselma archeri*		5/23/2018	2018	California S	40.70245	-124.2028	411.3	-8.67	-29.28	21.23		1320	11.9	18.5	52	1.14	52.48	53.69	46.03509
ESS Lab	et al. 2020	CA_CSUCR	892	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Callitris*	*Callitris rhomboidea*		5/23/2018	2018	California S	40.70245	-124.2028	411.3	-8.67	-29.65	21.62		1320	11.9	18.5	52	1.27	51.10	46.92	40.23622
ESS Lab	et al. 2020	CA_CSUGP	899	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Glyptostrob*	*Glyptostrobus pensilis*		5/23/2018	2018	California S	40.70245	-124.2028	411.3	-8.67	-29.72	21.70		1320	11.9	18.5	52	1.35	48.04	41.50	35.58519
ESS Lab	et al. 2020	CA_CSUCM	895	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Hesperocyp*	*Cupressus macrocarpa*		5/23/2018	2018	California S	40.70245	-124.2028	411.3	-8.67	-30.02	22.01		1320	11.9	18.5	52	0.83	51.30	72.08	61.80723
ESS Lab	et al. 2020	CA_CSUSS	905	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Sequoia*	*Sequoia sempervirens*		5/23/2018	2016	Arcata, Cali	40.70245	-124.2028	411.3	-8.67	-30.45	22.47		1320	11.9	18.5	52	0.98	48.80	58.07	49.79592
ESS Lab	et al. 2020	CA_CSUSV	904	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Sciadopitya	*Sciadopitys*	*Sciadopitys verticillata*		5/23/2018	2018	Eureka, Cal	40.70245	-124.2028	411.3	-8.67	-30.49	22.51		1320	11.9	18.5	52	0.69	50.55	85.44	73.26087
ESS Lab	et al. 2020	CA_CSUSG	906	n/a	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Sequoiader*	*Sequoiadendron gigant*		5/23/2018	2018	Arcata, Cali	40.70245	-124.2028	411.3	-8.67	-30.85	22.89		1320	11.9	18.5	52	0.73	45.82	73.20	62.76712
ESS Lab	et al. 2020	CA_CSUPO	903	S.N.	Mihai Tome	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Platycladus*	*Platycladus orientalis*		5/23/2018	2018	California S	40.70245	-124.2028	411.3	-8.67	-32.10	24.21		1320	11.9	18.5		1.19	46.79	45.85	39.31933
ESS Lab	et al. 2020	C_EGCLP2	912	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Larix*	*Larix potaninii*		7/9/2017	2017	Enshi Gran	30.46488	109.17343	407.2	-8.56	-29.34	21.41		1320	11.9	18.5	52	2.37	50.51	24.85	21.31224
ESS Lab	et al. 2020	CSPT1967	673	#811	Bathke	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		1967	1967	Robinson B	38.89903	-107.1087	324.09	-7.33	-26.50	19.69		1228	-0.3	18.8	3444	1.50	49.71	38.65	33.14
ESS Lab	et al. 2020	BHTP1963	547	#910	A Young	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		7/31/1963	1963	Vancouver	49.43454	-125.3034	319.74	-7.06	-22.78	16.09		3271	9.5	19.1	760	1.13	48.11	49.65	42.57522
ESS Lab	et al. 2020	FMTPND1	332	#747862	Murrey	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		No date		Strathcona,	49.52831	-125.8283	n/a	n/a	-24.78			1283	9.9	19.1	846	1.10	49.12	52.08	44.65454545
ESS Lab	et al. 2020	CO_QPPT2	855	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/5/2018	2018	Blue River,	39.39178	-106.0713	407.1	-8.42	-28.61	20.78		912	1.8	19.1	3561.5	3.25	54.31	19.49	16.71077
ESS Lab	et al. 2020	MN16-43	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Sequoia*	*Sequoia sempervirens*		12/21/2016	2016	Trinidad, Ca	41.10152	-124.1542	404.55	-8.49	-30.30	22.49		1432	11.2	19.2					
ESS Lab	et al. 2020	MN16-44	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Sequoia*	*Sequoia sempervirens*		12/21/2016	2016	Trinidad, Ca	41.10152	-124.1542	404.55	-8.49	-32.23	24.53		1432	11.2	19.2					
ESS Lab	et al. 2020	BHTP1987	556	#75	Brian D Co	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		6/30/1987	1987	Denny Islan	52.14991	-128.1166	351.26	-7.85	-24.16	16.72		2629	9.4	19.4	1584	0.90	48.27	62.55	53.63333333
ESS Lab	et al. 2020	MHTP1995	247	#3	Sarah K Ue	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		4/29/1995	1995	Multnomah	45.6656	-122.4133	363.45	-8.03	-25.69	18.13		193	11.6	19.4000	146.0000	0.73	48.52	77.51	66.46575
ESS Lab	et al. 2020	CO_HVPT2	839	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/3/2018	2018	Rocky Mou	40.39555	-105.653	407.1	-8.42	-29.27	21.48		1024	2.5	19.9	2854.6	2.56	50.10	22.82	19.57031
ESS Lab	et al. 2020	CO_HVPT2	841	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/3/2018	2018	Rocky Mou	40.39545	-105.6527	407.1	-8.42	-30.21	22.47		1024	2.5	19.9	2845.6	2.16	49.30	26.62	22.82407
ESS Lab	et al. 2020	CUBPT200	688	#4794	Hogan	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		7/23/2008	2008	Cottonwood	38.18902	-105.7965	386.25	-8.30	-26.52	18.72		439	3.6	20	2404	2.09	51.77	28.89	24.77033
ESS Lab	et al. 2020	BHTP1957	546	#21565	JA Calder	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		6/16/1957	1957	Yakoun Rive	53.6601	-132.2082	314.2	-7.07	-24.05	17.40		445	8.1	20	70	1.13	44.86	46.30	39.69912
ESS Lab	et al. 2020	OR_RBTP2	759	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		5/17/2018	2018	Rockaway E	45.55883	-123.9273	411.3	-8.67	-25.82	17.61		2630	11.7	20	13.4	1.90	51.75	31.76	27.23684
ESS Lab	et al. 2020	CO_AFPT2	844	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/3/2018	2018	Rocky Mou	40.30936	-105.6406	407.1	-8.42	-27.01	19.11		1301	2.8	20	2789.6	2.99	51.01	19.90	17.0602
ESS Lab	et al. 2020	CO_AFPT2	843	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/3/2018	2018	Rocky Mou	40.30929	-105.6406	407.1	-8.42	-27.50	19.62		1301	2.8	20	2789.6	3.07	50.88	19.33	16.57329
ESS Lab	et al. 2020	CO_AFPT2	842	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/3/2018	2018	Rocky Mou	40.30948	-105.6405	407.1	-8.42	-28.07	20.22		1301	2.8	20	2793.2	2.98	49.21	19.26	16.51342
ESS Lab	et al. 2020	MHTO1908	176	#1257	Bartlett	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*		4/24/1908	1908	Mt. Madison	44.3284	-71.2779	298.9	-6.85	-23.90	17.47		1328	1.4	20.4	1617	1.29	50.68	45.99	39.43969
ESS Lab	et al. 2020	MHTO1942	195	#4306	Harold and	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*		7/16/1942	1942	Mott Island,	48.0892	-88.5790	310.3	-6.96	-25.27	18.78		777	3.9	20.4000	190.0000	1.39	49.94	41.90	35.92806
ESS Lab	et al. 2020	BHTP1890/	524	#599	Piper	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		3/16/1890	1890	Seattle, Wa	47.6068	-122.3339	294.2	-6.76	-24.14	17.80		772	10.5	20.5	47	1.35	47.75	41.25	35.37037
ESS Lab	et al. 2020	BHTP1889	523	#599	Piper	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		3/4/1889	1889	Seattle, Wa	47.6068	-122.3339	294	-6.78	-24.22	17.87		772	10.5	20.5	47	1.41	48.61	40.20	34.47518
ESS Lab	et al. 2020	BHTP1890	525	S.N.	Wilhelm N S	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		7/11/1890	1890	Seattle, Wa	47.6068	-122.3339	294.2	-6.76	-25.74	19.48		772	10.5	20.5	47	0.92	45.72	57.95	49.69565
ESS Lab	et al. 2020	CUBPT198	678	S.N.	Stevens	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/25/1982	1982	Rocky Mou	40.32605	-105.6511	339.81	-7.46	-26.60	19.66		955	0.8	20.6	3052	2.89	48.89	19.73	16.91696
ESS Lab	et al. 2020	BHTP2008/	567	#1584	David Giblin	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		4/24/2008	2008	Cliff Island,	48.58981	-123.0138	386.77	-8.33	-26.47	18.63		620	9.2	20.7	24	0.97	47.50	57.11	48.96907216
ESS Lab	et al. 2020	MHTO1976	220	NA 9782	J K Morton	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*		8/29/1976	1976	Caribou Isla	47.3579	-85.8090	330.94	-7.44	-23.00	15.92		708	7.8	20.9000	516.0000	1.08	47.86	51.68	44.31481
ESS Lab	et al. 2020	NM_TSVOI	809	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		7/31/2018	2018	Taos Ski Va	36.5972	-105.4491	408.9	-8.54	-25.33	17.22		929	5.0	20.9	2892.2	2.19	47.99	25.55	21.91324
ESS Lab	et al. 2020	NM_TSVO	802	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		7/31/2018	2018	Taos Ski Va	36.59711	-105.4499	408.9	-8.54	-26.62	18.57		929	5.0	20.9	2880.9	1.88	47.32	29.35	25.17021
ESS Lab	et al. 2020	NM_TSVPT	801	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		7/31/2018	2018	Taos Ski Va	36.5961	-105.4497	408.9	-8.54	-26.70	18.66		929	5.0	20.9	2873.5	2.74	48.67	20.71	17.76277
ESS Lab	et al. 2020	NM_TSVO	808	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		7/31/2018	2018	Taos Ski Va	36.597	-105.4491	408.9	-8.54	-26.83	18.80		929	5.0	20.9	2885.7	2.38	48.03	23.53	20.18067
ESS Lab	et al. 2020	NM_TSVPT	799	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		7/31/2018	2018	Taos Ski Va	36.59639	-105.4749	408.9	-8.54	-26.96	18.93		929	5.0	20.9	2870.5	2.27	48.02	24.67	21.15419
ESS Lab	et al. 2020	NM_TSVO	803	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		7/31/2018	2018	Taos Ski Va	36.59711	-105.4499	408.9	-8.54	-27.03	19.00		929	5.0	20.9	2536	1.83	47.79	30.45	26.11475
ESS Lab	et al. 2020	NM_TSVPT	800	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		7/31/2018	2018	Taos Ski Va	36.59613	-105.4502	408.9	-8.54	-28.45	20.49		929	5.0	20.9	2870.5	2.55	49.13	22.47	19.26667
ESS Lab	et al. 2020	BHTP1928	533	S.N.	C H Kauffm	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		7/30/1928	1928	Flathead Na	48.01444	-113.8057	306.3	-6.91	-27.93	21.62		1418	3.3	21	1036	1.37	47.63	40.54	34.76642
ESS Lab	et al. 2020	BHTP2011	570	#2011-14	Regina Joh	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		10/9/2011	2011	Vendovi Isla	48.61282	-122.614	388.93	-8.17	-26.80	19.14		767	9.9	21	183	1.45	51.50	41.42	35.51724138
ESS Lab	et al. 2020	BHTP2008	568	#5-08	Peter Dunw	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		5/29/2008	2008	Matia Island	48.74789	-122.8419	388.51	-8.42	-27.59	19.72		774	9.5	21.1	24	1.14	50.13	51.28	43.97368421
ESS Lab	et al. 2020	CO_KLCPT	854	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/5/2018	2018	Alma, Color	39.2892	-106.0773	407.1	-8.42	-26.44	18.51		748	3.2	21.1	3225.6	3.09	51.35	19.38	16.61812
ESS Lab	et al. 2020	CO_67PT2	819	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/1/2018	2018	Cripple Cre	38.82941	-105.136	407.1	-8.42	-26.49	18.56		615	4.1	21.2	2949.9	1.78	47.96	31.42	26.94382
ESS Lab	et al. 2020	BHTP1931	534	#3484	Geo N Jone	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		8/1/1931	1931	Lake Cresc	48.09472	-123.8058	307.7	-6.98	-26.35	19.90		1526	8.7	21.3	188	1.18	48.68	48.11	41.25424
ESS Lab	et al. 2020	FMTO1940	312	#3825	Marie-Victo	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*		8/18/1940	1940	Reviere la M	63.1729	-116.8071	310.4	-6.94	-26.79	20.40		289	-4.3	21.3	157	1.93	46.99	28.39	24.34715026
ESS Lab	et al. 2020	CO_CCFPT	694	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/18/2017	2017	Thomas Tra	38.93308	-105.027	405.24	-8.55	-27.46	19.44		722	5.6	21.4	2545.7	2.12	48.66	26.77	22.95283
ESS Lab	et al. 2020	CO_CCFPT	693	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/18/2017	2017	Dirt road to	38.93432	-105.0247	405.24	-8.55	-27.66	19.65		722	5.6	21.4	2423	2.12	49.03	26.97	23.12736
ESS Lab	et al. 2020	C-PHTK20	502			Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja koraiensis*		9/7/2004	2004	Changbai, E	41.79611	127.9889	374.05	-8.02	-24.33	16.71		781	-0.1	21.4	728	1.96	52.52	31.25	26.79592
ESS Lab	et al. 2020	C-PHTK20	501			Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja koraiensis*		9/7/2004	2004	Changbai, E	41.79611	127.9889	374.05	-8.02	-24.99	17.41		781	-0.1	21.4	728	0.68	46.74	80.16	68.73529
ESS Lab	et al. 2020	MHTO2009	234	#291	David C Dis	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*		9/27/2009	2009	Ludington S	44.0300	-86.5100	384.65	-8.11	-25.65	18.00		917	7.0	21.6000	204.0000	0.81	30.56	43.99	37.72291
ESS Lab	et al. 2020	MN17-70	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*		8/17/2017	2017	Stuttgart, G	48.70958	9.208047	405.24	-8.55	-27.82	19.82		741	9.2	21.6					
ESS Lab	et al. 2020	CO_HVPT2	840	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/3/2018	2018	Rocky Mou	40.39586	-105.6524	407.1	-8.42	-29.27	21.48		899	3.7	21.6	2845.3	2.87	48.69	19.78	16.96516
ESS Lab	et al. 2020	CO_GCRP	824	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/1/2018	2018	Cripple Cre	38.7421	-105.0907	407.1	-8.42	-23.98	15.94		601	4.5	21.8	2949.7	1.93	48.13	29.08	24.93782
ESS Lab	et al. 2020	CO_GCRP	825	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/1/2018	2018	Cripple Cre	38.73578	-105.0632	407.1	-8.42	-24.25	16.22		601	4.5	21.8	2955.7	3.08	49.15	18.61	15.95779
ESS Lab	et al. 2020	CO_GCRP	822	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/1/2018	2018	Cripple Cre	38.74417	-105.1008	407.1	-8.42	-25.16	17.17		601	4.5	21.8	3003.2	2.74	47.09	20.04	17.18613
ESS Lab	et al. 2020	CO_GCRP	823	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/1/2018	2018	Cripple Cre	38.74604	-105.0971	407.1	-8.42	-27.26	19.36		601	4.5	21.8	2974.4	1.86	48.23	30.24	25.93011
ESS Lab	et al. 2020	WY_TCPT2	773	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		6/24/2018	2018	Tin Cup Tra	43.83739	-110.9026	410.88	-8.64	-29.03	21.00		1774	2.3	21.8	1964	2.60	50.56	22.68	19.44615
ESS Lab	et al. 2020	MSTO1888	411	S.N.	AA Farwell	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*		June 1888	1888	Keweenaw (	47.39176	-88.03127	293.8	-6.78	-24.75	18.43		647	4.9	21.9	274	0.93	53.35	66.90	57.3655914
ESS Lab	et al. 2020	MHPS1883	249	#2660	F. E. Wood	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*		08-1883	1883	Keneenaw (	47.38144	-88.09868	292.1	-6.73	-24.40	18.11		651	4.5	21.9	342	2.01	49.03	28.45	24.39303
ESS Lab	et al. 2020	BHTP2006/	565	#06-224	Victoria Wy	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		5/30/2006	2006	McConnell I	48.59835	-123.0241	384.92	-8.45	-27.73	19.83		736	10.4	21.9	24	0.93	47.72	59.84	51.31182796
ESS Lab	et al. 2020	BHTP1977/	552	#5504	E Hunn	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		2/11/1977	1977	Klickitat Riv	46.45437	-121.3929	333.42	-7.49	-24.79	17.75		1519	3.4	22	553	1.19	47.24	46.29	39.69748
ESS Lab	et al. 2020	YUPS1894B	375	#94	E L Rand	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*		6/30/1894	1894	Mount Dese	44.29514	-68.28658	294.7	-6.80	-25.74	19.45		1063	6.7	22	4	1.35	48.71	42.08	36.08148
ESS Lab	et al. 2020	CO_67PT2	818	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/1/2018	2018	Cripple Cre	38.81023	-105.1255	407.1	-8.42	-26.25	18.31		609	4.5	22	3020.4	1.90	47.92	29.41	25.22105
ESS Lab	et al. 2020	CO_67PT2	820	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/1/2018	2018	Cripple Cre	38.81049	-105.1255	407.1	-8.42	-27.43	19.55		609	4.5	22	3023.3	1.76	46.56	30.85	26.45455
ESS Lab	et al. 2020	CO_67PT2	821	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/1/2018	2018	Cripple Cre	38.80508	-105.1219	407.1	-8.42	-27.71	19.84		609	4.5	22	3032.2	1.86	48.41	30.35	26.02688
ESS Lab	et al. 2020	WA_MRTP	713	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		5/13/2018	2018	Top of Com	46.7959	-121.7809	411.3	-8.67	-28.40	20.31		3171	6.8	22.1	971	1.27	48.87	44.88	38.48031
ESS Lab	et al. 2020	WA_MRTP	712	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		5/13/2018	2018	Base of Chi	46.7809	-121.7798	411.3	-8.67	-29.50	21.47		3171	6.8	22.1	971	1.44	50.34	40.77	34.95833
ESS Lab	et al. 2020	FMTO1938	311	#185	Auray Blain	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*		7/17/1938	1938	Sante-Iren,	47.9704	-66.95481	310.2	-6.94	-25.89	19.45		1038	2.2	22.2	57	1.49	47.67	37.31	31.99328859
ESS Lab	et al. 2020	BHTP1969	549	#95	Delzie Dem	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		8/22/1969	1969	Kings Coun	47.61389	-121.8011	323.66	-7.31	-24.79	17.93		1564	9.3	22.3	300	0.95	48.34	59.34	50.88421
ESS Lab	et al. 2020	UT_PFPT2	868	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/6/2018	2018	Pando Fore	38.52666	-111.7484	407.1	-8.42	-25.55	17.57		651	4.6	22.3	2718.1	2.74	47.43	20.19	17.31022
ESS Lab	et al. 2020	CO_GCRP	826	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/1/2018	2018	Cripple Cre	38.72874	-105.0109	407.1	-8.42	-26.44	18.51		634	5.5	22.3	2977.6	3.02	51.39	19.84	17.01656
ESS Lab	et al. 2020	UT_PFPT2	870	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/6/2018	2018	Pando Fore	38.52666	-111.7484	407.1	-8.42	-26.89	18.98		651	4.6	22.3	2718.1	3.12	49.39	18.46	15.83013
ESS Lab	et al. 2020	UT_PFPT2	869	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/6/2018	2018	Pando Fore	38.52666	-111.7484	407.1	-8.42	-27.05	19.15		651	4.6	22.3	2718.1	2.31	49.10	24.79	21.25541
ESS Lab	et al. 2020	CSPT1998/	682	#260	Hall	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		6/10/1998	1998	Wet Mounta	37.72103	-105.5179	368.88	-8.20	-23.50	15.67		512	4.1	22.4	2804.2	2.71	48.46	20.85	17.88192
ESS Lab	et al. 2020	CO_TRRPT	836	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/3/2018	2018	Rocky Mou	40.39933	-105.6436	407.1	-8.42	-29.16	21.36		796	4.2	22.5	2823.6	2.22	50.46	26.51	22.72973
ESS Lab	et al. 2020	MHTP1944	240	S.N.	Ruth E. Hop	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		5/7/1944	1944	Gate Creek	45.6334	-121.7503	310.1	-6.97	-25.44	18.96		1335	6.6	22.5000	448.0000	0.73	49.82	79.59	68.24658
ESS Lab	et al. 2020	MN16-46	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Sequoia*	*Sequoia sempervirens*		12/21/2016	2016	Logging cor	41.05508	-123.8876	404.55	-8.49	-28.73	20.84		1477	11.5	22.6					
ESS Lab	et al. 2020	MN16-45	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Sequoia*	*Sequoia sempervirens*		12/21/2016	2016	Logging cor	41.05508	-123.8876	404.55	-8.49	-31.11	23.35		1477	11.5	22.6					
ESS Lab	et al. 2020	MHTP1890	400	S.N.	H R Talcott	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		May 21, 1890	1890	Seattle, Wa	47.61569	-122.3043	294.2	-6.76	-23.70	17.35		766	5.2	22.8	103	1.20	48.87	47.49	40.725
ESS Lab	et al. 2020	CUBPT195	666	#6188	Livingston a	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		1951	1951	Rio Grande	37.79292	-106.9156	311.1	-6.99	-24.03	17.45		400	1.7	22.8	2962	3.05	48.97	18.72	16.05574
ESS Lab	et al. 2020	BHTP1892	526	S.N.	Louis F Her	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		4/20/1892	1892	Olympia, W	47.03806	-122.8944	294.5	-6.79	-24.88	18.56		1078	10.1	22.9	16	0.96	44.48	54.03	46.33333
ESS Lab	et al. 2020	MN16-51	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Sequoia*	*Sequoia sempervirens*		12/22/2016	2016	Jackson Sta	39.38271	-123.4797	404.55	-8.49	-29.14	21.27		1332	12.0	23					
ESS Lab	et al. 2020	BHTP1904	529	S.N.	A S Pope	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		6/30/1904	1904	Friday Harb	48.54139	-123.0225	297.2	-6.83	-24.50	18.11		657	9.7	23.1	35	1.11	45.71	48.02	41.18018
ESS Lab	et al. 2020	MHTO1924	179	#680	Erlanson	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*		8/30/1924	1924	Scotty Bay,	45.98	-84.19	304.5	-6.89	-25.18	18.77		724	4.1	23.1	187	0.99	53.80	63.37	54.34343
ESS Lab	et al. 2020	MN16-53	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Sequoia*	*Sequoia sempervirens*		12/22/2016	2016	Jackson Sta	39.34855	-123.5422	404.55	-8.49	-32.15	24.44		1162	12.3	23.1					
ESS Lab	et al. 2020	CO_BCPT2	850	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		8/4/2018	2018	Vail, Colora	39.5968	-106.5228	407.1	-8.42	-27.93	20.07		687	4.9	23.1	2543.1	0.78	54.01	80.75	69.24359
ESS Lab	et al. 2020	MHTO1929	181	#4153	J H Ehlers	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*		8/24/1929	1929	Gulliver Lak	45.99	-86.03	306.8	-6.83	-29.26	23.11		782	3.9	23.2	190	1.10	53.36	56.57	48.50909
ESS Lab	et al. 2020	CSPT1972	674	#E-375	Brown	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*		1972	1972	Clear Creek	39.79365	-105.4057	329.09	-7.36	-25.34	18.45		458	4.1	23.3	2726	2.57	51.62	23.42	20.0856
ESS Lab	et al. 2020	MHTO1931	184	#1161	Carl O. Gra	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*		8/25/1931	1931	Siskiwat Ba	47.95	-88.76	307.7	-6.98	-23.81	17.24		657	5.8	23.3	183	1.85	50.42	31.78	27.25405
ESS Lab	et al. 2020	YUPS1848	372	S.N.	D C Eaton	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*		1/21/1905	1905	Nova Anglia	42.51802	-70.89381	297.6	-6.83	-25.43	19.08		1140	8.0	23.3	9	1.37	48.83	41.57	35.64234
ESS Lab	et al. 2020	FMTP1994	331	#7052	Hess, Winte	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		3/27/1994	1994	Skamania, \	46.03321	-121.8386	359.97	-7.90	-25.73	18.30		2687	6.2	23.3	791	0.79	48.23	71.20	61.05063291
ESS Lab	et al. 2020	BHTP1975/	550	#185	JoAnn Robb	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		4/25/1975	1975	Quinalt, Wa	47.45961	-123.8587	333.31	-7.42	-27.96	21.14		4368	9.3	23.3	76	1.29	47.80	43.21	37.05426
ESS Lab	et al. 2020	MN16-50	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Sequoia*	*Sequoia sempervirens*		12/22/2016	2016	Jackson Sta	39.39301	-123.4606	404.55	-8.49	-28.65	20.76		1333	12.1	23.3					
ESS Lab	et al. 2020	WA_ISTP2	710	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		10/22/2017	2017	Ira Springs	47.39781	-121.5358	401.5	-8.39	-28.88	21.10		3199	7.7	23.3	526	1.20	48.50	47.13	40.41667
ESS Lab	et al. 2020	WA_ISTP2	709	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		10/22/2017	2017	Ira Springs	47.39781	-121.5358	401.5	-8.39	-30.23	22.52		3199	7.7	23.3	526	0.93	49.41	61.96	53.12903
ESS Lab	et al. 2020	WA_ISTP2	708	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*		10/22/2017	2017	Ira Springs	47.39781	-121.5358	401.5	-8.39	-30.88	23.21		3199	7.7	23.3	526	1.07	49.29	53.72	46.06542

ESS Lab	et al. 2020	BHTP1926	532	#1645	J William Th	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	4/12/1926	1926	Governmen	45.30194	-121.7533	305.4	-6.91	-24.85	18.40		1642	7.2	23.4	1180	0.85	47.02	64.51	55.31765
ESS Lab	et al. 2020	CO_SCPT2	846	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/4/2018	2018	Vail, Colora	39.64414	-106.3712	407.1	-8.42	-26.11	18.16		638	4.5	23.4	2560.4	3.05	51.65	19.75	16.93443
ESS Lab	et al. 2020	CO_VRPT2	849	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/4/2018	2018	Vail, Colora	39.64388	-106.3692	407.1	-8.42	-27.17	19.28		637	4.5	23.4	2576.3	2.76	52.75	22.29	19.11232
ESS Lab	et al. 2020	CO_VRPT2	847	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/4/2018	2018	Vail, Colora	39.64388	-106.3692	407.1	-8.42	-27.20	19.31		637	4.5	23.4	2576.3	2.66	52.43	22.99	19.71053
ESS Lab	et al. 2020	CO_VRPT2	848	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/4/2018	2018	Vail, Colora	39.64388	-106.3692	407.1	-8.42	-29.15	21.35		637	4.5	23.4	2576.3	2.29	51.67	26.31	22.56332
ESS Lab	et al. 2020	CSPT2000/	684	#279	Holt	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/2/2000	2000	Central Col	39.48817	-106.3666	371.69	-8.14	-27.16	19.55		630	3.3	23.5	2743.2	4.12	48.96	13.86	11.8835
ESS Lab	et al. 2020	MHTO1924	178	#426	Erlanson	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	7/18/1924	1924	Petoskey, M	45.37	-84.97	304.5	-6.89	-24.74	18.30		792	5.3	23.6	207	0.86	51.49	70.23	60.22222
ESS Lab	et al. 2020	CO_TRRPT	837	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/3/2018	2018	Rocky Mour	40.38675	-105.6318	407.1	-8.42	-28.59	20.77		760	5.4	23.7	2920.3	2.50	48.57	22.66	19.428
ESS Lab	et al. 2020	CO_FLPT2	835	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/3/2018	2018	Rocky Mour	40.35519	-105.6329	407.1	-8.42	-29.38	21.60		760	5.4	23.7	2513.6	2.43	49.82	23.91	20.50206
ESS Lab	et al. 2020	CO_TRRPT	838	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/3/2018	2018	Rocky Mour	40.38538	-105.6315	407.1	-8.42	-29.43	21.65		760	5.4	23.7	2876.7	2.38	49.15	24.08	20.65126
ESS Lab	et al. 2020	CO_FLPT2	832	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/3/2018	2018	Rocky Mour	40.35709	-105.6198	407.1	-8.42	-29.57	21.79		760	5.4	23.7	2470	1.97	48.30	28.59	24.51777
ESS Lab	et al. 2020	CO-FLPT2	834	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/3/2018	2018	Rocky Mour	40.35497	-105.6322	407.1	-8.42	-29.64	21.87		760	5.4	23.7	2487.4	2.05	45.62	25.95	22.25366
ESS Lab	et al. 2020	CO_FLPT2	833	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/3/2018	2018	Rocky Mour	40.35515	-105.6326	407.1	-8.42	-30.39	22.66		760	5.4	23.7	2504.2	1.73	45.31	30.54	26.19075
ESS Lab	et al. 2020	CO_CLTPT	831	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/3/2018	2018	Rocky Mour	40.3555	-105.6161	407.1	-8.42	-30.42	22.69		760	5.4	23.7	2470	3.31	49.03	17.27	14.81269
ESS Lab	et al. 2020	MHTO1968D	213	#12816	E. G. Voss	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	8/31/1968	1968	St. Helena I	45.8600	-84.8700	322.11	-7.24	-26.78	20.07		846	6.2	23.8000	242.0000	0.78	48.61	72.68	62.32051
ESS Lab	et al. 2020	MHPS1968A	276	#12582	E. G. Voss	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	5/26/1968	1968	Nestoria, M	46.57066	-88.2642	325.57	-7.24	-27.53	20.87		1123	3.9	23.8	508	1.14	48.94	50.06	42.92982
ESS Lab	et al. 2020	BHTP1942/	539	#1097	H T Rogers	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	7/17/1942	1942	Near city re	48.39142	-114.0842	310.3	-6.96	-24.42	17.90		896	4.0	23.8	944	1.05	49.30	54.75	46.95238
ESS Lab	et al. 2020	MN16-40	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Sequoia*	*Sequoia sempervirens*	12/20/2016	2016	Portola Red	37.25625	-122.2193	404.55	-8.49	-29.30	21.43		702	13.5	23.8					
ESS Lab	et al. 2020	MN16-41	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Sequoia*	*Sequoia sempervirens*	12/20/2016	2016	Portola Red	37.25355	-122.218	404.55	-8.49	-29.72	21.88		702	13.5	23.8					
ESS Lab	et al. 2020	MN16-42	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Sequoia*	*Sequoia sempervirens*	12/20/2016	2016	Portola Red	37.25362	-122.2184	404.55	-8.49	-29.96	22.13		702	13.5	23.8					
ESS Lab	et al. 2020	CSPT2000I	685	#50183	Nelson	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/29/2000	2000	North Park,	40.40414	-106.4567	371.69	-8.14	-27.55	19.95		617	3.4	23.8	2632	3.11	48.50	18.19	15.59486
ESS Lab	et al. 2020	CO_CCFPT	695	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/18/2017	2017	Thomas Tra	38.92982	-105.0173	405.24	-8.55	-27.79	19.79		710	6.9	23.8	2452.7	1.99	48.95	28.69	24.59799
ESS Lab	et al. 2020	CO_CCFPT	696	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/18/2017	2017	Thomas Tra	38.9298	-105.0171	405.24	-8.55	-29.68	21.77		710	6.9	23.8	2415.2	2.35	49.96	24.79	21.25957
ESS Lab	et al. 2020	YUTO1902B	356	#417	C K Averill	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	8/31/1902	1902	Canaan, Co	41.96627	-73.31242	296.5	-6.82	-24.88	18.52		1344	7.7	23.9	239	1.10	48.56	51.48	44.14545455
ESS Lab	et al. 2020	CUBPT195	667	#429	Green	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1952	1952	Twin Lakes,	39.08072	-106.3821	311.5	-7.00	-24.57	18.01		297	2.0	23.9	1599	2.45	49.45	23.54	20.18367
ESS Lab	et al. 2020	CO_MSPT2	816	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/1/2018	2018	Mueller Stat	38.88333	-105.1755	407.1	-8.42	-24.70	16.69		534	5.6	23.9	2918.1	2.17	48.64	26.14	22.41475
ESS Lab	et al. 2020	NM_TSVO(	807	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/31/2018	2018	Taos Ski Va	36.59469	-105.4795	408.9	-8.54	-25.01	16.89		786	6.9	23.9	2740.9	2.89	48.74	19.67	16.86505
ESS Lab	et al. 2020	NM_TSVPT	798	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/31/2018	2018	Taos Ski Va	36.5845	-105.4949	408.9	-8.54	-26.09	18.02		786	6.9	23.9	2651.6	2.13	48.42	26.51	22.73239
ESS Lab	et al. 2020	NM_TSVO(	806	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/31/2018	2018	Taos Ski Va	36.58242	-105.499	408.9	-8.54	-27.42	19.41		786	6.9	23.9	2740.9	1.94	48.02	28.87	24.75258
ESS Lab	et al. 2020	MN16-56	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Sequoia*	*Sequoia sempervirens*	12/23/2016	2016	UC Santa C	37.00082	-122.0619	404.55	-8.49	-27.84	19.91		849	13.9	24.1					
ESS Lab	et al. 2020	MHTO1931	183	S.N.	Grassl	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	7/4/1931	1931	Chene Islan	46.5022	-84.5501	307.7	-6.98	-24.31	17.76		852	4.8	24.2000	183	1.13	50.83	52.46	44.9823
ESS Lab	et al. 2020	MHTO1975	219	S.N.	J H Soper a	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	8/26/1975	1975	Algoma Dist	47.6459	-84.7952	330.06	-7.42	-25.88	18.95		852	4.8	24.2000	516.0000	1.24	49.18	46.25	39.66129
ESS Lab	et al. 2020	MN16-55	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Sequoia*	*Sequoia sempervirens*	12/23/2016	2016	UC Santa C	36.9996	-122.053	404.55	-8.49	-29.33	21.47		825	14.1	24.3					
ESS Lab	et al. 2020	MN16-54	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Sequoia*	*Sequoia sempervirens*	12/23/2016	2016	UC Santa C	36.99752	-122.0532	404.55	-8.49	-29.69	21.85		825	14.1	24.3					
ESS Lab	et al. 2020	BHTP1957/	545	S.N.	Carl A Linde	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	4/3/1957	1957	Along Blaine	48.92319	-122.3202	314.2	-7.07	-24.67	18.04		915	9.6	24.4	27	0.95	46.33	56.87	48.76842
ESS Lab	et al. 2020	MHTP1933	239	S.N.	P. A. Young	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	8/1/1933	1933	Glacier Nati	48.7198	-113.7938	308.6	-6.91	-27.08	20.72		1659	3.9	24.4000	1218.0000	1.25	40.80	38.06	32.64
ESS Lab	et al. 2020	WY_TCGPT	774	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/25/2018	2018	Teton Cany	43.75769	-110.957	410.88	-8.64	-27.20	19.08		1381	3.6	24.4	2095	1.80	51.00	33.04	28.33333
ESS Lab	et al. 2020	WY_TCGPT	775	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/25/2018	2018	Teton Cany	43.75769	-110.957	410.88	-8.64	-28.32	20.25		1381	3.6	24.4	2095	1.48	52.70	41.53	35.60811
ESS Lab	et al. 2020	WA_BWTP	726	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/14/2018	2018	Along U.S.2	47.776	-120.9515	411.3	-8.67	-28.62	20.53		2215	6.5	24.4	812.3	0.74	48.34	76.18	65.32432
ESS Lab	et al. 2020	BHTP1977I	553	#103	Richard R H	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	9/5/1977	1977	Hood River	45.39833	-121.4705	331.59	-7.49	-24.98	17.94		949	6.5	24.4	680	0.78	47.31	70.73	60.65385
ESS Lab	et al. 2020	UT_FLPT2(	864	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/6/2018	2018	Richfield, U	38.58189	-111.4792	407.1	-8.42	-24.84	16.84		449	6.0	24.5	2729.7	2.40	53.92	26.20	22.46667
ESS Lab	et al. 2020	UT_FLPT2(	865	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/6/2018	2018	Richfield, U	38.58189	-111.4792	407.1	-8.42	-25.00	17.00		449	6.0	24.5	2729.7	2.33	49.51	24.78	21.24893
ESS Lab	et al. 2020	UT_FLPT2(	866	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/6/2018	2018	Richfield, U	38.58189	-111.4792	407.1	-8.42	-26.17	18.23		449	6.0	24.5	2729.7	2.30	49.44	25.07	21.49565
ESS Lab	et al. 2020	UT_FLPT2(	867	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/6/2018	2018	Richfield, U	38.58189	-111.4792	407.1	-8.42	-26.24	18.30		449	6.0	24.5	2729.7	2.22	50.14	26.34	22.58559
ESS Lab	et al. 2020	UT_FLPT2(	863	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/6/2018	2018	Richfield, U	38.58496	-111.4805	407.1	-8.42	-29.02	21.21		449	6.0	24.5	2712.4	1.95	48.64	29.09	24.94359
ESS Lab	et al. 2020	MHTO1985A	223	S.N.	B J Madsen	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	7/21/1985	1985	Shingleton F	46.3483	-86.4702	346.56	-7.68	-25.59	18.38		983	4.9	24.6000	252.0000	0.86	48.58	65.88	56.48837
ESS Lab	et al. 2020	MHTO1985B	224	#3504	Brian T Haz	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	7/22/1985	1985	Otter Creek	44.7500	-86.0600	346.56	-7.68	-25.72	18.52		1090	7.3	24.6000		1.12	50.23	52.30	44.84821
ESS Lab	et al. 2020	MHPS1985A	289	#3502	Brian T Haz	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	7/23/1985	1985	Sleeping Be	45.06908	-86.00289	346.56	-7.68	-28.53	21.46		952	7.1	24.6	182				
ESS Lab	et al. 2020	BHTP1941	538	#7354	C L Hitchco	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	6/18/1941	1941	Hope, Britis	49.40405	-121.4205	310.4	-7.00	-23.66	17.06		1754	10.8	24.6	110	1.10	47.20	50.04	42.90909
ESS Lab	et al. 2020	MHTO1901	401	S.N.	H R Talcott	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	8/23/1901	1901	Marquette C	46.55357	-87.41629	296.1	-6.82	-22.68	16.22		735	10.9	24.6	228	1.28	50.34	45.86	39.328125
ESS Lab	et al. 2020	MN16-48	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Sequoia*	*Sequoia sempervirens*	12/21/2016	2016	Brookings,	42.12092	-124.1965	404.55	-8.49	-29.05	21.18		1952	13.1	24.6					
ESS Lab	et al. 2020	MN16-47	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Sequoia*	*Sequoia sempervirens*	12/21/2016	2016	Brookings,	42.11937	-124.196	404.55	-8.49	-29.51	21.66		1952	13.1	24.6					
ESS Lab	et al. 2020	MN17-59	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/17/2017	2017	Bordeaux, F	44.85021	0.57973	405.24	-8.55	-30.24	22.36		968	13.0	24.6					
ESS Lab	et al. 2020	MN16-49	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Sequoia*	*Sequoia sempervirens*	12/21/2016	2016	Brookings,	42.12194	-124.1967	404.55	-8.49	-30.32	22.51		1952	13.1	24.6					
ESS Lab	et al. 2020	AZ_MELPT	787	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/29/2018	2018	Mount Elder	35.27122	-111.6487	408.9	-8.54	-25.21	17.10		625	8.6	24.6	2167.4	2.37	47.45	23.35	20.0211
ESS Lab	et al. 2020	AZ_MELPT	788	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/29/2018	2018	Mount Elder	35.27724	-111.6482	408.9	-8.54	-26.06	17.99		625	8.6	24.6	2356.4	2.50	48.27	22.52	19.308
ESS Lab	et al. 2020	FMTO1918	305	#4244	C F Millspa	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	7/12/1918	1918	Ephraim, W	45.1533	-87.16671	302.4	-6.88	-25.03	18.61		1080	-1.9	24.7	213	1.44	48.56	39.33	33.72222222
ESS Lab	et al. 2020	MHTO1936	188	#7585	Grassl	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	9/16/1936	1936	Pardee Tow	48.0834	-89.63345	309.8	-6.94	-23.72	17.19		1025	-1.0	24.8	323	1.45	50.77	40.97	35.13495
ESS Lab	et al. 2020	YUTO1917	363	#2103	Harold St. J	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	7/10/1917	1917	St. John Po	46.4738	-69.90387	302.1	-6.88	-24.94	18.52		1126	1.4	24.8	476	1.00	46.24	53.92	46.24
ESS Lab	et al. 2020	FMTP1930	327	#1020	C B Wolf	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	10/25/1930	1930	Humboldt, C	40.73645	-123.9332	307.2	-6.92	-24.52	18.04		1053	12.2	24.9	444	0.98	51.61	61.41	52.66326531
ESS Lab	et al. 2020	MHTO1983	222	#5469	M J Schepa	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	8/13/1983	1983	Minnehaha	45.8425	-78.7250	342.38	-7.58	-25.26	18.14		1062	6.8	24.9000	396.0000	1.16	50.59	50.86	43.61207
ESS Lab	et al. 2020	YUTO1902A	355	S.N.	Nellie E Fly	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	4/25/1902	1902	Burlington,	41.76546	-72.95318	296.5	-6.82	-24.15	17.75		1459	8.3	24.9	254	1.27	44.07	40.47	34.7007874
ESS Lab	et al. 2020	YUTO1899B	353	#2269	Emile F Will	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	7/18/1899	1899	Mt. Desert,	44.34783	-68.33505	295.5	-6.68	-21.92	15.57		1088	6.8	25	21	1.53	49.18	37.49	32.14379085
ESS Lab	et al. 2020	CO_CCPT2	815	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/1/2018	2018	Cascade C	38.92067	-104.997	407.1	-8.42	-26.37	18.44		540	7.3	25	2333.5	2.74	47.72	20.31	17.41606
ESS Lab	et al. 2020	CO_CCPT2	814	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/1/2018	2018	Cascade C	38.92067	-104.997	407.1	-8.42	-27.38	19.50		540	7.3	25	2333.5	3.08	48.53	18.37	15.75649
ESS Lab	et al. 2020	CO_CCPT2	813	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/1/2018	2018	Cascade C	38.92031	-104.9938	407.1	-8.42	-27.78	19.92		540	7.3	25	2307.3	2.53	48.30	22.26	19.09091
ESS Lab	et al. 2020	MI_MMTO2	888	n/a	Ashley Ham	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	8/19/2018	2018	Marquette M	46.51	-87.422	407.1	-8.42	-28.62	20.79		1034	5.4	25.1	245.5	1.39	47.87	40.16	34.43885
ESS Lab	et al. 2020	FMTO1936C	310	#10162	Ray C Fies	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	8/22/1936	1936	Waldo Cour	44.5072	-69.01914	309.8	-6.94	-26.22	19.80		1359	6.9	25.1	61	1.29	48.60	43.94	37.6744186
ESS Lab	et al. 2020	CO_ELPT2	851	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/4/2018	2018	Vail, Colora	39.59959	-106.6053	407.1	-8.42	-27.88	20.02		599	5.8	25.1	2392.6	3.06	54.78	20.88	17.90196
ESS Lab	et al. 2020	MHTO1961	206	#9876	E. G. Voss	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/10/1961	1961	South Manit	45.0200	-86.1300	319.77	-7.07	-23.98	17.32		757	7.4	25.2000	182.0000	1.74	48.65	32.61	27.95977
ESS Lab	et al. 2020	BHTP2011/	569	#2011-039	John Flober	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/1/2011	2011	Brinnon, Wa	47.64917	-122.9345	394.28	-8.47	-25.24	17.21		1294	9.4	25.2	6	1.11	47.80	50.22	43.06306306
ESS Lab	et al. 2020	WY_GVPT2	772	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/22/2018	2018	Gros Ventre	43.62685	-110.5469	410.88	-8.64	-28.28	20.21		759	2.8	25.2	3156	1.80	50.45	32.69	28.02778
ESS Lab	et al. 2020	MI_PTO20	886	n/a	Ashley Ham	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	8/19/2018	2018	Paradise, M	46.623	-85.038	407.1	-8.42	-26.03	18.09		1225	5.1	25.3	193.3	1.81	49.17	31.68	27.16575
ESS Lab	et al. 2020	BHTP1908	530	S.N.	C S Eaton	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	1/5/1908	1908	Bellevue W	47.57994	-122.1547	298.9	-6.85	-26.16	19.83		904	10.4	25.3	84	1.06	47.07	51.79	44.40566
ESS Lab	et al. 2020	MHPS1968C	278	#12580	E. G. Voss	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	5/26/1968	1968	Felch, Mich	45.99704	-87.82559	325.57	-7.24	-26.34	19.61		938	5.3	25.3	365	1.39	45.93	38.53	33.04317
ESS Lab	et al. 2020	BHTP1934	535	#4356	Geo N Jone	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	3/10/1934	1934	Ames Lake,	47.63306	-121.965	309	-6.94	-26.55	20.15		1160	11.8	25.3	109	0.79	46.70	68.94	59.11392
ESS Lab	et al. 2020	MSTP1890	418	#236	Hicks	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	June 1890	1890	Portland, O	45.52215	-122.6325	294.2	-6.76	-25.80	19.54		864	11.0	25.3	58	0.54	50.02	108.02	92.62962963
ESS Lab	et al. 2020	BHTP1895	528	S.N.	J B Flett	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	8/10/1895	1895	Tacoma Wa	47.25306	-122.4431	294.8	-6.80	-26.53	20.27		916	10.4	25.3	68	0.87	46.61	62.48	53.57471
ESS Lab	et al. 2020	CO_FPT20	856	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/5/2018	2018	Frisco, Col	39.57442	-106.1001	407.1	-8.42	-25.92	17.97		490	4.0	25.3	2764.8	2.63	53.24	23.61	20.24335
ESS Lab	et al. 2020	CO_FPT20	853	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/4/2018	2018	Frisco, Col	39.58965	-106.0954	407.1	-8.42	-27.54	19.66		490	4.0	25.3	3225.6	2.34	53.58	26.70	22.89744
ESS Lab	et al. 2020	CSPT2003	686	#5140	Reif	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/10/2003	2003	Santa Fe N	35.63	-105.779	378.13	-8.29	-28.03	20.31		366	7.5	25.3	2331.7	2.80	52.15	21.72	18.625
ESS Lab	et al. 2020	MHTO1960	205	#9456	Voss	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	5/15/1960	1960	Cadillac, Mi	44.2500	-85.4000	320.04	-7.04	-24.53	17.93		775	5.8	25.3000	398.0000	1.48	48.89	38.52	33.03378
ESS Lab	et al. 2020	CUBPT198	681	#434	Colorado N	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/23/1984	1984	Hornbeck H	38.9275	-105.2821	346.8	-7.86	-27.84	20.55		464	3.2	25.4	2583	2.98	49.66	19.43	16.66443
ESS Lab	et al. 2020	FMTO1873	297	S.N.	H H Babcoc	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	7/25/1873	1873	Thousand Is	46.2213	-89.4000	288.1	-6.72	-23.81	17.50		662	3.7	25.4000	520.0000	0.85	50.87	69.79	59.84706
ESS Lab	et al. 2020	MHPS1978	284	#4232	Ruth B. Alfo	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	6/14/1978	1978	Greenland T	46.80847	-89.05851	337.89	-7.50	-25.51	18.48		889	4.7	25.4	291	1.14	49.27	50.40	43.2193
ESS Lab	et al. 2020	MHPS1857	248	S.N.	Geo. L. Am	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	10/10/1857	1857	Pownal, Ver	42.79437	-73.21687	285.7	-6.65	-27.63	21.57		951	6.6	25.5	333	1.51	48.11	37.16	31.86093
ESS Lab	et al. 2020	FMPS1998	345	#8419	Hess, Allen	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	8/26/1998	1993	Manistee, M	44.24433	-86.3338	365.78	-7.97	-26.98	19.54		820	9.7	25.5	199	1.06	49.20	54.13	46.41509
ESS Lab	et al. 2020	MHPS1956	268	#1896	Jennie V A	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	8/17/1956	1956	Traverse C	44.76068	-85.60535	313.6	-7.01	-27.52	21.09		736	7.1	25.5	184	1.23	43.67	41.40	35.50407
ESS Lab	et al. 2020	MHPS1968B	277	#47	M f Tessen	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	7/31/1968	1968	Delta Count	45.96836	-86.88642	324.14	-7.24	-25.25	18.47		958	5.9	25.5	214	1.46	47.45	37.90	32.5
ESS Lab	et al. 2020	FMPS1920	336	S.N.	H. H. York	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	5/1/1920	1920	Forestport,	43.44183	-75.20706	303	-6.93	-25.15	18.69		1230	5.9	25.6	342	2.07	46.31	26.09	22.37198
ESS Lab	et al. 2020	BHTP2003I	562	#270	Ben Legler	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	4/26/2003	2003	Airport Trail	48.15441	-122.1648	377.65	-8.29	-25.68	17.85		1128	10.6	25.8	38	1.17	51.01	50.84	43.5982906
ESS Lab	et al. 2020	BHTP2003	563	#280	Ben Legler	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	4/29/2003	2003	Arlington, W	48.19486	-122.1271	377.65	-8.29	-27.65	19.91		1160	10.6	25.8	35	1.11	49.24	51.73	44.36036036
ESS Lab	et al. 2020	BHTP2004	564	#531	Don Knoke	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/25/2004	2004	Cle Elum ,W	47.41546	-121.0825	380.62	-8.34	-25.09	17.18		1114	7.1	25.8	773	1.17	48.02	47.86	41.04273504
ESS Lab	et al. 2020	BHTP2012I	572	#24	Katie Parke	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	2/4/2012	2012	RW Johnso	47.02696	-122.9394	393.35	-8.34	-28.03	20.26		1754	9.9	25.8	41	0.82	48.95	69.62	59.69512195
ESS Lab	et al. 2020	CO_RGPT2	804	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/31/2018	2018	Beaver Cre	37.64764	-106.652	408.9	-8.54	-26.69	18.65		418	5.4	25.8	2531.8	1.83	47.06	29.99	25.71585
ESS Lab	et al. 2020	CO_RGPT2	805	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/31/2018	2018	Beaver Cre	37.64792	-106.6519	408.9	-8.54	-27.12	19.10		418	5.4	25.8	2612.3	2.68	48.66	21.17	18.15672
ESS Lab	et al. 2020	CO_RGFPT	811	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/31/2018	2018	Rio Grande	37.64789	-106.6518	408.9	-8.54	-27.34	19.33		418	5.4	25.8	2533.1	2.23	50.36	26.34	22.58296
ESS Lab	et al. 2020	CO_EPPT2	830	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/3/2018	2018	Rocky Mour	40.32553	-105.4968	407.1	-8.42	-27.53	19.65		581	6.9	25.8	2457.7	2.82	50.24	20.78	17.8156
ESS Lab	et al. 2020	WA_BGTP2	767	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/18/2018	2018	Bear Gulch	47.50404	-123.3143	411.3	-8.67	-28.12	20.01		3196	10.4	25.8	224.3	1.10	50.08	53.09	45.52727
ESS Lab	et al. 2020	CO_RGFPT	810	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/31/2018	2018	Rio Grande	37.64792	-106.6519	408.9	-8.54	-28.04	20.06		418	5.4	25.8	2531.9	2.55	48.51	22.18	19.02353
ESS Lab	et al. 2020	CO_RGFPT	812	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/31/2018	2018	Rio Grande	37.64764	-106.652	408.9	-8.54	-28.11	20.14		418	5.4	25.8	2536	2.02	47.94	27.68	23.73267
ESS Lab	et al. 2020	WA_METP2	765	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/18/2018	2018	NFD-24, Mt	47.49553	-123.2597	411.3	-8.67	-28.26	20.16		3169	10.4	25.8	237.4	1.36	49.67	42.59	36.52206
ESS Lab	et al. 2020	WA_METP2	764	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/18/2018	2018	NFD-24, Mt	47.49553	-123.2597	411.3	-8.67	-28.45	20.36		3169	10.4	25.8	237.4	0.97	48.22	57.97	49.71134
ESS Lab	et al. 2020	WA_DFTP2	724	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/14/2018	2018	Deception F	47.71553	-121.1957	411.3	-8.67	-28.78	20.70		2200	8.9	25.8	549.6	0.85	48.35	66.34	56.88235
ESS Lab	et al. 2020	WA_METP2	766	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/18/2018	2018	NFD-24, Mt	47.49553	-123.2597	411.3	-8.67	-29.05	20.99		3169	10.4	25.8	237.4	0.67	47.70	83.03	71.19403
ESS Lab	et al. 2020	WA_METP2	763	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/18/2018	2018	NFD-24, Mt	47.49553	-123.2597	411.3	-8.67	-29.27	21.22		3169	10.4	25.8	237.4	1.00	49.79	58.06	49.79
ESS Lab	et al. 2020	WA_CMTP	770	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/18/2018	2018	Copper Mou	47.51687	-123.3284	411.3	-8.67	-30.11	22.10		3196	10.4	25.8	289.56	0.79	50.93	75.18	64.46835
ESS Lab	et al. 2020	WA_DFTP2	725	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/14/2018	2018	Deception F	47.71701	-121.1974	411.3	-8.67	-30.81	22.85		2200	8.9	25.8	559.6	0.78	47.93	71.66	61.44872
ESS Lab	et al. 2020	WA_SCTP2	769	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/18/2018	2018	Staircase C	47.51609	-123.3274	411.3	-8.67	-32.23	24.35		3196	10.4	25.8	289.3	0.99	50.49	59.48	51
ESS Lab	et al. 2020	WA_SCTP2	768	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/18/2018	2018	Staircase C	47.51615	-123.3277	411.3	-8.67	-32.41	24.54		3196	10.4	25.8	296.6	1.22	49.10	46.93	40.2459
ESS Lab	et al. 2020	FMPS1939	341	#3129	Olga Lakela	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	7/12/1962	1962	Duluth, Minn	46.7797	-92.15932	319.61	-7.09	-26.52	19.95		655	4.2	25.9	409	1.40	46.33	38.59	33.09286
ESS Lab	et al. 2020	NM_TSVPT	797	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/31/2018	2018	Taos Ski Va	36.56231	-105.5309	408.9	-8.54	-25.18	17.07		633	7.9	25.9	2492.1	1.94	47.94	28.82	24.71134
ESS Lab	et al. 2020	WA_TMTP2	702	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	10/22/2017	2017	Tiger Mount	47.44207	-121.7039	401.5	-8.39	-31.18	23.53		2144	11.2	25.9	204.8	1.59	47.21	34.63	29.6918239
ESS Lab	et al. 2020	MHTO1954	201	#1304	Jennie V A	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	8/25/1954	1954	Traverse C	44.7600	-85.6200	312.4	-7.01	-25.22	18.68		778	7.7	26.0000	185.0000	1.50	48.07	37.37	32.04667
ESS Lab	et al. 2020	AZ_ASPT2(	784	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/29/2018	2018	Arizona Snc	35.25881	-111.6201	408.9	-8.54	-25.67	17.58		524	9.2	26	2374.1	2.05	47.71	27.14	23.27317
ESS Lab	et al. 2020	AZ_ASPT2(	783	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/29/2018	2018	Arizona Snc	35.25868	-111.6206	408.9	-8.54	-25.70	17.61		524	9.2	26	2375.9	2.23	47.30	24.74	21.21076
ESS Lab	et al. 2020	UT_FLPT2(	861	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/6/2018	2018	Fremont, Ut	38.60374	-111.4675	407.1	-8.42	-27.71	19.84		357	7.0	26	2672.5	2.04	48.00	27.44	23.52941
ESS Lab	et al. 2020	UT_FLPT2(	862	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/6/2018	2018	Fremont, Ut	38.60374	-111.4675	407.1	-8.42	-28.23	20.39		357	7.0	26	2672.5	2.11	52.35	28.93	24.81043
ESS Lab	et al. 2020	MHTP1928	238	S.N.	C H Kauffm	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	7/30/1928	1928	Echo Lake,	48.1152	-114.0350	306.3	-6.91	-28.11	21.81		390	6.2	26.1000	918.0000	1.14	48.58	49.70	42.61404
ESS Lab	et al. 2020	YUTO1903	357	S.N.	E. H. Thom	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	4/25/1903	1903	Litchfield, C	41.74093	-73.18949	296.8	-6.77	-23.13	16.75		1410	7.7	26.1	313	1.36	46.33	39.73	34.06617647
ESS Lab	et al. 2020	FMPS1937	339	#554	G E Jenning	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	9/25/1937	1937	Buckstown,	40.04631	-78.88389	310	-6.95	-26.35	19.93		1149	8.4	26.1	736	0.64	47.14	85.90	73.65625
ESS Lab	et al. 2020	BHTP2012(	573	#2012-035	Karen Peter	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	7/20/2012	2012	NF-3155, M	48.95534	-117.2315	394.52	-8.38	-28.48	20.69		1241	5.5	26.1	1052	0.93	50.85	63.76	54.67741935
ESS Lab	et al. 2020	MI_GATO2	872	n/a	Rebecca D	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	7/20/2018	2018	Glen Arbor,	44.89987	-86.01445	408.9	-8.54	-27.93	19.94		904	8.1	26.1	181.6	2.52	43.94	20.33	17.43650794
ESS Lab	et al. 2020	CO_SLSPF	857	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/5/2018	2018	Gypsum, Co	39.50353	-106.7519	407.1	-8.42	-25.56	17.59		471	5.8	26.1	2445.3	2.37	53.01	26.08	22.36709
ESS Lab	et al. 2020	CO_SLSPF	859	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/5/2018	2018	Gypsum, Co	39.50668	-106.7517	407.1	-8.42	-26.54	18.61		471	5.8	26.1	2437.8	2.45	54.81	26.09	22.37143

ESS Lab	et al. 2020	CO_SLSPF	871	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides		8/5/2018	2018	Gypsum, Co	39.50668	-106.7517	407.1	-8.42	-27.10	19.20	471	5.8	26.1	2437.8	2.36	49.39	24.41	20.92797
ESS Lab	et al. 2020	CO_SLSPF	860	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides		8/5/2018	2018	Gypsum, Co	39.50668	-106.7517	407.1	-8.42	-27.71	19.84	471	5.8	26.1	2437.8	2.32	51.18	25.73	22.06034
ESS Lab	et al. 2020	CO_SLSPF	858	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides		8/5/2018	2018	Gypsum, Co	39.50456	-106.7517	407.1	-8.42	-29.30	21.51	471	5.8	26.1	2444.2	1.79	54.07	35.23	30.2067
ESS Lab	et al. 2020	MHPS1951A	264	#856	H. H. Bartle	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus strobus		9/16/1951	1951	Marathon C	44.86257	-89.73459	311.1	-6.99	-26.27	19.79	900	4.7	26.2	379	1.12	49.86	51.92	44.51786
ESS Lab	et al. 2020	YUTO1887	349	#282	J H Schuett	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja occidentalis		8/2/1887	1887	Brown Cour	44.52727	-87.99325	293.6	-6.77	-25.47	19.18	499	6.0	26.2	178	1.24	47.27	44.46	38.12096774
ESS Lab	et al. 2020	MN16-38	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Taxodium	Taxodium distichum		9/11/2016	2016	Matthaei Bo	42.3004	-83.6614	401.01	-8.35	-27.07	19.24	850	8.9	26.2					
ESS Lab	et al. 2020	WA_MSTP	711	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja plicata		5/12/2018	2018	Mt. Si Trail	47.50472	-121.7399	411.3	-8.67	-29.76	21.73	2365	10.6	26.2	1102	1.05	50.07	55.61	47.68571
ESS Lab	et al. 2020	FMPS1938	340	#C165	Chester C	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus strobus		8/17/1938	1938	Baileys Har	45.06485	-87.12423	310.2	-6.94	-26.77	20.37	874	7.1	26.3	179	1.41	47.97	39.67	34.02128
ESS Lab	et al. 2020	MHPS1982	288	JVF #79	JV & T Freu	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus strobus		7/17/1982	1982	Mikado, Mic	44.59089	-83.4222	342.06	-7.67	-28.96	21.93	636	6.7	26.3	198	2.06	48.63	27.53	23.6068
ESS Lab	et al. 2020	YUTO1984	368	#9536	Leslie J Me	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja occidentalis		3/16/1984	1984	Canaan, Co	41.96627	-73.31242	345.28	-7.81	-25.91	18.58	1313	10.6	26.3	239	1.07	46.65	50.84	43.59813084
ESS Lab	et al. 2020	YUTP1876	369	#10	T J Howell	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja plicata		2/18/1905	1905	Sauvies Isla	45.70244	-122.8174	297.6	-6.83	-25.36	19.01	990	10.8	26.3	7	1.23	47.94	45.45	38.97560976
ESS Lab	et al. 2020	YUTO1879	348	S.N.	George H. I	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja occidentalis		July 1879	1879	Newport, Ve	44.93789	-72.20038	290.2	-6.74	-24.55	18.25	853	5.7	26.4	217	1.04	48.55	54.44	46.68269231
ESS Lab	et al. 2020	MN16-57	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Sequoia	Sequoia sempervirens		12/23/2016	2016	San Louis O	35.27982	-120.6647	404.55	-8.49	-28.01	20.09	599	15.6	26.4					
ESS Lab	et al. 2020	MN16-58	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Sequoia	Sequoia sempervirens		12/23/2016	2016	San Louis O	35.27985	-120.6645	404.55	-8.49	-29.10	21.23	599	15.6	26.4					
ESS Lab	et al. 2020	MHTO2007	232	#11883	Timoth L W	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja occidentalis		5/16/2007	2007	Whitewater	44.7700	-85.4000	386.41	-8.40	-28.51	20.70	659	7.9	26.4000	214.0000	0.79	61.44	90.70	77.776
ESS Lab	et al. 2015	6_H98004_	192	n/a	Chelsea Me	Angiosperm	Woody	C3	Woody Ang	Sapindacea	Acer	Acer saccharu m		10/15/2014	2014	Hidden Lake	42.02897	-84.11142	395.65	-8.19	-27.88	20.26	824	8.9	26.5		0.51	43.43	99.31	
ESS Lab	et al. 2015	6_90013	204	n/a	Chelsea Me	Angiosperm	Woody	C3	Woody Ang	Sapindacea	Acer	Acer griseum		10/15/2014	2014	Hidden Lake	42.02961	-84.11139	395.65	-8.19	-27.88	20.26	824	8.9	26.5		2.21	47.24	24.93	
ESS Lab	et al. 2020	YUPS1897	379	#2525	C. W. Swan	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus strobus		4/25/1897	1897	Lexington, M	42.45272	-71.23522	295	-6.80	-24.34	17.98	1134	8.6	26.5	67	1.37	48.75	41.50	35.58394
ESS Lab	et al. 2015	1_H10001K	6	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Cupressace	Juniperus	Juniperus sabina		8/25/2014	2014	Hidden Lake	42.02894	-84.11183	397.21	-8.27	-22.63	14.70	824	8.9	26.5		1.60	49.80	36.30	
ESS Lab	et al. 2015	1_H10138A	40	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Cupressace	Thujopsis	Thujopsis d	(Chamaecy	8/25/2014	2014	Hidden Lake	42.02908	-84.11228	397.21	-8.27	-23.26	15.35	824	8.9	26.5		1.27	49.21	45.19	
ESS Lab	et al. 2015	2_H81017	108	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Cupressace	Chamaecy	Chamaecyparis obtusa		9/5/2014	2014	Hidden Lake	42.02936	-84.11281	395.4	-8.20	-23.22	15.38	824	8.9	26.5		1.43	48.89	39.87	
ESS Lab	et al. 2015	5_H09410A	182	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Cupressace	Juniperus	Juniperus squamata		10/5/2014	2014	Hidden Lake	42.03025	-84.1125	395.65	-8.19	-24.94	17.17	824	8.9	26.5		1.94	47.32	28.45	
ESS Lab	et al. 2015	2_H83072	94	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus parviflora		9/5/2014	2014	Hidden Lake	42.02908	-84.11294	395.4	-8.20	-25.05	17.29	824	8.9	26.5		1.29	50.99	46.10	
ESS Lab	et al. 2015	1_H81261	63	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Cupressace	Taxodium	Taxodium distichum		8/25/2014	2014	Hidden Lake	42.02947	-84.11247	397.21	-8.27	-25.70	17.89	824	8.9	26.5		1.63	47.90	34.27	
ESS Lab	et al. 2015	1_H81023	41	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Cupressace	Chamaecy	Chamaecyparis obtusa		8/25/2014	2014	Hidden Lake	42.02903	-84.11228	397.21	-8.27	-25.71	17.90	824	8.9	26.5		1.65	49.63	35.08	
ESS Lab	et al. 2015	1_H81043	32	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Cupressace	Chamaecy	Chamaecyparis pisifera		8/25/2014	2014	Hidden Lake	42.02903	-84.11206	397.21	-8.27	-26.05	18.25	824	8.9	26.5		1.32	47.24	41.74	
ESS Lab	et al. 2015	1_H88007	35	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Cupressace	Xanthocypa	Cupressus nootkatensis		8/25/2014	2014	Hidden Lake	42.02906	-84.11208	397.21	-8.27	-26.17	18.38	824	8.9	26.5		0.86	49.47	67.08	
ESS Lab	et al. 2015	4_H10084A	155	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Sciadopitya	Sciadopitys	Sciadopitys verticillata		10/1/2014	2014	Hidden Lake	42.02844	-84.11206	395.65	-8.19	-26.29	18.58	824	8.9	26.5		1.07	49.68	54.15	
ESS Lab	et al. 2015	2_H81285	96	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Cupressace	Thuja	Thuja occidentalis		2014	2014	Hidden Lake	42.02911	-84.11281	401.31	-8.20	-26.45	18.75	824	8.9	26.5		1.58	48.08	35.49	
ESS Lab	et al. 2015	1_H81291	62	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Cupressace	Thuja	Thuja occidentalis		2014	2014	Hidden Lake	42.02947	-84.11242	401.31	-8.20	-26.53	18.83	824	8.9	26.5		1.67	50.44	35.22	
ESS Lab	et al. 2015	5_H84249	187	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Cupressace	Xanthocypa	Cupressus nootkatensis		10/5/2014	2014	Hidden Lake	42.02975	-84.11228	395.65	-8.19	-26.58	18.89	824	8.9	26.5		1.40	50.98	42.47	
ESS Lab	et al. 2015	1_H81225	53	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus strobus		8/25/2014	2014	Hidden Lake	42.02928	-84.11244	397.21	-8.27	-26.67	18.90	824	8.9	26.5		2.30	50.88	25.80	
ESS Lab	et al. 2015	1_H81164	44	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Picea	Picea pungens		8/25/2014	2014	Hidden Lake	42.02914	-84.11175	397.21	-8.27	-26.82	19.06	824	8.9	26.5		1.42	48.33	39.69	
ESS Lab	et al. 2015	1_H82173	50	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Cupressace	Juniperus	Juniperus chinensis		8/25/2014	2014	Hidden Lake	42.02922	-84.11242	397.21	-8.27	-26.90	19.14	824	8.9	26.5		1.67	48.61	33.94	
ESS Lab	et al. 2015	2_H11008A	82	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Cupressace	Xanthocypa	Cupressus nootkatensis		9/5/2014	2014	Hidden Lake	42.02889	-84.11261	395.4	-8.20	-26.91	19.23	824	8.9	26.5		1.20	53.33	51.83	
ESS Lab	et al. 2015	64113	207	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Cupressace	Juniperus	Juniperus horizontalis		11/1/2014	2014	Hidden Lake	42.02581	-84.11481	397.23	-8.29	-27.09	19.33	824	8.9	26.5		1.37	48.92	41.64	
ESS Lab	et al. 2015	4_H11004A	146	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Cupressace	Microbiota	Microbiota decussata		10/1/2014	2014	Hidden Lake	42.02864	-84.11214	395.65	-8.19	-27.01	19.34	824	8.9	26.5		1.09	52.12	55.76	
ESS Lab	et al. 2015	1_H83230	37	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Cupressace	Thuja	Thuja occidentalis		2014	2014	Hidden Lake	42.02908	-84.11214	401.31	-8.20	-27.10	19.43	824	8.9	26.5		1.58	49.13	36.26	
ESS Lab	et al. 2015	1_H81328	64	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Tsuga	Tsuga canadensis		8/25/2014	2014	Hidden Lake	42.02961	-84.11242	397.21	-8.27	-27.21	19.47	824	8.9	26.5		1.60	49.01	35.72	
ESS Lab	et al. 2015	5_H14027A	179	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Abies	Abies homolepis		10/5/2014	2014	Hidden Lake	42.03008	-84.11289	395.65	-8.19	-27.14	19.48	824	8.9	26.5		1.08	54.94	59.32	
ESS Lab	et al. 2015	1_H10026C	11	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Cupressace	Juniperus	Juniperus procumbens		9/5/2014	2014	Hidden Lake	42.02581	-84.11192	395.4	-8.20	-27.20	19.53	824	8.9	26.5		1.40	45.35	37.78	
ESS Lab	et al. 2015	5_H10016A	185	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Abies	Abies homolepis		10/5/2014	2014	Hidden Lake	42.02969	-84.11219	395.65	-8.19	-27.20	19.54	824	8.9	26.5		1.51	52.11	40.24	
ESS Lab	et al. 2015	4_H81134	160	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Tsuga	Tsuga diversifolia		10/1/2014	2014	Hidden Lake	42.02917	-84.11308	395.65	-8.19	-27.21	19.56	824	8.9	26.5		1.15	50.99	51.71	
ESS Lab	et al. 2015	1_H81174	68	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus cembra		8/25/2014	2014	Hidden Lake	42.02958	-84.11233	397.21	-8.27	-27.32	19.58	824	8.9	26.5		1.39	44.05	36.96	
ESS Lab	et al. 2015	2_H81129	87	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Picea	Picea asperata		9/5/2014	2014	Hidden Lake	42.02886	-84.11278	395.4	-8.20	-27.41	19.75	824	8.9	26.5		1.28	48.85	44.51	
ESS Lab	et al. 2015	6_Ubed#2_	200	n/a	Chelsea Me	Angiosperm	Woody	C3	Woody Ang	Lauraceae	Sassafras	Sassafras officinale		10/15/2014	2014	Hidden Lake	42.03021	-84.11268	395.65	-8.19	-27.45	19.80	824	8.9	26.5		1.71	48.16	32.84	
ESS Lab	et al. 2015	67131	208	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Cupressace	Thuja	Thuja occidentalis		2014	2014	Hidden Lake	42.02597	-84.11478	401.31	-8.20	-27.60	19.95	824	8.9	26.5		1.86	51.76	32.45	
ESS Lab	et al. 2015	4_H81010	161	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Abies	Abies lasiocarpa		10/1/2014	2014	Hidden Lake	42.02925	-84.11303	395.65	-8.19	-27.68	20.04	824	8.9	26.5		1.81	50.80	32.73	
ESS Lab	et al. 2015	1_H81143	39	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Picea	Picea omorika		8/25/2014	2014	Hidden Lake	42.02914	-84.11228	397.21	-8.27	-27.77	20.06	824	8.9	26.5		0.89	44.53	58.35	
ESS Lab	et al. 2015	1_H05005	46	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus koraiensis		8/25/2014	2014	Hidden Lake	42.02931	-84.11256	397.21	-8.27	-27.88	20.17	824	8.9	26.5		1.09	50.47	54.00	
ESS Lab	et al. 2015	2_08113	107	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Picea	Picea engelmannii		9/5/2014	2014	Hidden Lake	42.02925	-84.11275	395.4	-8.20	-27.90	20.26	824	8.9	26.5		1.92	45.64	27.72	
ESS Lab	et al. 2015	2_H81182	103	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus densiflora		9/5/2014	2014	Hidden Lake	42.02897	-84.11269	395.4	-8.20	-28.02	20.39	824	8.9	26.5		1.09	51.11	54.68	
ESS Lab	et al. 2015	1_H83004	29	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus densiflora		8/25/2014	2014	Hidden Lake	42.02889	-84.11231	397.21	-8.27	-28.16	20.47	824	8.9	26.5		1.38	50.08	42.32	
ESS Lab	et al. 2015	2_H03002	112	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Abies	Abies fraseri		9/5/2014	2014	Hidden Lake	42.02922	-84.11294	395.4	-8.20	-28.17	20.55	824	8.9	26.5		1.70	50.48	34.63	
ESS Lab	et al. 2015	3_H05024	132	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus pumila		9/24/2014	2014	Hidden Lake	42.02822	-84.11258	395.4	-8.20	-28.33	20.72	824	8.9	26.5		1.44	50.82	41.16	
ESS Lab	et al. 2015	2_H94004	102	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Abies	Abies koreana		9/5/2014	2014	Hidden Lake	42.02894	-84.11267	395.4	-8.20	-28.34	20.72	824	8.9	26.5		1.79	51.90	33.81	
ESS Lab	et al. 2015	5_H05001	177	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Abies	Abies nordmanniana		10/5/2014	2014	Hidden Lake	42.03003	-84.11281	395.65	-8.19	-28.62	21.03	824	8.9	26.5		1.53	49.92	38.05	
ESS Lab	et al. 2015	1_H81121	31	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Picea	Picea abies		8/25/2014	2014	Hidden Lake	42.02903	-84.11206	397.21	-8.27	-28.77	21.10	824	8.9	26.5		1.80	47.23	30.60	
ESS Lab	et al. 2015	1_H05012	15	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pseudotsug	Pseudotsuga menziesii		8/25/2014	2014	Hidden Lake	42.02892	-84.11175	397.21	-8.27	-28.79	21.13	824	8.9	26.5		1.45	50.45	40.58	
ESS Lab	et al. 2015	1_H81327	58	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Tsuga	Tsuga canadensis		8/25/2014	2014	Hidden Lake	42.02942	-84.11244	397.21	-8.27	-28.83	21.17	824	8.9	26.5		1.96	49.66	29.55	
ESS Lab	et al. 2015	3_H95052	119	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Tsuga	Tsuga canadensis		9/24/2014	2014	Hidden Lake	42.02858	-84.11253	395.4	-8.20	-28.95	21.37	824	8.9	26.5		1.33	48.68	42.68	
ESS Lab	et al. 2015	3_H95005	140	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Abies	Abies numidica		9/24/2014	2014	Hidden Lake	42.02836	-84.11217	395.4	-8.20	-28.96	21.38	824	8.9	26.5		1.67	48.07	33.57	
ESS Lab	et al. 2015	5_H97080	174	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Abies	Abies chensiensis		10/5/2014	2014	Hidden Lake	42.02969	-84.11297	395.65	-8.19	-29.16	21.60	824	8.9	26.5		1.49	48.56	38.01	
ESS Lab	et al. 2015	2_H81002	110	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Abies	Abies concolor		9/5/2014	2014	Hidden Lake	42.02942	-84.11275	395.4	-8.20	-29.23	21.67	824	8.9	26.5		1.36	50.99	43.72	
ESS Lab	et al. 2015	2_H81236	97	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus strobus		2014	2014	Hidden Lake	42.02914	-84.11275	401.31	-8.20	-29.32	21.76	824	8.9	26.5		1.64	50.52	35.92	
ESS Lab	et al. 2015	1_H85065	1	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Picea	Picea abies		8/25/2014	2014	Hidden Lake	42.02903	-84.11172	397.21	-8.27	-29.41	21.78	824	8.9	26.5		1.29	48.79	44.11	
ESS Lab	et al. 2015	1_H93032	52	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Picea	Picea glauca		8/25/2014	2014	Hidden Lake	42.02925	-84.11242	397.21	-8.27	-29.54	21.92	824	8.9	26.5		1.57	49.82	37.01	
ESS Lab	et al. 2015	6_90012	205	n/a	Chelsea Me	Angiosperm	Woody	C3	Woody Ang	Cornaceae	Cornus	Cornus kou	unresolved	10/15/2014	2014	Hidden Lake	42.02969	-84.11139	395.65	-8.19	-29.47	21.93	824	8.9	26.5		1.64	39.79	28.29	
ESS Lab	et al. 2015	2_H10002A	81	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus heldreichii		9/5/2014	2014	Hidden Lake	42.02889	-84.11258	395.4	-8.20	-29.55	22.00	824	8.9	26.5		0.94	50.08	62.13	
ESS Lab	et al. 2015	5_H83037	189	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus cembra		2014	2014	Hidden Lake	42.02992	-84.11247	401.31	-8.20	-29.56	22.01	824	8.9	26.5		2.29	52.53	26.75	
ESS Lab	et al. 2015	1_H99018	8	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus sylvestris		8/25/2014	2014	Hidden Lake	42.02894	-84.11183	397.21	-8.27	-29.68	22.06	824	8.9	26.5		0.91	47.21	60.50	
ESS Lab	et al. 2015	1_H84244	17	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus cembra		8/25/2014	2014	Hidden Lake	42.02881	-84.11203	397.21	-8.27	-29.74	22.13	824	8.9	26.5		1.84	50.63	32.09	
ESS Lab	et al. 2015	1_H85116	36	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Picea	Picea orientalis		8/25/2014	2014	Hidden Lake	42.02914	-84.11208	397.21	-8.27	-29.75	22.14	824	8.9	26.5		1.08	49.78	53.75	
ESS Lab	et al. 2015	4_H97033	159	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus nigra		10/1/2014	2014	Hidden Lake	42.0285	-84.11225	395.65	-8.19	-29.90	22.38	824	8.9	26.5		1.02	49.65	56.77	
ESS Lab	et al. 2015	4_H96001	152	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Cupressace	Juniperus	Juniperus chinensis		10/1/2014	2014	Hidden Lake	42.02853	-84.11211	395.65	-8.19	-29.98	22.46	824	8.9	26.5		1.68	48.83	33.90	
ESS Lab	et al. 2015	1_H92113	22	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus mugo		8/25/2014	2014	Hidden Lake	42.02892	-84.11206	397.21	-8.27	-30.15	22.56	824	8.9	26.5		1.24	48.92	46.01	
ESS Lab	et al. 2015	1_H97041	27	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Tsuga	Tsuga canadensis		8/25/2014	2014	Hidden Lake	42.02894	-84.11222	397.21	-8.27	-30.15	22.56	824	8.9	26.5		1.53	46.79	35.66	
ESS Lab	et al. 2015	6_86091_R	194	n/a	Chelsea Me	Angiosperm	Woody	C3	Woody Ang	Cornaceae	Cornus	Cornus kou	unresolved	10/15/2014	2014	Hidden Lake	42.02955	-84.11144	395.65	-8.19	-30.82	23.35	824	8.9	26.5		0.85	41.56	57.02	
ESS Lab	et al. 2015	5_H10029A	184	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus banksiana		10/5/2014	2014	Hidden Lake	42.02967	-84.11228	395.65	-8.19	-31.01	23.55	824	8.9	26.5		1.77	51.12	33.68	
ESS Lab	et al. 2015	6_86064	197	n/a	Chelsea Me	Angiosperm	Woody	C3	Woody Ang	Rosaceae	Prunus	Prunus subhirtella		10/15/2014	2014	Hidden Lake	42.0283	-84.11206	395.65	-8.19	-31.17	23.72	824	8.9	26.5		3.23	43.02	15.53	
ESS Lab	et al. 2015	3_H99011	123	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Larix	Larix laricina		9/24/2014	2014	Hidden Lake	42.02844	-84.11264	395.4	-8.20	-31.25	23.79	824	8.9	26.5		1.81	49.52	31.91	
ESS Lab	et al. 2015	2_H76371	99	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Larix	Larix kaempferi		9/5/2014	2014	Hidden Lake	42.02911	-84.11269	395.4	-8.20	-31.34	23.89	824	8.9	26.5		2.24	48.42	25.21	
ESS Lab	et al. 2015	6_86091_G	193	n/a	Chelsea Me	Angiosperm	Woody	C3	Woody Ang	Cornaceae	Cornus	Cornus kou	unresolved	10/15/2014	2014	Hidden Lake	42.02939	-84.11148	395.65	-8.19	-31.36	23.92	824	8.9	26.5		1.39	41.69	34.98	
ESS Lab	et al. 2015	2_H03001	80	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Abies	Abies cephalonica		9/5/2014	2014	Hidden Lake	42.02908	-84.11244	395.4	-8.20	-31.76	24.33	824	8.9	26.5		1.30	49.86	44.73	
ESS Lab	et al. 2015	6_90010_G	196	n/a	Chelsea Me	Angiosperm	Woody	C3	Woody Ang	Altingiaceae	Liquidamba	Liquidamba	unresolved	10/15/2014	2014	Hidden Lake	42.02955	-84.11144	395.65	-8.19	-32.01	24.61	824	8.9	26.5		1.60	43.12	31.43	
ESS Lab	et al. 2015	6_Ubed#1_	201	n/a	Chelsea Me	Angiosperm	Woody	C3	Woody Ang	Lauraceae	Sassafras	Sassafras officinale		10/15/2014	2014	Hidden Lake	42.03022	-84.11264	395.65	-8.19	-32.08	24.68	824	8.9	26.5		1.85	47.79	30.13	
ESS Lab	et al. 2015	6_90010_R	195	n/a	Chelsea Me	Angiosperm	Woody	C3	Woody Ang	Altingiaceae	Liquidamba	Liquidamba	unresolved	10/15/2014	2014	Hidden Lake	42.02955	-84.11144	395.65	-8.19	-32.14	24.74	824	8.9	26.5		1.38	44.02	37.20	
ESS Lab	et al. 2020	MHPS1951B	265	#907	H. H. Bartle	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus strobus		9/17/1951	1951	Portage Co	44.51923	-89.5068	311.1	-6.99	-25.26	18.74	885	4.9	26.5	336	1.05	48.95	54.37	46.61905
ESS Lab	et al. 2020	MHTO1962B	208	S.N.	A Walther, A	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja occidentalis		9/23/1962	1962	Otter Lake,	45.8489	-76.4297	316.25	-7.09	-25.01	18.37	885	4.4	26.6000	210.0000	1.22	49.21	47.04	40.33607
ESS Lab	et al. 2020	BHTP1942I	540	#153	George H W	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja plicata		9/1/1942	1942	Big Creek C	47.562	-120.7795	310.3	-6.96	-25.24	18.75	832	5.8	26.6	642	1.42	47.70	39.17	33.59155
ESS Lab	et al. 2020	BHTP1994	560	#3160	James F Sr	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja plicata		7/9/1994	1994	Priest River	48.16662	-116.9666	359.55	-7.84	-25.87	18.51	1270	10.8	26.6	694	0.91	49.16		
ESS Lab	et al. 2020	MHTO1941	194	S.N.	M N Zinck	Gymnosper	Woody	C3	Woody Gym	Cupressace	Thuja	Thuja occidentalis		7/3/1941	1941	Goulbourn T	45.2350	-75.9040	310.4	-7.00	-24.60	18.05	868	6.0	26.6000	115.0000	1.07	50.47	55.01	47.16822
ESS Lab	et al. 2020	WA_HLTP2	720	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja plicata		5/14/2018	2018	Heybrook L	47.80802	-121.5345	411.3	-8.67	-26.18	17.98	2935	10.7	26.6	250.2	1.47	49.83	39.53	33.89796
ESS Lab	et al. 2020	WA_HLTP2	721	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja plicata		5/14/2018	2018	Heybrook L	47.80783	-121.5339	411.3	-8.67	-26.66	18.49	2935	10.7	26.6	251.8	0.65	50.67	90.91	77.95385
ESS Lab	et al. 2020	WA_HLTP2	719	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja plicata		5/14/2018	2018	Heybrook L	47.80829	-121.5348	411.3	-8.67	-27.37	19.22	2935	10.7	26.6	233.5	1.46	50.64	40.45	34.68493
ESS Lab	et al. 2020	WA_HLTP2	722	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja plicata		5/14/2018	2018	Heybrook L	47.80886	-121.5328	411.3	-8.67	-28.38	20.29	2935	10.7	26.6	311.5	1.17	47.98	47.82	41.00855
ESS Lab	et al. 2020	BHTP1992	559	G&R019	Sarah Gage	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja plicata		5/3/1992	1992	Olympia, W	47.06632	-122.8337	359.66	-7.99	-28.31	20.92	991	11.4	26.6	48	1.05	47.83	53.12	45.55238095
ESS Lab	et al. 2020	MHTO2008	233	#12004	Thomas G L	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja occidentalis		8/11/2008	2008	Menominee	45.5200	-87.4000	384.08	-8.16	-25.90	18.21	701	5.3	26.6000	182.0000	0.90	57.79	74.88	64.20988
ESS Lab	et al. 2020	WY_CGPT2	771	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides		6/19/2018	2018	Laramie, W	41.17924	-105.2423	410.88	-8.64	-26.11	17.94	567	6.0	26.7	2217.42	2.36	47.98	23.71	20.33051
ESS Lab	et al. 2020	WY_JLPT2	776	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides		7/2/2018	2018	Jackson La	43.9771	-110.6569	408.9	-8.54	-29.68	21.79	1033	2.7	26.7	2075	2.31	51.67	26.09	22.36797
ESS Lab	et al. 2020	YUPS1958	388	#758	J. Ebinger	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus strobus		8/28/1958	1958	Bethany, Co	41.42641	-72.99016	314.93	-7.02	-23.65	17.03	1390	8.4	26.8	175	1.06	46.32	50.96	43.69811
ESS Lab	et al. 2020	FMTO1896	299	#56	M C Jensar	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja occidentalis		3/10/1905	1905	Lake Fores	42.2533	-87.8339	297.6	-6.83	-24.35	17.96	715	5.1	26.8000	207.0000	1.21	48.67	46.91	40.22314
ESS Lab	et al. 2020	YUTO1920	364	S.N.	H Castle	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja occidentalis		8/1/1920	1920	Ithaca, New	42.44216	-76.49752	303	-6.93	-23.28	16.74	944	7.2	26.9	124	1.77	46.68	30.76	26.37288136
ESS Lab	et al. 2020	MN16-39	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Taxodium	Taxodium distichum		9/13/2016	2016	Panera Bre	42.27874	-83.73975	401.01	-8.35	-25.09	17.17	869	9.4	26.9					
ESS Lab	et al. 2020	YUTO1891	350	#652	Anna E Car	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja occidentalis		5/17/1891	1891	Norwalk, Co	41.11904	-73.42139	294.3	-6.79	-22.62	16.20	969	9.0	27	13	1.70	47.11	32.32	27.71176471
ESS Lab	et al. 2020	MI_SSCTO	879	n/a	Ashley Ham	Gymnosper	Woody	C3	Woody Gym	Cupressace	Thuja	Thuja occidentalis		8/19/2018	2018	Sea Shell C	45.64932	-84.58447	407.1	-8.42	-25.99	18.04	959	6.7	27	214.9	1.46	48.39	38.65	33.14384
ESS Lab	et al. 2020	MI_EATO2	885	n/a	Ashley Ham	Gymnosper	Woody	C3	Woody Gym	Cupressace	Thuja	Thuja occidentalis		8/19/2018	2018	Eckerman A	46.358	-85.031	407.1	-8.42	-26.32	18.38	1097	5.1	27	244	1.40	49.11	40.91	35.07857
ESS Lab	et al. 2020	MI_SSCTO	880	n/a	Ashley Ham	Gymnosper	Woody	C3	Woody Gym	Cupressace	Thuja	Thuja occidentalis		8/19/2018	2018	Sea Shell C	45.64932	-84.58447	407.1	-8.42	-27.66	19.79	959	6.7	27	214.9	1.08	51.54	55.65	47.72222222
ESS Lab	et al. 2020	MI_SSCTO	881	n/a	Ashley Ham	Gymnosper	Woody	C3	Woody Gym	Cupressace	Thuja	Thuja occidentalis		8/19/2018	2018	Sea Shell C	45.64932	-84.58447	407.1	-8.42	-28.58	20.76	959	6.7	27	214.9	1.01	49.25	56.87	48.76237624
ESS Lab	et al. 2020	MSTO1865	410	S.N.	Beal	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja occidentalis		5/24/1865	1865	Cambridge,	42.37065	-71.11514	286.9	-6.70	-24.32	18.06	1157	9.3	27	4	0.69	49.95	84.42	72.39130435
ESS Lab	et al. 2020	YUPS1919	386	S.N.	Evans, Ferr	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus strobus		5/31/1919	1919	West Stock	42.31378	-73.38621	302.7	-6.88	-26.25	19.88	1104	7.6	27	274	1.06	45.73	50.31	43.14151
ESS Lab	et al. 2020	MHTO1838	403	#42	H E Sargen	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja occidentalis		6/4/1838	1838	St. Clair Riv	43.00811	-82.42497	283.4	-6.60	-24.22	18.06	676	6.9	27	180	1.13	46.99	48.49	41.5840708
ESS Lab	et al. 2020	YUTO1892	351	S.N.	John K Sma	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja occidentalis		7/4/1892	1892	Mouth of Hu	36.88855	-81.52152	294.5	-6.79	-23.34	16.94	968	10.5	27	699	1.18	47.17	46.62	39.97457627
ESS Lab	et al. 2020	MHPS1970C	281	#70-358	Merkle	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus strobus		9/26/1970	1970	Harrison, M	44.01912	-84.80884	323.1	-7.29	-28.86	22.21	847	6.5	27	363	0.80	46.05	67.13	57.5625
ESS Lab	et al. 2020	MN16-63	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Sequoia	Sequoia sempervirens		12/29/2016	2016	Santa Barba	34.4496	-119.8462	404.55	-8.49	-28.06	20.14	427	16.2	27					
ESS Lab	et al. 2020	MN16-62	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Sequoia	Sequoia sempervirens		12/29/2016	2016	Santa Barba	34.44948	-119.8462	404.55	-8.49	-28.29	20.38	427	16.2	27					
ESS Lab	et al. 2020	MN16-64	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Sequoia	Sequoia sempervirens		12/29/2016	2016	Santa Barba	34.44949	-119.8461	404.55	-8.49	-28.73	20.84	427	16.2	27					
ESS Lab	et al. 2020	FMTO1936B	309	#1701	Olga Lakela	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja occidentalis		8/12/1936	1936	Duluth, Minr	46.7637	-92.13323	309.8	-6.94	-24.37	17.87	612	3.3	27	196	1.75	48.25	32.15	27.57142857
ESS Lab	et al. 2020	MHTO1892	172	#576	S. R. and D	Gymnosper	Woody	C3	Woody Gym	Cupressace	Thuja	Thuja occidentalis		7/21/1892	1892	Topinabee,	45.48	-84.59	294.5	-6.79	-26.24	19.97	433	6.3	27	54.6	1.29	51.40	46.47	39.84496
ESS Lab	et al. 2020	YUPS1894A	374	#294	Charles H E	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus strobus		6/16/1894	1894	Southington	41.59329	-72.87897	294.7	-6.80	-24.81	18.47	1120	9.5	27.1	46	1.35	48.04	41.50	35.58519
ESS Lab	et al. 2020	MHTO1957A	202	#3872	E G Voss	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja occidentalis		5/25/1957	1957	Beaver Isla	45.6500	-85.5500	314.2	-7.07	-27.86	21.38	757	6.2	27.1000	183.0000	1.16	48.98	49.24	42.22414
ESS Lab	et al. 2020	MHTO1957B	203	S.N.	P A Hyypio	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja occidentalis		6/13/1957	1957	Limestone T	46.8100	-88.7000	314.2	-7.07	-27.49	21.00	688	5.2	27.1000	296.0000	1.25	48.48	45.23	38.784
ESS Lab	et al. 2020	CO_TCPT2	691	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides		8/18/2017	2017	Lone saplin	39.31163	-105.0738	405.24	-8.55	-30.48	22.62	836	8.1	27.1	2428	2.39	47.15	23.01	19.72803
ESS Lab	et al. 2020	MHTO1940	193	#K-162	Cook	Gymnosper	Woody	C3	Woody Gym	Cupressace	Thuja	Thuja occidentalis		8/12/1940	1940	Wilson, Wis	43.6829	-87.7665	310.4	-6.94	-25.74	19.30	795	7.3	27.2000	210.0000	1.31	51.03	45.60	39.10345
ESS Lab	et al. 2020	YUPS1908	380	S.N.	G.H.G.	Gymnosper	Woody	C3	Woody Gym	Pinaceae	Pinus	Pinus strobus		8/13/1908	1908	Brooklin, Ma	44.29446	-68.58471	298.9	-6.85	-25.79	19.45	1005	7.4	27.2	36	1.51	53.22	41.10	35.24503
ESS Lab	et al. 2020	BHTP1946	541	#2911	William H B	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja plicata		6/3/1946	1946	Lowell, Ore	43.90898	-122.7496	310.1	-6.98	-25.20	18.69	1142	10.3	27.2	289	1.33	48.07	42.15	36.14286
ESS Lab	et al. 2020	YUTO1915	362	#007	H C Bigelow	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja occidentalis		11/14/1915	1915	Berlin, Conn	41.6255	-72.75342	301.4	-6.87	-26.89	20.57	991	8.0	27.3	14	0.91	48.47	62.12	53.26373626
ESS Lab	et al. 2020	WA_LCCTI	762	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja plicata		5/18/2018	2018	NFD-24, N	47.49533	-123.2212	411.3	-8.67	-26.80	18.63	3108	11.0	27.3	332.8	1.23	50.18	47.58	40.79675
ESS Lab	et al. 2020	WA_GPTP	723	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja plicata		5/14/2018	2018	NF Road	47.77705	-121.4829	411.3	-8.67	-28.13	20.02	3020	10.9	27.3	273.1	1.18	47.77	47.21	40.48305
ESS Lab	et al. 2020	WA_LCCTI	761	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	Thuja	Thuja plicata		5/18/2018	2018	NFD-24, W	47.50102	-123.1931	411.3	-8.67	-29.90	21.88	3108	11.0	27.3	279.8	1.46	49.78	39.76	34.09589
ESS Lab	et al. 2020	MHTO1932	185	S.N.	Sister M. Vi	Gymnosper	Woody	C3	Woody Gym	Cupressace	Thuja	Thuja occidentalis		10/1/1932	1932	Harbor Bea	43.84	-82.65	308.2	-6.91	-24.54	18.08	787	3.5	27.3	181	1.15	52.67	53.64	46
ESS Lab	et al. 2020	CUBPT198	679	#16965	Weber & Be	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides		8/1/1983	1983	Black Canyo	38.54083	-107.6929	342.38	-7.58	-26.97	19.93	688	6.0	27.3	2469	2.52	49.34	22.83	19.57937

ESS Lab	et al. 2020	BHTP1952	544	#9004	William H B	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	6/1/1952	1952	Pend Oreille	48.31984	-116.3831	311.5	-7.00	-23.71	17.12		479	6.8	27.3	660	1.07	47.41	51.67	44.30841
ESS Lab	et al. 2020	MHTO1830	399	S.N.	Douglass H	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	July 1830	1830	Trenton Fall	43.25649	-75.19267	284.4	-6.57	-24.90	18.79		968	6.8	27.4	247	1.42	48.61	39.92	34.23239437
ESS Lab	et al. 2020	BHTP1951	543	#5858	H A Senn	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	9/16/1951	1951	Kootenay L	49.51944	-116.7792	311.1	-6.99	-25.84	19.35		662	8.5	27.4	552	0.89	41.86	54.85	47.03371
ESS Lab	et al. 2020	FMTO1999A	319	#8818	Hess, Leidr	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	7/15/1999	1999	Waldo Coun	44.5072	-69.01914	369.27	-8.06	-25.45	17.84		1189	8.5	27.4	61	1.34	48.93	42.58	36.51492537
ESS Lab	et al. 2020	YUTO1905	358	S.N.	O W Knight	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	5/10/1905	1905	Orono, Mai	44.87872	-68.68756	297.6	-6.83	-24.35	17.96		799	5.6	27.4	38	1.20	45.48	44.20	37.9
ESS Lab	et al. 2020	FMPS1936	338	#1444	Olga Lakela	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	6/23/1936	1936	Duluth, Minr	46.7797	-92.15932	309.8	-6.94	-25.39	18.94		611	2.6	27.4	409	1.49	45.31	35.46	30.4094
ESS Lab	et al. 2020	AATO2017	617	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	8/3/2017	2017	Ann Arbor,	42.289	-83.74804	405.24	-8.55	-25.57	17.47		849	9.4	27.4	242	1.48	47.63	37.53	32.18243243
ESS Lab	et al. 2020	AATO2017	616	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	8/3/2017	2017	Ann Arbor,	42.2806	-83.73841	405.24	-8.55	-25.67	17.57		849	9.4	27.4	268	1.41	48.57	40.17	34.44680851
ESS Lab	et al. 2020	WA_GBTP	716	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/14/2018	2018	Wallace Riv	47.86539	-121.6721	411.3	-8.67	-27.86	19.74		2076	11.4	27.4	101.5	1.39	48.89	41.02	35.17266
ESS Lab	et al. 2020	WA_GBTP	718	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/14/2018	2018	Wallace Riv	47.86565	-121.6719	411.3	-8.67	-28.02	19.90		2076	11.4	27.4	103.6	1.23	50.95	48.31	41.42276
ESS Lab	et al. 2020	WA_GBTP	717	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/14/2018	2018	Wallace Riv	47.86772	-121.6704	411.3	-8.67	-30.16	22.15		2076	11.4	27.4	86.87	0.96	49.16	59.72	51.20833
ESS Lab	et al. 2020	MHPS1985B	290	#3799	Brian T Haz	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	8/15/1985	1985	Leelanau C	44.87088	-85.88836	344.67	-7.50	-25.40	18.36		1130	7.7	27.5	242	1.26	47.21	43.69	37.46825
ESS Lab	et al. 2020	MHTO1972	217	#13980	E. G. Voss	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	7/14/1972	1972	Middle Islan	45.1900	-83.3300	328.04	-7.36	-22.32	15.30		759	5.3	27.5000	215.0000	1.36	49.69	42.61	36.53676
ESS Lab	et al. 2020	MSTO1904	417	#75	Pepoon	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	8/1/1904	1904	Cass Count	41.92541	-85.98762	297.2	-6.83	-25.98	19.66		846	7.9	27.5	277	0.77	44.11	66.81	57.28571429
ESS Lab	et al. 2020	WA_CBPT	714	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/14/2018	2018	Coulon Bea	47.50373	-122.2018	411.3	-8.67	-28.13	20.02		1080	13.0	27.5	12.8	1.32	48.01	42.42	36.37121
ESS Lab	et al. 2020	WA_CBPT	715	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/14/2018	2018	Coulon Bea	47.50373	-122.2007	411.3	-8.67	-28.65	20.57		1080	13.0	27.5	16.8	1.46	50.80	40.58	34.79452
ESS Lab	et al. 2020	YUTO1857	347	#6B	#6B	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	1/30/1905	1905	New Haven	41.31377	-72.9212	297.6	-6.83	-23.41	16.97		1078	10.0	27.5	10	1.58	47.07	34.74	29.79113924
ESS Lab	et al. 2020	YUPS1890	373	#660	Anna E Car	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	8/25/1890	1890	Greenville,	42.41375	-74.02297	294.2	-6.76	-26.40	20.17		867	7.4	27.6	215	1.36	46.54	39.91	34.22059
ESS Lab	et al. 2020	MI_STO20	887	n/a	Ashley Ham	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	8/19/2018	2018	Seney, Mich	46.346	-85.947	407.1	-8.42	-28.95	21.14		1223	5.6	27.6	223.5	1.41	49.81	41.20	35.32624
ESS Lab	et al. 2020	YUTO1899A	352	#2270	Emile F Will	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	4/9/1899	1899	Middlesex F	42.4553	-71.09138	295.5	-6.68	-22.61	16.30		1005	9.4	27.6	51	1.34	47.73	41.54	35.61940299
ESS Lab	et al. 2020	OR_GCTP	755	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/17/2018	2018	Gales Cree	45.64023	-123.356	411.3	-8.67	-26.18	17.98		1325	12.1	27.6	354.2	1.30	48.95	43.91	37.65385
ESS Lab	et al. 2020	YUTO1958	366	#286	John Ebinge	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/24/1958	1958	New Haven	41.31429	-72.93082	317.24	-7.02	-25.36	18.82		1461	8.7	27.7	17	0.86	47.30	64.14	55
ESS Lab	et al. 2020	MN16-36	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/26/2016	2016	Dawes Arbo	39.97847	-82.41206	402.24	-8.42	-28.01	20.16		1037	10.4	27.7					
ESS Lab	et al. 2020	MN16-35	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/26/2016	2016	Dawes Arbo	39.97853	-82.41219	402.24	-8.42	-28.31	20.47		1037	10.4	27.7					
ESS Lab	et al. 2020	MN16-37	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/26/2016	2016	Dawes Arbo	39.97829	-82.41213	402.24	-8.42	-28.61	20.78		1037	10.4	27.7					
ESS Lab	et al. 2020	SWTO2017	700	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	9/24/2017	2017	Pinckney, M	42.4068	83 56.431	401.01	-8.42	-26.02	18.07		794	8.8	27.7	275.8	1.89	49.46	30.52	26.16931217
ESS Lab	et al. 2020	SWTO2017	699	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	9/24/2017	2017	Pinckney, M	42.4067	-83.9406	401.01	-8.42	-26.17	18.23		794	8.8	27.7	287.4	1.87	50.21	31.31	26.85026738
ESS Lab	et al. 2020	MI_SWTO2	918	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	10/6/2018	2018	Stinchfield	42.28154	-83.73957	405.99	-8.36	-26.34	18.47		794	8.8	27.7		1.75	51.63	34.41	29.50286
ESS Lab	et al. 2020	SWTO2017	697	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	9/24/2017	2017	Pinckney, M	42.40638	-83.94193	401.01	-8.42	-26.71	18.80		794	8.8	27.7	281.94	1.80	50.79	32.91	28.21666667
ESS Lab	et al. 2020	SWTO2017	698	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	9/24/2017	2017	Pinckney, M	42.40647	83.940917	401.01	-8.42	-27.21	19.32		794	8.8	27.7	277.7	1.72	50.21	34.04	29.19186047
ESS Lab	et al. 2020	WA_TFTP2	704	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	10/22/2017	2017	Twin Falls T	47.45183	-121.7039	401.5	-8.39	-28.44	20.63		2144	11.2	27.7	201.5	1.16	50.52	50.79	43.55172
ESS Lab	et al. 2020	WA_TFTP2	707	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	10/22/2017	2017	Twin Falls T	47.44647	-121.6991	401.5	-8.39	-29.09	21.32		2144	11.2	27.7	267	1.27	49.44	45.40	38.92913
ESS Lab	et al. 2020	WA_TFTP2	705	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	10/22/2017	2017	Twin Falls T	47.45045	-121.7036	401.5	-8.39	-29.55	21.81		2144	11.2	27.7	201.5	1.45	50.02	40.23	34.49655
ESS Lab	et al. 2020	MI_SWTO1	915	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	10/13/2018	2018	Stinchfield	42.28154	-83.73957	405.99	-8.36	-29.84	22.14		794	8.8	27.7		0.98	50.68	60.31	51.71429
ESS Lab	et al. 2020	MI_SWTO1	914	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	10/13/2018	2018	Stinchfield	42.28154	-83.73957	405.99	-8.36	-30.11	22.42		794	8.8	27.7		1.08	49.48	53.43	45.81481
ESS Lab	et al. 2020	WA_TMTP	703	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	10/22/2017	2017	Tiger Mount	47.44323	-121.9764	401.5	-8.39	-30.26	22.56		2018	10.9	27.7	180.1	1.47	48.58	38.54	33.04761905
ESS Lab	et al. 2020	YUPS1984	394	#9535	Leslie J Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	3/16/1984	1984	Canaan, Co	41.9622	-73.29988	345.28	-7.81	-26.43	19.13		1239	8.3	27.8	243	1.49	51.54	40.34	34.5906
ESS Lab	et al. 2020	CO_OTPT2	845	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/4/2018	2018	Evergreen (	39.65204	-105.253	407.1	-8.42	-27.25	19.36		551	8.8	27.8	2283.3	2.64	49.88	22.03	18.89394
ESS Lab	et al. 2020	CO_ELPT2	852	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/4/2018	2018	Vail, Colora	39.6104	-106.6136	407.1	-8.42	-28.21	20.37		421	6.4	27.8	2354.3	3.51	52.27	17.37	14.89174
ESS Lab	et al. 2020	FMTO1902	303	#679	Chas. J. Br	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/1/1902	1902	Bemidji, Min	47.4806	-94.8842	296.5	-6.82	-24.27	17.88		604	4.4	27.9000	417.0000	0.88	48.18	63.85	54.75
ESS Lab	et al. 2020	BHTP1937	536	#1980	Fred A Bark	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	9/18/1937	1937	West Glacie	48.60454	-113.8866	310	-6.95	-25.43	18.96		542	5.1	27.9	969	0.92	46.05	58.37	50.05435
ESS Lab	et al. 2020	YUPS1921	387	S.N.	P.E. Nichol	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	6/11/1921	1921	Burlington, (	41.76958	-72.95902	303.4	-6.89	-28.65	22.40		1189	9.5	27.9	235	1.31	49.03	43.65	37.42748
ESS Lab	et al. 2020	MHPS1958	269	#8037	Voss	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	9/13/1958	1958	Constantine	41.84233	-85.66501	313.2	-7.02	-25.25	18.71		800	8.8	27.9	239	0.69	47.03	79.49	68.15942
ESS Lab	et al. 2020	MHPS1986	291	#3928	Brian T Haz	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	6/4/1986	1986	Cleveland T	44.87088	-85.88836	349.55	-7.71	-25.60	18.36		1069	7.8	28	242	0.98	46.95	55.87	47.90816
ESS Lab	et al. 2020	BHTP1975	551	#1676	Joy Mastro	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	7/17/1975	1975	Summit Lak	48.28518	-119.1485	331.9	-7.42	-25.41	18.46		410	5.6	28	1005	0.85	47.51	65.18	55.89412
ESS Lab	et al. 2020	MHTO1998	230	S.N.	Timothy L W	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/3/1998	1998	Norman To	44.2100	-85.8900	368.88	-8.20	-27.02	19.34		825	9.4	28.0000	212.0000	1.00	47.28	55.14	47.28
ESS Lab	et al. 2020	MHPS1911B	254	#22	H. E. Sarge	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	7/15/1911	1911	Torch Lake	44.90958	-85.27763	300.1	-6.86	-26.48	20.16		788	7.8	28.1	211	1.49	49.32	38.60	33.10067
ESS Lab	et al. 2020	OR_TSTP2	756	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/17/2018	2018	Tillamook S	45.60733	-123.4641	411.3	-8.67	-24.73	16.47		1325	12.1	28.1	261	1.88	48.84	30.30	25.97872
ESS Lab	et al. 2020	CO_TCPT2	692	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/18/2017	2017	Sapling stic	39.31447	-105.0604	405.24	-8.55	-29.14	21.21		802	8.8	28.1	2418.6	1.63	50.26	35.96	30.83436
ESS Lab	et al. 2020	MHTO1989	227	#602	W. W. Brod	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	9/28/1989	1989	Byron, Kent	42.8000	-85.7100	349.8	-7.61	-24.59	17.41		803	7.6	28.1000	211.0000	1.51	48.27	37.28	31.96689
ESS Lab	et al. 2020	YUPS1909A	381	#3738	Arthur E Ble	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	3/27/1909	1909	Waterbury,	41.56113	-73.03399	299.3	-6.85	-29.11	22.93		1158	9.7	28.2	118	1.44	47.32	38.32	32.86111
ESS Lab	et al. 2020	YUPS1971	389	#	Bruce H Tif	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	7/6/1971	1971	Sharon, Ma	42.11528	-71.18819	327.36	-7.35	-27.37	20.58		991	9.2	28.2	84	1.73	47.51	32.03	27.46243
ESS Lab	et al. 2020	YUTO1909B	360	S.N.	C H Bissell	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	9/11/1909	1909	Wethersfiel	41.70227	-72.66991	299.3	-6.85	-24.06	17.63		1049	9.8	28.2	32	1.53	48.38	36.88	31.62091503
ESS Lab	et al. 2020	YUPS1909B	382	#159	Charles H E	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	11/9/1909	1909	Wethersfiel	41.70356	-72.66648	299.3	-6.85	-28.27	22.04		1046	9.8	28.2	39	1.67	49.07	34.27	29.38323
ESS Lab	et al. 2020	YUTO1909C	361	#5565	E B Harger	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/17/1909	1909	New Milford	41.596	-73.41539	299.3	-6.85	-25.58	19.23		1273	9.3	28.2	70	0.90	46.40	60.12	51.55555556
ESS Lab	et al. 2020	YUTO1909A	359	S.N.	H S Clark	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/6/1909	1909	Wethersfiel	41.70227	-72.66991	299.3	-6.85	-24.71	18.31		1049	9.8	28.2	32	1.53	47.93	36.53	31.32679739
ESS Lab	et al. 2020	MHTO1970A	214	#70-432	Merkle	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	10/18/1970	1970	Tom Creek,	43.5600	-85.0000	323.06	-7.29	-24.79	17.94		844	6.2	28.2000	302.0000	1.06	49.00	53.91	46.22642
ESS Lab	et al. 2020	MHPS1932C	260	N.S.	Sister M. Vi	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	10/1/1932	1932	Harbor Bea	43.84721	-82.65173	308.2	-6.91	-24.76	18.30		839	8.4	28.2	183	1.66	46.90	32.95	28.25301
ESS Lab	et al. 2020	MHTO1970B	215	#13224	Voss	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/24/1970	1970	Thunder Ba	45.0400	-83.2000	327.67	-7.29	-24.26	17.39		844	6.4	28.2000	215.0000	0.82	48.08	68.38	58.63415
ESS Lab	et al. 2020	MHPS1961A	271	#9766	Voss	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	5/13/1961	1961	Albert Town	43.18608	-85.60125	320.58	-7.07	-27.15	20.65		795	8.7	28.2	258	1.02	46.65	53.34	45.73529
ESS Lab	et al. 2020	MHTO2003	231	#84	Abbie Goss	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/9/2003	2003	YMCA Cam	42.6700	-85.5100	378.13	-8.29	-28.30	20.59		888	8.4	28.3000	238.0000	1.20	39.04	37.94	32.53472
ESS Lab	et al. 2020	MHPS1971	282	#13783	E. G. Voss	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	10/7/1971	1971	Onaway, Mi	45.36098	-84.22818	323.56	-7.35	-28.10	21.36		840	6.6	28.3	252	3.05	62.55	23.92	20.5082
ESS Lab	et al. 2020	YUTO1932	365	#13	K P Jansso	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	8/5/1932	1932	New London	41.36188	-72.10412	308.2	-6.91	-24.42	17.95		1304	11.0	28.3	43	2.28	49.33	25.23	21.63596491
ESS Lab	et al. 2020	YUTO1901	354	S.N.	Nellie E Fly	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	5/17/1901	1901	Burlington, (	41.76546	-72.95318	296.1	-6.82	-25.05	18.70		1653	8.3	28.3	254	1.03	47.45	53.72	46.06796117
ESS Lab	et al. 2020	MHTO1973	218	#49852	R. Kral	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	5/5/1973	1973	Pickett Stat	36.5500	-84.8000	332.48	-7.39	-27.59	20.77		1723	13.3	28.3000	392.0000	0.68	46.52	79.78	68.41176
ESS Lab	et al. 2020	AZ_FSPT2	789	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/30/2018	2018	Flagstaff, A	35.20209	-111.6215	408.9	-8.54	-28.13	20.16		443	9.9	28.3	2096	1.87	48.31	30.13	25.83422
ESS Lab	et al. 2020	MHPS1970A	279	S.N.	Sylvia Taylo	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	6/24/1970	1970	Ann Arbor,	42.27025	-83.73084	327.67	-7.29	-24.67	17.81		805	4.7	28.3	264	1.10	47.65	50.52	43.31818
ESS Lab	et al. 2020	YUPS1910	383	#1753	Anna E Car	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	6/21/1910	1910	Greenville,	42.41895	-74.02469	299.7	-6.89	-27.21	20.89		951	7.7	28.4	229	1.27	47.16	43.30	37.13386
ESS Lab	et al. 2020	MSTO1900	416	#141922	CFW	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/25/1900	1900	Crystal Lake	44.68818	-86.16841	295.8	-6.75	-24.38	18.07		796	7.9	28.4	229	0.67	46.87	81.58	69.95522388
ESS Lab	et al. 2020	MHTO1938	190	S.N.	Chester C (	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	7/27/1938	1938	Belgium, Wi	43.4997	-87.8504	310.2	-6.94	-23.77	17.23		928	9.1	28.4000	224.0000	1.67	51.62	36.04	30.90719
ESS Lab	et al. 2020	MN_MTO2	917	n/a	Rebecca D	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	10/6/2018	2018	Minneapolis	44.94134	-93.29846	405.99	-8.36	-25.40	17.48		875	8.6	28.4		1.23	49.35	46.79	40.12195
ESS Lab	et al. 2020	MN_MTO2	916	n/a	Rebecca D	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	10/6/2018	2018	Minneapolis	44.94134	-93.29846	405.99	-8.36	-27.16	19.33		875	8.6	28.4		2.19	50.88	27.09	23.23288
ESS Lab	et al. 2020	AZ_CNFPT	782	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/29/2018	2018	Coconino N	35.09071	-111.6882	408.9	-8.54	-25.37	17.27		451	10.5	28.4	2060.1	2.09	48.61	27.12	23.25837
ESS Lab	et al. 2020	MSTO1899	415	S.N.	S.N.	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	5/27/1899	1899	Grayling, Cr	44.65698	-84.70587	295.5	-6.68	-24.96	18.75		708	5.6	28.4	347	0.39	48.83	146.01	125.2051282
ESS Lab	et al. 2020	CUBPT196	670	#341	Hall	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1961	1961	Haystack G	40.85487	-105.3859	319.77	-7.07	-24.36	17.72		567	6.3	28.5	2017	1.98	51.27	30.20	25.89394
ESS Lab	et al. 2020	FMTO1926	306	#703b	J Francis M	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	8/30/1926	1926	Trout Park,	42.0643	-88.26736	305.4	-6.91	-23.64	17.13		960	8.4	28.5	242	1.80	49.58	32.12	27.54444444
ESS Lab	et al. 2020	MHTO1930	182	S.N.	Marcus W L	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	7/17/1930	1930	Stevensville	42.013	-86.52	307.2	-6.92	-26.63	20.24		574	10.1	28.5	193	1.24	50.93	47.90	41.07258
ESS Lab	et al. 2020	AZ_SVNMF	786	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/29/2018	2018	Sunset Volc	35.36375	-111.5238	408.9	-8.54	-26.74	18.70		379	9.6	28.5	2115.9	2.82	47.20	19.52	16.73759
ESS Lab	et al. 2020	AZ_SVNMF	785	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/29/2018	2018	Sunset Volc	35.36371	-111.5231	408.9	-8.54	-27.03	19.00		379	9.6	28.5	2115.9	1.97	47.23	27.96	23.97462
ESS Lab	et al. 2020	BHTP2006	566	#06-200	Steve Hahn	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	6/29/2006	2006	Howard Lak	48.38777	-120.829	384.03	-8.35	-24.66	16.73		1610	7.9	28.5	1772	0.97	47.76	57.42	49.2371134
ESS Lab	et al. 2020	NM_BSPPT	790	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/30/2018	2018	Bluewater S	35.42289	-108.5534	408.9	-8.54	-24.82	16.70		378	9.7	28.6	2276	2.40	48.45	23.54	20.1875
ESS Lab	et al. 2020	NM_BSPPT	792	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/30/2018	2018	Bluewater S	35.42284	-108.5536	408.9	-8.54	-25.82	17.74		378	9.7	28.6	2273.2	3.19	49.47	18.08	15.50784
ESS Lab	et al. 2020	NM_BSPPT	791	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/30/2018	2018	Bluewater S	35.42284	-108.5536	408.9	-8.54	-27.62	19.63		378	9.7	28.6	2273.2	1.94	46.43	27.91	23.93299
ESS Lab	et al. 2020	WA_HCTT	760	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/18/2018	2018	Hoodsport (	47.41468	-123.1925	411.3	-8.67	-29.05	20.99		2703	11.9	28.6	202	1.21	49.63	47.83	41.01653
ESS Lab	et al. 2020	MSTO1892	412	S.N.	John K Sma	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/1/1892	1892	Hungry's M	36.88675	-81.52043	294.5	-6.79	-23.93	17.56		974	10.5	28.7	694	0.80	45.75	66.69	57.1875
ESS Lab	et al. 2020	MSTO1892	413	S.N.	John K Sma	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/8/1892	1892	Smyth Coun	36.88675	-81.52043	294.5	-6.79	-26.31	20.04		974	10.5	28.7	694	0.86	47.92	64.98	55.72093023
ESS Lab	et al. 2020	MHPS1973	283	#5531	M. Nee	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	1/21/1973	1973	Richland Co	43.37536	-90.46448	328.55	-7.39	-27.59	20.77		955	9.0	28.7	328	1.41	45.74	37.83	32.43972
ESS Lab	et al. 2020	CSPT1998	683	#118	Rice	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/29/1998	1998	20ft tall off r	41.17552	-105.0987	365.78	-7.97	-28.82	21.47		358	7.4	28.8	2400	2.02	46.72	26.97	23.12871
ESS Lab	et al. 2020	MHTO1911	402	S.N.	Bronson Ba	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	7/15/1911	1911	Torch Lake	44.9159	-85.27832	300.1	-6.86	-24.14	17.71		788	7.8	28.9	214	1.11	47.54	49.95	42.82882883
ESS Lab	et al. 2020	MHPS1938	261	#C356	Chester C (	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	10/10/1938	1938	Delton, Wis	43.56243	-89.79249	310.2	-6.94	-26.09	19.65		1087	8.7	28.9	294	1.55	49.14	36.97	31.70323
ESS Lab	et al. 2020	BHTP1893	527	#8324	J H Sandbe	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	7/1893	1893	Peshastin, \	47.57083	-120.6028	294.6	-6.79	-23.81	17.43		415	8.8	28.9	320	0.94	46.30	57.44	49.25532
ESS Lab	et al. 2020	CO_MSPT2	817	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/1/2018	2018	Mueller Stat	38.87907	-104.1764	407.1	-8.42	-26.40	18.47		512	9.3	28.9	1929	2.77	47.19	19.87	17.0361
ESS Lab	et al. 2020	MHTO1952B	200	#1201	E G Voss	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/28/1952	1952	Hume Town	43.9800	-83.0600	311.5	-7.00	-25.94	19.44		727	8.4	29.0000	180.0000	1.55	50.39	37.91	32.50968
ESS Lab	et al. 2020	YUPS1981B	393	S.N.	Joan Raise	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	11/15/1981	1981	Fairfield, CT	41.17128	-73.25563	338.36	-7.46	-28.45	21.61		1024	10.3	29	39	2.09	50.95	28.43	24.37799
ESS Lab	et al. 2020	C-PHTO20	510	#2009-038	Kim, Yang,	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Platycladus*	*Platycladus orientalis*	4/19/2009	2009	Jecheon So	37.05744	128.305	389.57	-8.41	-27.22	19.33		1275	10.4	29	229	1.33	44.59	39.10	33.52631579
ESS Lab	et al. 2020	CSPT2013	690	#808b	McAleer	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/6/2013	2013	Soapstone	40.96167	-105.1131	395.41	-8.29	-25.08	17.22		571	7.0	29	1938.2	2.09	49.49	27.61	23.67943
ESS Lab	et al. 2020	CSPT2012	689	#492a	McAleer & (	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	9/1/2012	2012	Red Mounta	40.93805	-105.1373	391.13	-8.20	-29.65	22.11		265	8.9	29	1949.2	2.22	52.31	27.48	23.56306
ESS Lab	et al. 2020	OR_MCPT	754	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/17/2018	2018	Metzler Co	45.22883	-122.3628	411.3	-8.67	-27.77	19.64		1325	12.1	29	213.7	1.67	48.81	34.08	29.22754
ESS Lab	et al. 2020	OR_MCPT	752	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/17/2018	2018	Metzler Co	45.22822	-122.3675	411.3	-8.67	-29.61	21.57		1325	12.1	29	208.5	1.18	48.59	48.02	41.17797
ESS Lab	et al. 2020	OR_MCPT	753	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/17/2018	2018	Metzler Co	45.22818	-122.3671	411.3	-8.67	-30.24	22.24		1325	12.1	29	201.2	1.28	48.92	44.57	38.21875
ESS Lab	et al. 2020	OR_MCPT	751	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/17/2018	2018	Metzler Co	45.22849	-122.3668	411.3	-8.67	-30.84	22.87		1325	12.1	29	205.7	0.76	48.56	74.51	63.89474
ESS Lab	et al. 2020	C-PHTK20	500a			Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja koraiensis*	9/5/2004	2004	Fusong, Bai	41.7667	127.9333	374.05	-8.02	-24.86	17.27		1279	4.1	29	1699	1.28	51.50	46.92	40.23438
ESS Lab	et al. 2020	C-PHTK20	500b			Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja koraiensis*	9/5/2004	2004	Fusong, Bai	41.7667	127.9333	374.05	-8.02	-25.18	17.60		1279	4.1	29	1699	1.36	51.52	44.18	37.88235
ESS Lab	et al. 2020	MSTO1894	414	S.N.	H. C. Skeel	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	10/7/1894	1894	Agricultural	42.74993	-84.49164	294.7	-6.80	-24.15	17.78		660	7.6	29.1	260	0.96	51.08	62.05	53.20833333
ESS Lab	et al. 2020	MHPS1922	256	N.S.	Marcus W L	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	8/27/1922	1922	Porter Cour	41.6444	-87.03484	303.8	-6.89	-28.29	22.02		829	10.8	29.1	199	1.31	49.41	43.99	37.71756
ESS Lab	et al. 2020	MN16-01	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	7/3/2016	2016	Rose Garde	39.94721	-75.14877	404.5	-8.55	-28.26	20.28		1126	12.4	29.1					
ESS Lab	et al. 2020	MHTO1894	173	#51233	Mrs. James	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	4/03/1894	1894	Lowell, Ken	42.94	-85.35	294.7	-6.80	-24.99	18.66		972	9.5	29.1	59.7	1.53	50.65	38.73	33.21311
ESS Lab	et al. 2020	MI_SWTO2	778	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	7/25/2018	2018	Pinckney, M	42.40653	-83.9416	408.9	-8.54	-28.12	20.15		962	9.8	29.1	282.9	1.97	48.43	28.67	24.58375635
ESS Lab	et al. 2020	MI_SWTO2	777	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	7/25/2018	2018	Pinckney, M	42.40642	-83.94167	408.9	-8.54	-29.09	21.16		962	9.8	29.1	278.3	1.10	47.48	50.34	43.16363636
ESS Lab	et al. 2020	MI_SWTO2	779	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	7/25/2018	2018	Pinckney, M	42.40656	-83.9416	408.9	-8.54	-29.52	21.62		962	9.8	29.1	276.5	0.82	47.31	67.28	57.69512195
ESS Lab	et al. 2020	YUPS1973B	391	S.N.	Joann Rosk	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	12/10/1973	1973	West Thorn	43.93547	-71.68516	328.64	-7.39	-29.30	22.57		1378	7.3	29.2	194	1.46	50.70	40.50	34.72603
ESS Lab	et al. 2020	WA_CWTP	727	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/14/2018	2018	US Highway	47.63787	-120.7227	411.3	-8.67	-25.71	17.49		947	9.8	29.2	493.2	1.08	47.55	51.34	44.02778
ESS Lab	et al. 2020	YUPS1973A	390	#15	Robert Mue	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	9/22/1973	1973	New Haven	41.31289	-72.92017	327.51	-7.39	-27.77	20.95		1360	11.8	29.2	9	1.39	48.97	41.08	35.23022
ESS Lab	et al. 2020	FMPS1902	335	#98	Chas S. Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	19-04-1902	1902	Columbus, (	40.01207	-83.00185	296.5	-6.82	-27.83	21.60		900	10.5	29.3	258	2.10	49.07	27.25	23.36667
ESS Lab	et al. 2020	FMPS1999	346	#8643	Hess, Leidr	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	7/3/1999	1999	Rock Hill, N	41.61926	-74.59254	369.27	-8.06	-26.53	18.97		1156	9.0	29.3	438	1.22	46.41	44.36	38.04098
ESS Lab	et al. 2020	CLTO2017	423	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	3/26/2017	2017	3050 Kensi	41.4976	-81.5704	407.06	-8.62	-24.44	16.22		1124	10.3	29.3	281	1.37	49.87	42.45	36.40145985
ESS Lab	et al. 2020	NM_DLPPT	796	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/31/2018	2018	Sandia Park	35.17461	-106.3767	408.9	-8.54	-26.68	18.64		504	10.9	29.3	2213	2.17	45.16	24.27	20.81106
ESS Lab	et al. 2020	MI_SWPT2	780	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/25/2018	2018	Pinckney, M	42.39242	-83.93674	408.9	-8.54	-29.31	21.40		967	9.8	29.3	267.3	2.41	51.75	25.04	21.47303

ESS Lab	et al. 2020	MHTP1994	246	#3160	James F. S	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	7/9/1994	1994	Priest Lake	48.5704	-116.8227	359.55	-7.84	-25.78	18.42		696	6.9	29.4000	884.0000	0.62	51.32	96.53	82.77419
ESS Lab	et al. 2020	FMTO1953	317	#2310	Swink	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	7/26/1953	1953	Kenosha C	42.5737	-87.83506	311.9	-7.00	-25.10	18.56		641	9.8	29.4	190	1.61	48.00	34.77	29.8136646
ESS Lab	et al. 2020	FMTO1952	316	#838	Floyd A Swi	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	4/26/1952	1952	Warren Dun	41.9151	-86.58931	311.5	-7.00	-24.06	17.49		783	10.2	29.5	199	1.61	50.72	36.74	31.50310559
ESS Lab	et al. 2020	MHTO1895	174	#42440	Fyfe, Living	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	7/21/1895	1895	Grand Rapi	42.96	-85.66	294.8	-6.80	-23.72	17.33		616	6.4	29.5	63.7	1.42	53.90	44.42	38.08834
ESS Lab	et al. 2020	CUBPT200	687	#4298	Hogan & Te	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/8/2004	2004	Black Cany	38.57078	-107.7364	379.55	-8.29	-27.70	19.96		421	8.3	29.5	2529.8	2.16	52.70	28.45	24.39815
ESS Lab	et al. 2020	YUPS1988	395	#47	K. D. Parde	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	7/16/1988	1988	Redding, C	41.3138	-73.39936	352.38	-7.77	-27.72	20.52		1039	9.5	29.5	168	1.60	50.06	36.49	31.2875
ESS Lab	et al. 2020	MHTO1926	180	S.N.	Lyon Jr.	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	8/18/1926	1926	Mineral Spri	41.3262	-85.7442	305.4	-6.91	-25.34	18.91		896	8.4	29.5	258	0.70	51.94	87.14	74.72662
ESS Lab	et al. 2020	C-PHTO19	507	#49297	Miyoshi Fur	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Platycladus*	*Platycladus orientalis*	7/25/1970	1970	Mt. Kushiga	35.5854	138.36921	326.34	-7.29	-27.25	20.52		1055	13.9	29.5	733	1.54	46.82	35.45	30.4025974
ESS Lab	et al. 2020	MI_AABPT	913	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	10/6/2018	2018	Burns Park,	42.26516	-83.72959	405.99	-8.36	-25.79	17.89		946	10.0	29.6		1.68	51.13	35.49	30.43452
ESS Lab	et al. 2020	WA_CGTP	743	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/15/2018	2018	Cedar Grov	46.53888	-114.6578	411.3	-8.67	-27.53	19.39		826	7.2	29.6	1105.8	0.69	48.55	82.06	70.36232
ESS Lab	et al. 2020	WA_CGTP	742	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/15/2018	2018	Cedar Grov	46.53888	-114.6758	411.3	-8.67	-28.18	20.07		826	7.2	29.6	1105.8	0.93	47.85	60.00	51.45161
ESS Lab	et al. 2020	WA_LITP2	741	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/15/2018	2018	Route 12 W	46.5547	-114.6675	411.3	-8.67	-28.90	20.83		826	7.2	29.6	1119.2	0.68	48.69	83.50	71.60294
ESS Lab	et al. 2020	MHTO1907	175	#1313	Frank C Ga	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	3/23/1907	1907	Mt. Hope C	40.1001	-88.2266	298.5	-6.84	-24.22	17.81		1036	10.2	29.7	231	1.59	53.07	39.04	33.4795
ESS Lab	et al. 2020	CO_GrPT2	828	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/2/2018	2018	Boulder, Co	39.99488	-105.3082	407.1	-8.42	-27.17	19.27		594	11.1	29.7	2062.4	2.90	49.15	19.76	16.94828
ESS Lab	et al. 2020	CO_GrPT2	827	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/2/2018	2018	Boulder, Co	39.99488	-105.3082	407.1	-8.42	-27.60	19.73		594	11.1	29.7	2062.4	2.30	49.92	25.31	21.70435
ESS Lab	et al. 2020	MHTO1939	192	#C-1525	Harold Neu	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	12/14/1939	1939	Menominee	45.0025	-88.6668	310.3	-6.99	-26.07	19.58		569	9.1	29.8000	284.0000	1.31	51.22	45.77	39.24521
ESS Lab	et al. 2020	BHTP1914	531	#4395	W C Cusick	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	7/30/1914	1914	Douglas, Or	43.12864	-123.2534	301.1	-6.87	-26.42	20.08		1146	11.9	29.8	216	0.96	47.23	57.37	49.19792
ESS Lab	et al. 2020	FMTO1930	307	#2315	F J Herman	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	7/19/1930	1930	Lebanon To	43.0711	-84.75366	307.2	-6.92	-24.54	18.06		506	9.1	29.9	196	1.66	52.38	36.80	31.55421687
ESS Lab	et al. 2020	MHTO1946	196	#21453	H H Bartlett	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	7/13/1946	1946	Waterloo, J	42.1800	-84.3500	310.1	-6.98	-24.54	18.00		668	10.2	29.9000	293.0000	1.79	49.90	32.51	27.87709
ESS Lab	et al. 2020	FMPS1935	337	#7180	Hermann	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	5/9/1935	1935	Lake Georg	43.96304	-84.94716	309.4	-6.98	-25.79	19.31		610	6.4	29.9	341	1.50	46.54	36.18	31.02667
ESS Lab	et al. 2020	OR_MFTP2	748	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/17/2018	2018	Multnomah	45.57719	-122.1168	411.3	-8.67	-25.13	16.88		1786	12.9	29.9	26.2	1.10	47.87	50.75	43.51818
ESS Lab	et al. 2020	OR_TCTP2	750	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/17/2018	2018	Tickle Cree	45.3982	-122.2913	411.3	-8.67	-26.47	18.29		1469	12.7	29.9	230.7	1.79	48.99	31.92	27.36872
ESS Lab	et al. 2020	OR_MFTP2	747	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/17/2018	2018	Multnomah	45.5788	-122.1172	411.3	-8.67	-27.13	18.97		1786	12.9	29.9	9.1	1.72	49.41	33.50	28.72674
ESS Lab	et al. 2020	OR_MFTP2	746	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/17/2018	2018	Multnomah	45.5788	-122.1172	411.3	-8.67	-27.26	19.11		1786	12.9	29.9	9.1	0.83	49.21	69.14	59.28916
ESS Lab	et al. 2020	OR_TCTP2	749	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/17/2018	2018	Tickle Cree	45.39809	-122.2917	411.3	-8.67	-29.38	21.34		1469	12.7	29.9	225.6	1.41	48.63	40.22	34.48936
ESS Lab	et al. 2020	MI_AATO2	408	S.N.	Peking	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	3/9/2017	2017	Ann Arbor, I	42.27545	-83.74783	407.06	-8.62	-26.22	18.07		849	9.4	30	256	0.66	46.26	81.74	70.09090909
ESS Lab	et al. 2020	NM_EMPT2	793	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/30/2018	2018	El Malpais N	34.96967	-108.0052	408.9	-8.54	-23.65	15.48		259	10.1	30	2216.8	2.11	50.46	27.89	23.91469
ESS Lab	et al. 2020	NM_EMPT2	794	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/30/2018	2018	El Malpais N	34.96976	-108.0052	408.9	-8.54	-24.44	16.30		259	10.1	30	2216.8	2.41	51.25	24.80	21.26556
ESS Lab	et al. 2020	NM_EMPT2	795	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/30/2018	2018	El Malpais N	34.96962	-108.0052	408.9	-8.54	-26.33	18.27		259	10.1	30	2217.8	1.92	49.79	30.24	25.93229
ESS Lab	et al. 2020	MI_AATO2	407	#5513	Voss	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	3/9/2017	2017	Ann Arbor, I	42.27649	-83.74772	407.06	-8.62	-25.53	17.35		849	9.4	30	258	0.77	45.31	68.62	58.84415584
ESS Lab	et al. 2020	MHPS1893A	250	#9307	Wilfred Nar	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	5/25/1893	1893	Grand Rapi	42.95276	-85.65186	294.6	-6.79	-24.04	17.67		691	7.7	30.1	213	1.62	50.01	36.00	30.87037
ESS Lab	et al. 2020	MHPS1893B	251	#9309	Wilfred Nar	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	6/18/1893	1893	Grand Rapi	42.95276	-85.65186	294.6	-6.79	-25.70	19.40		691	7.7	30.1	213	2.33	49.98	25.02	21.45064
ESS Lab	et al. 2020	MHPS1930	286	#330	Gereau	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	4/13/1930	1930	Jacskson C	42.23943	-84.40718	307.2	-6.92	-27.06	20.70		538	9.4	30.2	304	1.90	46.02	28.25	24.22105
ESS Lab	et al. 2020	YUPS1889	378	S.N.	John K Sma	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	12/28/1889	1889	Conewago,	39.79252	-77.01064	294	-6.78	-26.48	20.23		825	10.4	30.3	168	0.98	47.08	56.02	48.04082
ESS Lab	et al. 2020	FMTO1980	318	#19081	M Nee	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	7/21/1980	1980	Jefferson C	43.027	-88.79805	339.56	-7.59	-25.12	17.98		769	12.9	30.3	257	1.98	49.03	28.88	24.76262626
ESS Lab	et al. 2020	C-PHTS19	518	#14369	Miyoshi Fur	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja standishii*	8/13/1980	1980	senjuga-har	36.39501	139.85948	337.6	-7.47	-24.39	17.34		1373	13.9	30.3	59	1.02	50.45	57.68	49.46078431
ESS Lab	et al. 2020	YUTO1982	367	#1815	David D Ta	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	7/14/1982	1982	Madison, K	37.70854	-84.27226	342.06	-7.67	-25.53	18.32		1333	10.0	30.4	313	1.70	46.83	32.12	27.54705882
ESS Lab	et al. 2020	OR_TyCTP	757	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/17/2018	2018	Tyron Cree	45.44155	-122.6757	411.3	-8.67	-28.17	20.06		1188	13.7	30.4	85.6	1.26	50.90	47.11	40.39683
ESS Lab	et al. 2020	WA_SWTP	745	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/16/2018	2018	Columbia S	45.69444	-121.8813	411.3	-8.67	-28.76	20.68		1873	12.3	30.4	261	1.84	49.38	31.30	26.83696
ESS Lab	et al. 2020	OR_TyCTP	758	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/17/2018	2018	Tyron Cree	45.44143	-122.6758	411.3	-8.67	-30.51	22.53		1188	13.7	30.4	88.1	1.51	50.16	38.74	33.21854
ESS Lab	et al. 2020	YUPS1981A	392	S.N.	Thomas Ha	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	12/3/1981	1981	New Haven	41.31379	-72.91966	339.61	-7.58	-27.93	20.93		1047	11.8	30.4	11	1.71	50.84	34.67	29.73099
ESS Lab	et al. 2020	MHTO1948	197	#I0I67	Chase	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	9/19/1948	1948	Starved Ro	41.3198	-88.9934	310.3	-7.04	-25.76	19.21		812	9.0	30.5000	176.0000	2.05	48.28	27.46	23.55122
ESS Lab	et al. 2020	YUPS1879	376	S.N.	Frank Twee	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	May 1879	1879	Plainfield, N	40.62716	-74.41243	290.2	-6.74	-27.75	21.61		994	11.0	30.5	34	1.64	49.92	35.50	30.43902
ESS Lab	et al. 2020	BHTP2003A	561	#3643	Karen L Gr	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	3/15/2003	2003	Deary, Idah	46.80303	-116.5319	376.11	-8.24	-27.21	19.50		830	8.0	30.6	863	0.94	49.96	61.98	53.14893617
ESS Lab	et al. 2020	MN16-05	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	7/5/2016	2016	National Ar	38.91034	-76.97127	404.5	-8.55	-29.85	21.95		1073	13.3	30.6					
ESS Lab	et al. 2020	MHTO1838	171	n/a	John Sampl	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	3/24/1838	1838	Champaign	40.1084	-83.7524	283.4	-6.60	-24.22	18.05		1060	10.5	30.7	97.5	1.11	50.90	53.48	45.85586
ESS Lab	et al. 2020	FMTO1949	315	#68345	Julian A Ste	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/29/1949	1949	Trout Park,	42.0643	-88.26736	310.5	-6.99	-23.88	17.30		844	9.7	30.7	242	1.76	48.37	32.05	27.48295455
ESS Lab	et al. 2020	FMPS1941	342	#40716	Julian A Ste	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	7/5/1941	1941	Polo, Illinois	41.98536	-89.58042	310.4	-7.00	-25.58	19.07		1095	10.6	30.7	260	1.48	48.78	38.44	32.95946
ESS Lab	et al. 2020	BHTP1947	542	#3126	Marion Owr	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	8/3/1947	1947	Selway Falls	46.05352	-115.3097	310.2	-7.01	-24.95	18.40		952	8.8	30.7	520	1.45	48.60	39.09	33.51724
ESS Lab	et al. 2020	C-PHTS19	519	#18014	Meyer	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja standishii*	10/28/1980	1980	Edge of bog	36.74002	139.49453	336.02	-7.48	-25.35	18.34		1325	14.2	30.7	1275	0.95	49.15	60.33	51.73684211
ESS Lab	et al. 2020	MN16-03	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	7/5/2016	2016	National Ar	38.90606	-76.9718	404.5	-8.55	-27.61	19.60		1069	13.3	30.7					
ESS Lab	et al. 2020	MN16-06	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	7/5/2016	2016	National Ar	38.91016	-76.96189	404.5	-8.55	-28.41	20.44		1073	13.3	30.7					
ESS Lab	et al. 2020	YUPS1911	384	#13-5-1	R W Wood	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	7/5/1911	1911	Franklin, C	41.61605	-72.13775	300.1	-6.86	-28.93	22.73		1092	9.9	30.7	1214	1.23	47.77	45.29	38.8374
ESS Lab	et al. 2020	C-PHTO19	505	#6856	Shiu Ying H	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Platycladus*	*Platycladus orientalis*	3/30/1969	1969	Lanna Islan	22.19849	113.13167	325.63	-7.31	-25.02	18.17		2152	22.6	30.7	8	1.98	44.87	26.43	22.66161616
ESS Lab	et al. 2020	C-PHTO19	504	#6153	Shiu Ying H	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Platycladus*	*Platycladus orientalis*	11/12/1968	1968	Chung Chi C	22.41682	114.20896	321.32	-7.24	-26.86	20.16		2152	22.6	30.7	14	2.20	47.40	25.13	21.54545455
ESS Lab	et al. 2020	C-PHTO19	508	#13170	Shiu Ying H	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Platycladus*	*Platycladus orientalis*	3/28/1972	1972	Lam Tsuen	22.40189	114.24104	327.75	-7.36	-27.28	20.48		2152	22.6	30.7	25	2.00	46.50	27.11	23.25
ESS Lab	et al. 2020	C-PHTO19	509	#13532	Shiu Ying H	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Platycladus*	*Platycladus orientalis*	2/6/1975	1975	Chung Chi C	22.41682	114.20896	331.4	-7.42	-27.75	20.92		2152	22.6	30.7	14	2.13	46.62	25.52	21.88732394
ESS Lab	et al. 2020	C-PHTO19	506	#9411	Shiu Ying H	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Platycladus*	*Platycladus orientalis*	2/6/1970	1970	Chung Chi,	22.41682	114.20896	325.98	-7.29	-26.90	20.14		2152	22.6	30.7	14	1.73	45.70	30.81	26.41618497
ESS Lab	et al. 2020	MHPS1988	292	#665	Peter Fritsc	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	6/21/1988	1988	Hillsdale, M	41.926	-84.62991	353.79	-7.88	-29.82	22.62		825	8.4	30.8	333	1.53	48.59	37.04	31.75817
ESS Lab	et al. 2020	CO_BDPT2	829	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/2/2018	2018	Boulder, Co	39.97065	-105.2617	407.1	-8.42	-27.85	19.98		559	11.6	30.8	1730.9	2.47	48.86	23.07	19.78138
ESS Lab	et al. 2020	WA_NPTP2	744	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/15/2018	2018	Route 12 W	46.45015	-115.0838	411.3	-8.67	-28.76	20.68		806	8.4	30.9	831.2	0.91	47.71	61.14	52.42857
ESS Lab	et al. 2020	BHTP1938	537	S.N.	William H B	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	8/20/1938	1938	Jones Cam	44.17501	-122.1369	310.2	-6.94	-26.48	20.07		1828	9.8	30.9	432	0.99	48.10	56.66	48.58586
ESS Lab	et al. 2020	MN17-10	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Sequoia*	*Sequoia sempervirens*	7/17/2017	2016	Kunming Ins	21.93112	101.25383	407.2	-8.56	-29.54	21.62		1663	22.7	31		2.03	47.90	27.58	23.65185
ESS Lab	et al. 2020	MSTP1903	419	#726	Umbach	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	8/21/1903	1903	Billings, Mo	45.77705	-108.5438	296.8	-6.77	-24.34	18.01		306	8.2	31.2	973	0.71	49.81	81.81	70.15492958
ESS Lab	et al. 2020	MHTO1988A	225	#2418	Robert W S	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	5/4/1988	1988	Rome Town	41.9500	-84.2100	354.22	-7.97	-26.57	19.11		762	8.8	31.3000	299.0000	1.10	44.07	46.72	40.06364
ESS Lab	et al. 2020	FMPS1895B	334	#321215	Dr. J T Roth	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	05/12/1895	1895	Chester, Pe	39.84653	-75.27504	294.8	-6.80	-26.05	19.76		881	12.6	31.4	7	2.09	46.65	26.03	22.32057
ESS Lab	et al. 2020	MHTO1988B	226	#2433	Robert W. S	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	5/11/1988	1988	Cambridge	42.0300	-84.2100	354.22	-7.97	-26.77	19.32		760	8.8	31.4000	305.0000	0.89	53.84	70.55	60.49741
ESS Lab	et al. 2020	WA_DCTP2	733	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/15/2018	2018	Dry Creek F	47.19552	-115.0751	411.3	-8.67	-28.02	19.91		879	7.5	31.6	1006.8	1.35	47.78	41.27	35.39259
ESS Lab	et al. 2020	WA_DCTP2	729	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/15/2018	2018	Dry Creek F	47.20015	-115.0624	411.3	-8.67	-28.49	20.40		639	8.3	31.6	981.8	0.86	48.15	65.29	55.98837
ESS Lab	et al. 2020	WA_DCTP2	732	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/15/2018	2018	Dry Creek F	47.19572	-115.0747	411.3	-8.67	-28.51	20.42		879	7.5	31.6	1008.9	1.34	49.06	42.70	36.61194
ESS Lab	et al. 2020	WA_SFLCT	736	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/15/2018	2018	South Fork	46.7352	-114.2953	411.3	-8.67	-28.54	20.45		464	7.7	31.6	1172.3	0.57	45.87	93.85	80.47368
ESS Lab	et al. 2020	WA_DCPT2	738	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	5/15/2018	2018	Dry Creek F	47.20316	-115.0517	411.3	-8.67	-28.54	20.45		639	8.3	31.6	961.3	2.64	51.07	22.56	19.3447
ESS Lab	et al. 2020	WA_DCTP2	731	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/15/2018	2018	Dry Creek F	47.19572	-115.0747	411.3	-8.67	-28.60	20.52		879	7.5	31.6	1008.9	1.18	47.87	47.31	40.5678
ESS Lab	et al. 2020	WA_SFLCT	737	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/15/2018	2018	South Fork	46.73467	-114.2953	411.3	-8.67	-28.75	20.67		464	7.7	31.6	1173.2	0.56	46.91	97.69	83.76786
ESS Lab	et al. 2020	WA_SFLCT	739	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/15/2018	2018	South Fork	46.7356	-114.2953	411.3	-8.67	-29.38	21.34		464	7.7	31.6	1203.96	0.47	47.45	117.73	100.9574
ESS Lab	et al. 2020	WA_SFLCT	735	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/15/2018	2018	South Fork	47.7356	-114.2953	411.3	-8.67	-29.50	21.46		464	7.7	31.6	1203.96	0.58	41.87	84.19	72.18966
ESS Lab	et al. 2020	WA_DCTP2	730	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/15/2018	2018	Dry Creek F	47.19572	-115.0747	411.3	-8.67	-29.68	21.66		879	7.5	31.6	1008.9	0.57	46.95	96.06	82.36842
ESS Lab	et al. 2020	WA_DCPT2	734	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	5/15/2018	2018	Dry Creek F	47.20316	-115.0517	411.3	-8.67	-30.08	22.07		639	8.3	31.6	961.3	2.13	50.45	27.62	23.68545
ESS Lab	et al. 2020	WA_SFLCT	740	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/15/2018	2018	South Fork	46.73678	-114.2946	411.3	-8.67	-30.20	22.20		464	7.7	31.6	1199.7	0.62	47.84	89.98	77.16129
ESS Lab	et al. 2020	MHTO1952A	199	#12669	Virginius H	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/28/1952	1952	Pentwater,	43.7800	-86.4300	311.5	-7.00	-24.02	17.44		802	8.8	31.6000	184.0000	1.65	47.62	33.66	28.86061
ESS Lab	et al. 2015	_08097	92	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus cembra*	2014	2014		42.02897	-84.11275	401.31	-8.20	-28.91	21.33			1.6	31.67	23.375286				
ESS Lab	et al. 2020	FMPS1995	344	#56-95	K Altvatater	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	7/26/1995	1995	Hoosier Na	38.47585	-86.54021	361.89	-7.90	-28.04	20.73		1180	12.2	31.8	205	0.87	49.12	65.84	56.45977
ESS Lab	et al. 2020	MN16-33	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/15/2016	2016	Cypress Cr	37.33839	-89.07283	402.24	-8.42	-28.42	20.58		1201	14.0	31.9					
ESS Lab	et al. 2020	MN16-32	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/15/2016	2016	Cypress Cr	37.33851	-89.07297	402.24	-8.42	-28.45	20.62		1201	14.0	31.9					
ESS Lab	et al. 2020	MN16-59	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Sequoia*	*Sequoia sempervirens*	12/26/2016	2016	Huntington	34.13231	-118.1121	404.55	-8.49	-30.49	22.69		468	18.3	31.9					
ESS Lab	et al. 2020	MN17-28	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	7/17/2017	2017	Shanghai B	31.15058	121.44157	407.2	-8.56	-21.86	13.60		979	16.4	32					
ESS Lab	et al. 2020	MN17-29	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	7/17/2017	2017	Shanghai B	31.14845	121.43533	407.2	-8.56	-30.65	22.79		977	16.4	32					
ESS Lab	et al. 2020	MN16-34	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/15/2016	2016	Cypress Cr	37.28552	-89.15553	402.24	-8.42	-30.85	23.14		1202	14.0	32.1					
ESS Lab	et al. 2020	CUBPT198	677	#3834	Siplivinsky &	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/10/1982	1982	Colorado N	39.05614	-108.6936	342.06	-7.67	-26.01	18.83		318	9.0	32.1	2201.7	2.25	51.08	26.47	22.70222
ESS Lab	et al. 2020	MN16-08	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	7/6/2016	2016	Zuni, Virgini	36.84339	-76.82912	404.5	-8.55	-28.42	20.45		1210	15.1	32.4					
ESS Lab	et al. 2020	MN16-09	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	7/6/2016	2016	Zuni, Virgini	36.84337	-76.82909	404.5	-8.55	-30.07	22.19		1210	15.1	32.4					
ESS Lab	et al. 2020	FMTO1936A	308	#3088	Tryon, Jr.	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	7/2/1936	1936	Mineral Spri	41.6334	-87.08338	309.8	-6.94	-25.32	18.86		821	9.8	32.4	205	2.09	48.22	26.91	23.07177033
ESS Lab	et al. 2020	FMTO1999B	320	unk	Hess, Leidn	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/21/1999	1999	Lisle, Illinois	41.7991	-88.07509	370.35	-8.14	-25.08	17.38		944	11.2	32.5	204	2.02	49.05	28.32	24.28217822
ESS Lab	et al. 2020	MHTO1993A	228	#3169	Naczi, Rezn	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/21/1993	1993	Scott Count	36.6816	-82.6051	359.6	-7.90	-27.06	19.70		1078	7.9	32.6000	530.0000	1.02	48.95	55.97	47.99116
ESS Lab	et al. 2020	C-PHTO19	503	#476	Levine	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Platycladus*	*Platycladus orientalis*	3/20/1917	1917	Canton Chr	23.10045	113.22964	302.1	-6.88	-24.72	18.30		1720	22.2	32.8	8	1.48	48.88	38.52	33.02702703
ESS Lab	et al. 2020	MHTO2012	235	#13782	Thomas G L	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/27/2012	2012	Kalamazoo	42.2300	-85.5200	395.88	-8.45	-26.35	18.38		760	11.2	32.8000	261.0000	1.41	35.39	29.27	25.09934
ESS Lab	et al. 2020	MHTO1916	177	#8299	L M Umbac	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	7/31/1916	1916	Portage, Mi	42.23	-85.58	301.7	-6.90	-25.03	18.60		904	8.8	32.9	260	1.18	53.64	53.01	45.45339
ESS Lab	et al. 2020	MN17-07	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	7/17/2017	2017	Xishuangba	23.14878	113.27745	407.2	-8.56	-29.54	21.62		1673	22.0	33					
ESS Lab	et al. 2020	MN17-06	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	7/17/2017	2017	LiHu Park,	23.15222	113.27367	407.2	-8.56	-29.99	22.09		1648	22.0	33					
ESS Lab	et al. 2020	MN17-08	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	7/17/2017	2017	Xishuangba	23.14878	113.27745	407.2	-8.56	-30.42	22.55		1673	22.0	33					
ESS Lab	et al. 2020	MN17-09	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	7/17/2017	2017	Xishuangba	23.14878	113.27745	407.2	-8.56	-30.51	22.64		1673	22.0	33					
ESS Lab	et al. 2020	MN17-05	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	7/17/2017	2017	LiHu Park,	23.15222	113.27367	407.2	-8.56	-31.76	23.97		1648	22.0	33					
ESS Lab	et al. 2020	FMTO1900	300	#876	Lansing	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/4/1900	1900	Clarke, India	38.4098	-84.7051	295.8	-6.75	-24.62	18.32		1438	3.8	33.2000	246.0000	0.62	46.71	87.86	75.33871
ESS Lab	et al. 2020	MN16-12	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/5/2016	2016	Big Cypress	25.854	-81.01996	402.24	-8.42	-30.07	22.32		1313	23.7	33.2					
ESS Lab	et al. 2020	MN16-13	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/5/2016	2016	Big Cypress	25.85513	-81.01982	402.24	-8.42	-30.38	22.64		1313	23.7	33.2					
ESS Lab	et al. 2020	MN16-24	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/11/2016	2016	Attakapas Is	29.87826	-91.47115	402.24	-8.42	-28.39	20.56		1627	20.0	33.3					
ESS Lab	et al. 2020	MN16-15	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/6/2016	2016	Seminole St	28.87487	-81.48874	402.24	-8.42	-28.90	21.09		1284	21.3	33.3					
ESS Lab	et al. 2020	MN16-23	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/11/2016	2016	Attakapas Is	29.87951	-91.47157	402.24	-8.42	-28.95	21.14		1627	20.0	33.3					
ESS Lab	et al. 2020	MN16-22	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/11/2016	2016	Attakapas Is	29.87936	-91.4713	402.24	-8.42	-29.00	21.20		1627	20.0	33.3					
ESS Lab	et al. 2020	MN16-16	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/6/2016	2016	Seminole St	28.87489	-81.48871	402.24	-8.42	-29.85	22.09		1284	21.3	33.3					

ESS Lab	et al. 2020	MN17-04	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	7/17/2017	2017	LiHu Park,	23.17905	113.35317	407.2	-8.56	-30.72	22.86		1673	22.0	33.3					
ESS Lab	et al. 2020	WA_WWT	728	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	5/14/2018	2018	Along Colun	47.52853	-120.2841	411.3	-8.67	-24.88	16.62		353	12.6	33.3	226.8	2.02	47.56	27.46	23.54455
ESS Lab	et al. 2020	MSTP1971	420	#250	Jeffrey Hub	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	6/7/1971	1971	Winthrop, W	48.47052	-120.1784	328.57	-7.35	-24.10	17.16		423	6.3	33.4	536	0.65	47.07	84.45	72.41538462
ESS Lab	et al. 2020	MHTOR198	406	#6819	Kessler	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Platycladus*	*Platycladus orientalis*	3/21/1983	1983	Texas A&M	30.61852	-96.33558	343.1	-7.64	-24.85	17.65		819	20.9	33.4	100	0.65	47.27	84.81	72.72307692
ESS Lab	et al. 2020	MN16-14	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/6/2016	2016	Big Cypress	25.96495	-81.33611	402.24	-8.42	-28.75	20.93		1304	23.5	33.4					
ESS Lab	et al. 2020	MN16-19	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/8/2016	2016	Pearl River	30.39229	-89.72487	402.24	-8.42	-28.89	21.08		1559	19.4	33.6					
ESS Lab	et al. 2020	MN16-20	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/8/2016	2016	Pearl River	30.39498	-89.71277	402.24	-8.42	-30.22	22.48		1561	19.4	33.6					
ESS Lab	et al. 2020	MN16-21	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/8/2016	2016	Pearl River	30.39686	-89.69938	402.24	-8.42	-28.18	20.33		1564	19.4	33.7					
ESS Lab	et al. 2020	MN16-11	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	7/30/2016	2016	Francis Mai	33.047	-79.65773	404.5	-8.55	-29.13	21.20		1305	18.2	33.9					
ESS Lab	et al. 2020	MN16-10	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	7/30/2016	2016	Francis Mai	33.1624	-79.82964	404.5	-8.55	-28.69	20.73		1289	18.0	34					
ESS Lab	et al. 2020	MN16-30	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/14/2016	2016	Delta Natior	32.76945	-90.79974	402.24	-8.42	-27.48	19.60		1410	17.8	34.1					
ESS Lab	et al. 2020	MN16-31	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/14/2016	2016	Delta Natior	32.76945	-90.79973	402.24	-8.42	-28.75	20.93		1410	17.8	34.1					
ESS Lab	et al. 2020	MN16-29	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/14/2016	2016	Delta Natior	32.76935	-90.7953	402.24	-8.42	-28.76	20.95		1410	17.8	34.1					
ESS Lab	et al. 2020	MN16-18	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/7/2016	2016	Apalachicol	30.16759	-84.65544	402.24	-8.42	-27.93	20.07		1549	19.7	34.2					
ESS Lab	et al. 2020	MN16-25	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/12/2016	2016	San Bernar	29.17749	-95.84204	402.24	-8.42	-28.46	20.63		1176	20.4	34.2					
ESS Lab	et al. 2020	MN16-17	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/7/2016	2016	Apalachicol	30.16731	-84.65559	402.24	-8.42	-31.39	23.72		1549	19.7	34.2					
ESS Lab	et al. 2020	MN16-26	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/12/2016	2016	Guadalupe	29.87601	-98.48644	402.24	-8.42	-27.60	19.72		859	18.9	34.6					
ESS Lab	et al. 2020	MN16-27	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/12/2016	2016	Guadalupe	29.87596	-98.48687	402.24	-8.42	-29.09	21.29		859	18.9	34.6					
ESS Lab	et al. 2020	MN16-28	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Taxodium*	*Taxodium distichum*	8/12/2016	2016	Guadalupe	29.8758	-98.48716	402.24	-8.42	-29.66	21.89		859	18.9	34.6					
ESS Lab	et al. 2020	BHTP1967	548	#60906	unknown	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	8/8/1967	1967	Alta Lake, V	48.02905	-119.9344	320.92	-7.33	-25.14	18.27		269	10.5	35	361	0.84	46.66	64.78	55.54762
ESS Lab	et al. 2020	FMTP1946	329	#46131	C C Albers	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	8/10/1946	1946	Washington	30.20517	-96.43088	310.1	-6.98	-26.65	20.21		1383	20.6	35.9	92	1.55	45.88	34.52	29.6
ESS Lab	et al. 2020	MI_HLGTJ	936	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Juniperus*	*Juniperus × media*	5/16/2019	2019		42.02919	-84.11236	414.83	-8.76	-24.88	16.53					301.95	1.7	42.2	28.95	24.82352941
ESS Lab	et al. 2015	_09018	100	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea orientalis*	2014	2014		42.02906	-84.11269	401.31	-8.20	-28.86	21.27						0.9	44.65	58.51	50.16853933
ESS Lab	et al. 2020	MI_HLGPO	933	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Platycladus*	*Platycladus orientalis*	5/16/2019	2019		42.02908	-84.11227	414.83	-8.76	-25.19	16.86					302.1	1.9	44.8	27.50	23.57894737
ESS Lab	et al. 2015	2_H81148	73	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea orientalis*	2014	2014		42.02925	-84.1125	401.31	-8.20	-31.57	24.13					51.970106	1.0	45.01	51.97	44.56435644
ESS Lab	et al. 2015	2_H10014A	72	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Juniperus*	*Juniperus × media*	2014	2014		42.02922	-84.11247	401.31	-8.20	-24.69	16.91					20.535719	2.6	45.08	20.54	17.609375
ESS Lab	et al. 2015	H93036	144	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea orientalis*	2014	2014		42.02869	-84.11211	401.31	-8.20	-29.45	21.90						1.1	45.1	49.62	42.54716981
ESS Lab	et al. 2015	1_H10026C	11	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Juniperus*	*Juniperus procumbens*	2014	2014		42.02894	-84.11192	401.31	-8.20	-27.20	19.53					37.775935	1.4	45.35	37.78	32.39285714
ESS Lab	et al. 2020	CO_SSPT2	947	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	9/4/2019	2019		40.3612	-106.7786	408.54	-8.33	-28.17	20.41					2471.93	2.7	45.7	19.74	16.92592593
ESS Lab	et al. 2015	H03029	14	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus cembra*	2014	2014		42.02894	-84.11181	401.31	-8.20	-28.18	20.56					27.771939	1.9	46.2	27.77	23.81443299
ESS Lab	et al. 2020	MI_HLGCP	928	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Chamaecy*	*Chamaecyparis pisifera*	5/16/2019	2019		42.02905	-84.1121	414.83	-8.76	-26.20	17.91					298.1	2.0	46.2	26.94	23.1
ESS Lab	et al. 2015	H09034A	74	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus parviflora*	2014	2014		42.02925	-84.1125	401.31	-8.20	-28.52	20.91					47.74118	1.1	46.26	47.74	40.9380531
ESS Lab	et al. 2015	H10078C	186	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Juniperus*	*Juniperus horizontalis*	2014	2014		42.02969	-84.11219	401.31	-8.20	-29.07	21.49						1.5	46.29	35.75	30.65562914
ESS Lab	et al. 2015	1_H09138A	66	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Taxaceae	*Cedrus*	*Cedrus dec* hybrid	2014	2014		42.02967	-84.11239	401.31	-8.20	-25.96	18.24					32.937502	1.6	46.32	32.94	28.24390244
ESS Lab	et al. 2015	H96010	124	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea abies*	2014	2014		42.02853	-84.11272	401.31	-8.20	-30.18	22.67						1.2	46.33	46.18	39.5982906
ESS Lab	et al. 2020	MI_HLGJP2	925	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Juniperus*	*Juniperus procumbens*	5/16/2019	2019		42.01903	-84.1116	414.83	-8.76	-27.45	19.22					304.8	1.3	46.4	41.62	35.69230769
ESS Lab	et al. 2015	_09125	166	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus bungeana*	2014	2014		42.02958	-84.11286	401.31	-8.20	-28.13	20.51						1.1	46.64	49.00	42.01801802
ESS Lab	et al. 2015	2_H81139	86	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea omorika*	2014	2014		42.02886	-84.11269	401.31	-8.20	-28.14	20.52					55.32881	1.0	46.97	55.33	47.44444444
ESS Lab	et al. 2015	H05031	57	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea pungens*	2014	2014		42.02939	-84.11247	401.31	-8.20	-29.83	22.29					38.856158	1.4	46.98	38.86	33.31914894
ESS Lab	et al. 2015	H93028	164	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea abies*	2014	2014		42.02936	-84.11303	401.31	-8.20	-29.55	22.00						1.7	46.99	31.68	27.16184971
ESS Lab	et al. 2015	2_H81153A	105	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea orientalis*	2014	2014		42.02931	-84.11281	401.31	-8.20	-28.31	20.69						1.4	47.03	40.33	34.58088235
ESS Lab	et al. 2015	H95040	150	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	2014	2014		42.02858	-84.11219	401.31	-8.20	-28.61	21.01						1.7	47.1	31.75	27.22543353
ESS Lab	et al. 2020	MI_HLGJC	938	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Juniperus*	*Juniperus cyparis nootk*	5/16/2019	2019		42.02919	-84.11236	414.83	-8.76	-28.65	20.48					301.95	1.6	47.1	34.33	29.4375
ESS Lab	et al. 2020	MI_HLGTO	922	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	5/16/2019	2019		42.02903	-84.11172	414.83	-8.76	-26.20	17.91					299.9	1.9	47.2	28.97	24.84210526
ESS Lab	et al. 2020	MI_HLGJC	937	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Juniperus*	*Juniperus cyparis nootk*	5/16/2019	2019		42.02919	-84.11236	414.83	-8.76	-28.05	19.85					301.95	1.7	47.2	32.38	27.76470588
ESS Lab	et al. 2015	1_H81043	32	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Chamaecy*	*Chamaecyparis obtusa*	2014	2014		42.02903	-84.11206	401.31	-8.20	-26.05	18.33					41.735144	1.3	47.24	41.74	35.78787879
ESS Lab	et al. 2015	H09408A	183	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Juniperus*	*Juniperus squamata*	2014	2014		42.03025	-84.11253	401.31	-8.20	-26.66	18.97						1.7	47.24	32.60	27.95266272
ESS Lab	et al. 2015	H03027	136	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus cembra*	2014	2014		42.02825	-84.11233	401.31	-8.20	-28.12	20.49						2.3	47.25	23.55	20.19230769
ESS Lab	et al. 2020	MI_HLGCP	926	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Chamaecy*	*Chamaecyparis pisifera*	5/16/2019	2019		42.02905	-84.11202	414.83	-8.76	-26.81	18.55					297.2	1.7	47.3	32.45	27.82352941
ESS Lab	et al. 2015	2_H85165	111	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea glauca*	2014	2014		42.02933	-84.113	401.31	-8.20	-26.87	19.19						1.6	47.36	33.68	28.87804878
ESS Lab	et al. 2015	H03036	137	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus sylvestris*	2014	2014		42.02828	-84.11233	401.31	-8.20	-30.14	22.62						1.5	47.36	35.86	30.75324675
ESS Lab	et al. 2015	H10024A	83	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea pungens*	2014	2014		42.02892	-84.11256	401.31	-8.20	-29.77	22.23					56.45268	1.0	47.44	56.45	48.40816327
ESS Lab	et al. 2015	2_H81157	79	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea pungens*	2014	2014		42.02908	-84.1125	401.31	-8.20	-27.55	19.89					33.536538	1.7	47.45	33.54	28.75757576
ESS Lab	et al. 2015	H08043	3	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus banksiana*	2014	2014		42.02892	-84.11181	401.31	-8.20	-27.52	19.87					38.202481	1.5	47.5	38.20	32.75862069
ESS Lab	et al. 2020	MI_HLGJH	931	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Juniperus*	*Juniperus horizontalis*	5/16/2019	2019		42.02905	-84.1129	414.83	-8.76	-27.71	19.49					301.4	3.8	47.5	14.58	12.5
ESS Lab	et al. 2015	1_H07001D	9	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea omorika*	2014	2014		42.02894	-84.11189	401.31	-8.20	-28.59	20.99					63.000278	0.9	47.54	63.00	54.02272727
ESS Lab	et al. 2015	H83055	126	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea pungens*	2014	2014		42.02842	-84.11253	401.31	-8.20	-30.34	22.83						1.5	47.54	36.00	30.87012987
ESS Lab	et al. 2015	H92131	116	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea glauca*	2014	2014		42.02858	-84.11264	401.31	-8.20	-29.82	22.29						1.6	47.57	35.56	30.49358974
ESS Lab	et al. 2015	1_H81028	43	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Chamaecy*	*Chamaecyparis obtusa*	2014	2014		42.02903	-84.11228	401.31	-8.20	-25.69	17.95					38.670238	1.4	47.75	38.67	33.15972222
ESS Lab	et al. 2015	H00002	4	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea glauca*	2014	2014		42.02894	-84.11181	401.31	-8.20	-29.47	21.91					39.517821	1.4	47.78	39.52	33.88652482
ESS Lab	et al. 2015	2_H81106	71	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea abies*	2014	2014		42.02922	-84.11247	401.31	-8.20	-28.43	20.82					42.229888	1.3	47.8	42.23	36.21212121
ESS Lab	et al. 2015	1_H03021	23	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus densiflora*	2014	2014		42.02897	-84.11206	401.31	-8.20	-30.14	22.62					64.206977	0.9	47.9	64.21	55.05747126
ESS Lab	et al. 2015	H95027	142	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus mugo*	2014	2014		42.02872	-84.11214	401.31	-8.20	-29.49	21.94						1.5	48.03	37.59	32.23489933
ESS Lab	et al. 2015	1_H81021	70	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Chamaecy*	*Chamaecyparis obtusa*	2014	2014		42.0295	-84.11233	401.31	-8.20	-27.79	20.15					74.744428	0.8	48.07	74.74	64.09333333
ESS Lab	et al. 2020	MI_HLGTO	934	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	5/16/2019	2019		42.02908	-84.11227	414.83	-8.76	-26.04	17.75					302.255	1.5	48.1	37.40	32.06666667
ESS Lab	et al. 2020	MI_HLGCP	927	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Chamaecy*	*Chamaecyparis pisifera*	5/16/2019	2019		42.02905	-84.11202	414.83	-8.76	-27.74	19.52					297.2	1.7	48.1	33.00	28.29411765
ESS Lab	et al. 2015	H85169A	25	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea abies*	2014	2014		42.029	-84.11211	401.31	-8.20	-26.98	19.30					64.609108	0.9	48.2	64.61	55.40229885
ESS Lab	et al. 2015	1_H90735	51	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Taxaceae	*Taxus*	*Taxus cusp* hybrid	2014	2014		42.02922	-84.11242	401.31	-8.20	-28.64	21.05					24.124431	2.3	48.2	24.12	20.68669528
ESS Lab	et al. 2015	H85168	157	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea abies*	2014	2014		42.02847	-84.11214	401.31	-8.20	-28.21	20.59						1.7	48.33	33.55	28.76785714
ESS Lab	et al. 2015	4_H95029	149	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus mugo*	2014	2014		42.02861	-84.11217	401.31	-8.20	-30.14	22.62						1.7	48.34	33.36	28.6035503
ESS Lab	et al. 2015	1_H81013	59	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Taxaceae	*Cedrus*	*Cedrus liba* hybrid	2014	2014		42.02944	-84.11247	401.31	-8.20	-29.62	22.07					39.568603	1.4	48.52	39.57	33.93006993
ESS Lab	et al. 2015	64116	209	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Juniperus*	*Juniperus horizontalis*	2014	2014		42.02581	-84.11486	401.31	-8.20	-27.49	19.84						0.9	48.55	66.61	57.11764706
ESS Lab	et al. 2015	1_H95131	67	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	2014	2014		42.02964	-84.11233	401.31	-8.20	-26.08	18.36					46.820722	1.2	48.58	46.82	40.14876033
ESS Lab	et al. 2020	MI_HLGXN	945	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Xanthocypa*	*Cupressus nootkatensis*	5/16/2019	2019		42.02964	-84.11232	414.83	-8.76	-23.76	15.37					304.695	1.4	48.6	40.48	34.71428571
ESS Lab	et al. 2020	MI_HLGCO	930	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Chamaecy*	*Chamaecyparis obtusa*	5/16/2019	2019		42.02904	-84.11212	414.83	-8.76	-25.67	17.35					296.9	1.5	48.6	37.78	32.4
ESS Lab	et al. 2015	H95060	120	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus mugo*	2014	2014		42.02858	-84.11244	401.31	-8.20	-28.29	20.67						1.3	48.61	45.35	38.888
ESS Lab	et al. 2015	1_H92126	24	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea abies*	2014	2014		42.029	-84.11208	401.31	-8.20	-30.82	23.33					57.880657	1.0	48.64	57.88	49.63265306
ESS Lab	et al. 2015	2_H81114	78	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea abies*	2014	2014		42.02903	-84.11256	401.31	-8.20	-28.54	20.94					43.06035	1.3	48.74	43.06	36.92424242
ESS Lab	et al. 2015	1_H81264	65	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Taxaceae	*Taxus*	*Taxus bacc* hybrid	2014	2014		42.02964	-84.11242	401.31	-8.20	-27.41	19.75					22.470879	2.5	48.75	22.47	19.2687747
ESS Lab	et al. 2015	H00005	125	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus koraiensis*	2014	2014		42.02836	-84.11261	401.31	-8.20	-28.40	20.79						1.7	48.79	33.27	28.53216374
ESS Lab	et al. 2015	4_H96001	152	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Juniperus*	*Juniperus chinensis*	2014	2014		42.02853	-84.11211	401.31	-8.20	-29.98	22.45						1.7	48.83	33.90	29.06547619
ESS Lab	et al. 2015	2_H81098	75	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea abies*	2014	2014		42.02919	-84.11256	401.31	-8.20	-28.71	21.12					38.225691	1.5	48.84	38.23	32.77852349
ESS Lab	et al. 2020	MI_HLGCP	929	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Chamaecy*	*Chamaecyparis pisifera*	5/16/2019	2019		42.02905	-84.1121	414.83	-8.76	-27.55	19.32					298.1	1.6	49	35.71	30.625
ESS Lab	et al. 2015	4_H93054	156	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	2014	2014		42.02864	-84.11208	401.31	-8.20	-26.36	18.65						1.4	49.06	39.73	34.06944444
ESS Lab	et al. 2015	H10146A	131	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Chamaecy*	*Chamaecyparis obtusa*	2014	2014		42.02831	-84.11258	401.31	-8.20	-27.93	20.29						1.3	49.09	44.38	38.05426357
ESS Lab	et al. 2015	H08008A	128	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea glauca*	2014	2014		42.02839	-84.11253	401.31	-8.20	-28.27	20.66						1.0	49.16	59.10	50.68041237
ESS Lab	et al. 2015	H88228	153	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	2014	2014		42.02847	-84.11203	401.31	-8.20	-29.30	21.74						1.5	49.17	37.72	32.34868421
ESS Lab	et al. 2015	71480	210	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Taxaceae	*Taxus*	*Taxus × media*	2014	2014		42.02594	-84.11531	401.31	-8.20	-30.89	23.42						1.8	49.18	32.77	28.10285714
ESS Lab	et al. 2020	MI_HLGMG	940	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Metasequo*	*Metasequo cyparis nootk*	5/16/2019	2019		42.02975	-84.11282	414.83	-8.76	-28.26	20.07					304.695	4.6	49.2	12.47	10.69565217
ESS Lab	et al. 2020	MI_HLGJS	941	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Juniperus*	*Juniperus sabina*	5/16/2019	2019		42.0404	-84.11205	414.83	-8.76	-23.01	14.58					309.27	2.6	49.3	22.11	18.96153846
ESS Lab	et al. 2020	MI_HLGMD	946	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Microbiota*	*Microbiota decussata*	5/16/2019	2019		42.02803	-84.11222	414.83	-8.76	-26.12	17.83					298.9	1.7	49.3	33.82	29
ESS Lab	et al. 2020	MI_HLGJV	939	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Juniperus*	*Juniperus cyparis nootk*	5/16/2019	2019		42.02964	-84.11269	414.83	-8.76	-27.27	19.03					301.34	1.8	49.3	31.94	27.38888889
ESS Lab	et al. 2015	1_H81234	55	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	2014	2014		42.02928	-84.11244	401.31	-8.20	-27.99	20.36					33.635115	1.7	49.32	33.64	28.84210526
ESS Lab	et al. 2015	5_H81213A	175	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus parviflora*	2014	2014		42.02978	-84.11294	401.31	-8.20	-29.14	21.57						1.7	49.32	33.06	28.34482759
ESS Lab	et al. 2015	2_H09415A	115	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea engelmannii*	2014	2014		42.02925	-84.11289	401.31	-8.20	-27.93	20.30						1.6	49.39	36.45	31.25949367
ESS Lab	et al. 2015	H09340A	143	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Taxaceae	*Taxus*	*Taxus × media*	2014	2014		42.02869	-84.11211	401.31	-8.20	-28.56	20.96						2.3	49.48	25.53	21.89380531
ESS Lab	et al. 2015	4_H92133	145	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus sylvestris*	2014	2014		42.02864	-84.11208	401.31	-8.20	-29.99	22.47						1.5	49.8	39.24	33.64864865
ESS Lab	et al. 2020	MI_HLGCN	943	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Xanthocypa*	*Cupressus nootkatensis*	5/16/2019	2019		42.03034	-84.11205	414.83	-8.76	-26.30	18.02					309.27	1.4	49.8	41.48	35.57142857
ESS Lab	et al. 2015	2_H10002A	18	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea abies*	2014	2014		42.02886	-84.11214	401.31	-8.20	-28.52	20.92					42.728529	1.4	49.83	42.73	36.63970588
ESS Lab	et al. 2020	MI_HLGJP	924	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Juniperus*	*Juniperus procumbens*	5/16/2019	2019		42.01903	-84.1116	414.83	-8.76	-27.03	18.78					304.8	1.3	49.9	44.76	38.38461538
ESS Lab	et al. 2015	1_H81037	33	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Chamaecy*	*Chamaecyparis pisifera*	2014	2014		42.02906	-84.11211	401.31	-8.20	-26.02	18.30					36.377559	1.6	49.91	36.38	31.19375
ESS Lab	et al. 2015	1_H83229	38	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	2014	2014		42.02922	-84.11208	401.31	-8.20	-26.20	18.48					41.599342	1.4	49.94	41.60	35.67142857
ESS Lab	et al. 2015	1_H81179	61	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus densiflora*	2014	2014		42.02947	-84.11242	401.31	-8.20	-30.29	22.78					79.779561	0.7	49.94	79.78	68.4109589
ESS Lab	et al. 2015	1_H81181	56	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus densiflora*	2014	2014		42.02933	-84.1125	401.31	-8.20	-28.04	20.42					55.074548	1.1	50.06	55.07	47.22641509
ESS Lab	et al. 2015	3_H05014	118	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	2014	2014		42.02861	-84.11261	401.31	-8.20	-26.50	18.80						1.6	50.22	37.78	32.4
ESS Lab	et al. 2020	CO_SSPT2	950	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	9/4/2019	2019		40.34928	-106.7512	408.54	-8.33	-28.71	20.98						3.9	50.3	15.04	12.8974359
ESS Lab	et al. 2015	3_H03035	127	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Chamaecy*	*Chamaecyparis obtusa*	2014	2014		42.02842	-84.11253	401.31	-8.20	-25.53	17.78						1.0	50.42	56.54	48.48076923
ESS Lab	et al. 2015	2_H81131	89	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea alcoquiana*	2014	2014		42.02883	-84.11292	401.31	-8.20	-29.31	21.75					39.839264	1.5	50.56	39.84	34.16216216
ESS Lab	et al. 2015	1_H05049	47	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea abies*	2014	2014		42.02939	-84.11236	401.31	-8.20	-28.50	20.90					58.985435	1.0	50.58	58.99	50.58
ESS Lab	et al. 2015	1_H81101	20	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea abies*	2014	2014		42.02892	-84.11208	401.31	-8.20	-28.52	20.92					39.094094	1.5	50.62	39.09	33.52317881
ESS Lab	et al. 2015	2_H81267	98	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Taxaceae	*Taxus*	*Taxus × media*	2014	2014		42.02914	-84.11258	401.31	-8.20	-27.79	20.15						1.8	50.99	33.22	28.48603352
ESS Lab	et al. 2015	3_H93058	129	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Tsuga*	*Tsuga canadensis*	2014	2014		42.02836	-84.11253	401.31	-8.20	-30.38	22.88						1.1	51.15	56.27	48.25471698
ESS Lab	et al. 2015	3_H07077	122	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Taxaceae	*Taxus*	*Taxus × media*	2014	2014		42.02847	-84.11261	401.31	-8.20	-28.96	21.38						1.9	51.18	31.41	26.93684211
ESS Lab	et al. 2015	5_H05011	180	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus sp.*	2014	2014		42.03011	-84.11258	401.31	-8.20	-29.03	21.45						1.4	51.22	43.28	37.11594203
ESS Lab	et al. 2015	2_H82106A	95	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	2014	2014		42.02911	-84.11292	401.31	-8.20	-27.80	20.16						1.3	51.32	44.66	38.29850746
ESS Lab	et al. 2015	2_H94031	93	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Tsuga*	*Tsuga canadensis*	2014	2014		42.029	-84.11283	401.31	-8.20	-26.89	19.21						1.8	51.42	34.07	29.21590909
ESS Lab	et al. 2015	5_H07002	172	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Xanthocypa*	*Cupressus nootkatensis*	2014	2014		42.02956	-84.11275	401.31	-8.20	-25.72	17.98						1.4	51.45	44.12	37.83088235
ESS Lab	et al. 2020	MI_HLGJH	932	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Juniperus*	*Juniperus horizontalis*	5/16/2019	2019		42.02905	-84.1129	414.83	-8.76	-28.71	20.54					301.4	1.9	51.5	31.61	27.10526316
ESS Lab	et al. 2015	63266	206	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Taxaceae	*Taxus*	*Taxus × media*	2014	2014		42.02567	-84.11547	401.31	-8.20	-26.11	18.39						1.7	51.59	35.18	30.16959064
ESS Lab	et al. 2015	2_H81200	114	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus koraiensis*	2014	2014		42.02925	-84.11281	401.31	-8.20	-26.87	19.19						1.2	51.67	50.21	43.05833333
ESS Lab	et al. 2015	5_H97045	170	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus mugo*	2014	2014		42.02958	-84.1125	401.31	-8.20	-27.34	19.68						1.3	51.68	47.46	40.69291339
ESS Lab	et al. 2020	MI_SWTO2	920		Zoey Plonka	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	2/9/2019	2019		42.40651	-83.94184	411.66	-8.60	-29.31	21.34						1.9	51.7	31.73	27.21052632
ESS Lab	et al. 2015	2_81263	76	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Taxaceae	*Taxus*	*Taxus bacc* hybrid	2014	2014		42.02911	-84.11256	401.31	-8.20	-26.58	18.89					26.801431	2.3	51.71	26.80	22.98222222
ESS Lab	et al. 2015	1_H92144	34	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Xanthocypa*	*Cupressus nootkatensis*	2014	2014		42.02906	-84.11208	401.31	-8.20	-26.12	18.40					62.384672	1.0	51.89	62.38	53.49484536
ESS Lab	et al. 2020	MI_HLGTO	923	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	5/16/2019	2019		42.02903	-84.11172	414.83	-8.76	-27.55	19.32					299.9	1.8	51.9	33.62	28.83333333
ESS Lab	et al. 2015	1_H83117	48	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Chamaecy*	*Chamaecyparis pisifera*	2014	2014		42.02922	-84.11228	401.31	-8.20	-24.87	17.09					35.719438	1.7	52.07	35.72	30.62941176
ESS Lab	et al. 2015	5_H81018	169	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Chamaecy*	*Chamaecyparis obtusa*	2014	2014		42.02967	-84.11258	401.31	-8.20	-24.53	16.74						1.3	52.19	47.92	41.09448819
ESS Lab	et al. 2015	2_H82192	113	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Chamaecy*	*Chamaecyparis pisifera*	2014	2014		42.02919	-84.11286	401.31	-8.20	-25.80	18.07						1.6	52.24	38.80	33.27388535
ESS Lab	et al. 2020	MI_HLGCN	942	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Xanthocypa*	*Cupressus nootkatensis*	5/16/2019	2019		42.03034	-84.11205	414.83	-8.76	-26.37	18.08					309.27	1.6	53.1	38.70	33.1875
ESS Lab	et al. 2020	MI_HLGXN	944	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Xanthocypa*	*Cupressus nootkatensis*	5/16/2019	2019		42.02964	-84.11232	414.83	-8.76	-25.30	16.97					304.695	1.5	53.2	41.36	35.46666667
ESS Lab	et al. 2015	2_H11008A	82	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Chamaecy*	*Cupressus nootkatensis*	2014	2014		42.02889	-84.11261	401.31	-8.20	-26.91	19.23					51.827027	1.2	53.33	51.83	44.44166667
ESS Lab	et al. 2015	4_H86052	163	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Chamaecy*	*Chamaecyparis pisifera*	2014	2014		42.02847	-84.113	401.31	-8.20	-26.26	18.55						1.7	53.58	36.76	31.51764706
ESS Lab	et al. 2020	MI_SWTO2	921		Zoey Plonka	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	2/9/2019	2019		42.40677	-83.9419	411.66	-8.60	-28.84	20.84						1.7	53.7	36.84	31.58823529
ESS Lab	et al. 2020	MI_HLGTJ	935	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Juniperus*	*Juniperus × media*	5/16/2019	2019		42.02919	-84.11236	414.83	-8.76	-24.79	16.44					301.95	2.2	57.7	30.59	26.22727273
ESS Lab	et al. 2015	H81117	168	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea abies*	2014	2014		42.02964	-84.11261	401.31	-8.20	-29.53	21.98						3.1	77.32	29.47	25.26797386
ESS lab	et al. 2020	n/a	n/a	S.N.	Jokela	Angiosperm	Herbaceous	C3	Herbaceous	Cyperaceae	*Rhynchosp*	*Rhynchospora alba*								-27.11										
ESS lab	et al. 2020	n/a	n/a	#70377	Wilbur & Mc	Angiosperm	Herbaceous	C3	Herbaceous	Cyperaceae	*Rhynchosp*	*Rhynchospora corymbosa*								-28.54										
ESS Lab	et al. 2020	MHTO1980	221	#5486	A A Reznice	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	5/25/1980	1980	Ontario, no further information provid			341.47	-7.68	-24.99	17.75						0.78	47.96	71.71	61.48718
ESS Lab	et al. 2020	Gink_TX1	n/a	n/a	Aaron Pan	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/1/2011	2011	Fort Worth,	32.72	-97.32064	389	-8.15	-29.14	21.62		796	18.5		188.37				
ESS Lab	et al. 2020	Gink_CA_ Berk9	n/a	n/a	Ali Weaver	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sep-11	2011	Berkeley, C	37.88	-122.2827	389	-8.15	-28.02	20.44		647	14.2		34.44				
ESS Lab	et al. 2020	Gink_BC1	n/a	n/a	Alina Fisher	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sept/oct 2011	2011	Victoria, Bri	48.43	-123.3655	389	-8.17	-26.83	19.17		831	9.9		12.19				
ESS Lab	et al. 2020	UMPT1862	424	S.N.	Almendinge	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	5/14/1862	1862	Ann Arbor,	42.27776	-83.73185	286.5	-6.67	-26.24	20.09		660	8.1		274	4.59	51.87	13.18	11.30065359
ESS Lab	et al. 2020	UMPT1924	438	#138	Archer	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/2/1924	1924	Humboldt C	41.34652	-118.2103	304.5	-6.89	-24.70	18.26		193	8.5		1391	4.45	52.09	13.65	11.70561798

ESS Lab	et al. 2020	MI_ULPTO	883	n/a	Ashley Han	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	8/19/2018	2018	No further information provided			407.1	-8.42	-28.08	20.22						1.00	48.75	56.85	48.75
ESS Lab	et al. 2020	MI_ULPTO	884	n/a	Ashley Han	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	8/19/2018	2018	No further information provided			407.1	-8.42	-28.37	20.54						1.04	48.63	54.53	46.75962
ESS Lab	et al. 2020	MI_ULPTO	882	n/a	Ashley Han	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	8/19/2018	2018	No further information provided			407.1	-8.42	-28.47	20.63						1.03	47.85	54.18	46.45631
ESS Lab	et al. 2020	KKPT1992	624	#125	Austin, Aust	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	5/31/1992	1992	Blackhawk,	39.79673	-105.4901	359.66	-7.99	-27.26	19.81		496	4.8		2637	3.36	50.38	17.49	14.99404762
ESS Lab	et al. 2020	UMPT1934	446	#179	Bach	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/17/1934	1934	Ice Lake W	45.22861	-117.272	309	-6.94	-25.89	19.45		1324	3.3		2101	3.05	49.47	18.92	16.21967213
ESS Lab	et al. 2020	UMPT1967	462	#6196	Bagley	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	9/2/1967	1967	Lincoln Cou	43.26886	-110.9507	319.25	-7.33	-28.86	22.17		922	2.2		2491	2.54	47.69	21.90	18.77559055
ESS Lab	et al. 2020	UMPT1942	452	#4040	Bailey	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	5/24/1942	1942	Mott Island,	48.11083	-88.53493	310.3	-6.96	-27.24	20.84		784	4.4		183	5.74	49.78	10.11	8.672473868
ESS Lab	et al. 2020	CUBPT189	645	#667	Baker, Earl	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1898	1898	Chicken Cr	37.54263	-107.9067	295.2	-6.81	-23.53	17.12		606	3.4		2300	3.88	47.98	14.42	12.36597938
ESS Lab	et al. 2020	UMPT1937	448	#14154	Ball	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/6/1937	1937	Sawtooth N	42.54825	-114.4289	310	-6.95	-27.98	21.63		268	9.6		1160	2.59	47.38	21.33	18.29343629
ESS Lab	et al. 2020	UMPT1911	434	#2678	Bartall	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/21/1911	1911	Pawtucket,	41.88117	-71.38022	300.1	-6.86	-27.80	21.55		1045	10.3		11	2.57	54.15	24.57	21.07003891
ESS Lab	et al. 2020	FMTO1944	313	#6364	Benke	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	9/14/1944	1944	Wisconsin, no further information pro			310.1	-6.97	-23.92	17.36						1.10	51.25	54.33	46.59090909
ESS Lab	et al. 2020	CUBPT196	672	#10005	Blass, Britto	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1965	1965	Black Lake,	46.05951	-71.38453	321.87	-7.17	-24.41	17.68					2529.8	5.32	50.97	11.17	9.580827
ESS Lab	et al. 2020	KKPT1912	620	#31	Brumback &	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/17/1912	1912	Pikes Peak	38.84461	-105.0184	300.4	-6.86	-27.44	21.16		544	1.3		3163	2.37	49.93	24.57	21.06751055
ESS Lab	et al. 2020	MHTO1965	209	#578	Brunekt	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/19/1965	1965	Michigan, No further information prov			321.87	-7.17	-26.23	19.57						1.14	47.48	48.57	41.64912
ESS Lab	et al. 2020	UMPT1965	461	#721	Brunett	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/8/1965	1965	Muskegon,	43.21327	-86.32433	321.21	-7.17	-26.48	19.83		791	8.6		186	3.74	50.99	15.90	13.63368984
ESS Lab	et al. 2020	CUBPT197	676	#8003	Bye	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/14/1977	1977	De Bocoyna	27.78052	-107.5751	332.75	-7.49	-26.42	19.45		403	18.2		1781	1.08	50.56	54.59	46.81481
ESS Lab	et al. 2020	CUBPT198	680	#12877	Bye, Davis,	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/4/1984	1984	Chihuahua,	27.70558	-107.3968	346.8	-7.86	-25.30	17.90		403	18.2		2275	2.08	49.59	27.80	23.84135
ESS Lab	et al. 2020	FMTO1900C	302	S.N.	C Baenitz	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	5/16/1900	1900	Germany			295.8	-6.75	-21.98	15.57						1.45	48.08	38.67	33.15862069
ESS Lab	et al. 2020	FMTO1900B	301	S.N.	C Baenitz	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	5/9/1900	1900	Breslau, Wr	51.1354	17.0646	295.8	-6.75	-25.02	18.73		590	8.3		115.0000	0.87	47.97	64.30	55.13793103
ESS Lab	et al. 2020	MHTO1971	216	#14627	C. E. Garto	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	7/29/1971	1971	Algoma Dis	47.6459	-84.7952	327.36	-7.35	-24.70	17.79		852	4.8		516.0000	0.96	48.46	58.87	50.47917
ESS Lab	et al. 2020	C-KHTS19	487	S.N.	C. Kirt & L.	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja standishii*	6/28/1998	1998	Kunming, Yunnan, China			368.88	-8.20	-25.70	17.96						0.88	45.73	60.60	51.96590909
ESS Lab	et al. 2020	CSPT1897	644	#2325	Cacaen	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1897	1897	Rist Canyo	40.63303	-105.264	295	-6.80	-26.14	19.87		460	7.3		2006	2.01	48.25	27.99	24.00497512
ESS Lab	et al. 2020	MHPS1932B	259	#2167	Carl Grassl	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	8/25/1932	1932	Mt. McBean	51.08332	-117.5423	308.2	-6.91	-24.63	18.18					568	1.09	50.56	54.09	46.38532
ESS Lab	et al. 2020	MHPS1932A	258	#5779	Carl Grassl	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	8/10/1932	1932	Manitoulin I	45.68044	-82.08626	308.2	-6.91	-25.16	18.72					240	1.14	50.42	51.58	44.22807
ESS Lab	et al. 2020	MHPS1931	257	#1137	Carl Grassl	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	7/5/1931	1931	Algoma Dis	48.20894	-84.44308	307.7	-6.98	-26.81	20.37					516	2.10	49.34	27.40	23.49524
ESS Lab	et al. 2020	MHTO1933	186	#3062	Carl O Gras	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	10/1/1932	1932	Michigan, No further information prov			308.2	-6.91	-24.83	18.38						1.09	51.60	55.46	47.5576
ESS Lab	et al. 2020	Gink_NY_ Utica1	n/a	n/a	Carlie Phipp	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sept/oct 2011	2011	Utica, New	43.05	-75.38117	389	-8.17	-29.78	22.27		1085	7.5		179.53				
ESS Lab	et al. 2020	MHPS1919	255	S.N.	Cecil Billing	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	4/27/1919	1919	Michigan, No further information prov			302.7	-6.88	-26.68	20.34						1.24	47.57	44.74	38.3629
ESS Lab	et al. 2020	UMPT1982	472	#20911	CEG	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/24/1982	1982	Kilkenny tow	49.50307	-87.98165	343.35	-7.71	-28.22	21.10		825	1.9		347	3.15	50.34	18.64	15.98095238
ESS Lab	et al. 2020	C-PHTS19	521	94545	Ceming Tan	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja standishii*	10/20/1993	1993	Lianhuatai,	34.97418	111.41094	353.99	-7.64	-25.67	18.51					1100	0.94	35.80	44.41	38.08510638
ESS Lab	et al. 2020	MHPS1949	263	#2630	Charles D F	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	8/19/1949	1949	Michigan, No further information prov			310.5	-6.99	-25.44	18.93						1.14	48.25	49.36	42.32456
ESS Lab	et al. 2020	UMPT1919	436	#3406	Chase	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	10/5/1919	1919	Peona Cou	40.69944	-89.5916	302.7	-6.88	-28.00	21.73		815	9.7		158	2.60	49.87	22.37	19.18076923
ESS Lab	et al. 2015	4_H93054	164	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	2014	2014				401.31	-8.20	-26.36	18.65									
ESS Lab	et al. 2015	3_H94074	134	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Taxodium*	*Taxodium distichum*	2014	2014		42.02828	-84.11244	401.31	-8.20	-26.95	19.27						1.64	48.27		
ESS Lab	et al. 2015	1_H10026C	11	n/a	Chelsea Me	ymnosperm	Woody	C3	Woody Gyn	Cupressace	*Juniperus*	*Juniperus procumbens*	2014	2014				401.31	-8.20	-27.20	19.53									
ESS Lab	et al. 2015	1_H70021A	21	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Abies*	*Abies koreana*	2014	2014		42.02894	-84.11214	401.31	-8.20	-27.28	19.61						1.35	49.44	42.71	
ESS Lab	et al. 2015	4_H05013A	151	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Taxodium*	*Taxodium distichum*	2014	2014		42.02853	-84.11214	401.31	-8.20	-27.42	19.76						2.57	48.25		
ESS Lab	et al. 2015	**#2c**	n/a	n/a	Chelsea Me	Angiosperm	Woody	C3	Woody Ang	Lauraceae	*Sassafras*	*Sassafras officinale*	2014	2014				401.31	-8.20	-27.73	20.09									
ESS Lab	et al. 2015	2_08112	109	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Abies*	*Abies concolor*	2014	2014		42.02928	-84.11267	401.31	-8.20	-28.03	20.40						1.55	49.19		
ESS Lab	et al. 2015	1_H81135	30	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea omorika*	8/28/2014	2014	Hidden Lak	42.02881	-84.11225	397.21	-8.27	-28.11	20.41		824	8.9			1.75	50.50	33.65	
ESS Lab	et al. 2015	5_H1051A	178	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Abies*	*Abies concolor*	2014	2014		42.03003	-84.11289	401.31	-8.20	-28.33	20.72						1.24	50.73		
ESS Lab	et al. 2015	1_H10005A	n/a	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Picea*	*Picea abies*	2014	2014				401.31	-8.20	-28.56	20.96									
ESS Lab	et al. 2015	1_H92129	16	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Larix*	*Larix decidua*	2014	2014	Hidden Lak	42.02889	-84.11194	401.31	-8.20	-28.58	20.98						1.62	46.04	33.14	
ESS Lab	et al. 2015	#2a	199	n/a	Chelsea Me	Angiosperm	Woody	C3	Woody Ang	Lauraceae	*Sassafras*	*Sassafras officinale*	2014	2014		42.03021	-84.11268	401.31	-8.20	-29.39	21.83						0.69	45.49		
ESS Lab	et al. 2015	H09166A	2	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Abies*	*Abies lasiocarpa*	2014	2014		42.02892	-84.11175	401.31	-8.20	-29.39	21.83						1.34	47.76	41.56	
ESS Lab	et al. 2015	#1b	202	n/a	Chelsea Me	Angiosperm	Woody	C3	Woody Ang	Lauraceae	*Sassafras*	*Sassafras officinale*	2014	2014		42.03022	-84.11264	401.31	-8.20	-29.40	21.85						1.08	44.25		
ESS Lab	et al. 2015	3_H93018	133	n/a	Chelsea Me	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Larix*	*Larix laricina*	2014	2014				401.31	-8.20	-32.97	25.62									
ESS Lab	et al. 2020	MHTO1938	191	#C-142	Chester C (	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	8/16/1938	1938	Wisconsin, no further information pro			310.2	-6.94	-24.74	18.24						0.99	49.55	58.66	50.30457
ESS Lab	et al. 2020	CSPT1935	656	#1072	Christ	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1935	1935	Victor Ridge	38.70928	-105.1415	309.4	-6.98	-23.23	16.64		401	3.7		2895.6	3.16	48.90	18.05	15.47468354
ESS Lab	et al. 2020	MHTOR194	398	#5225	Chung In-Cl	Gymnosper	Woody	C3	Woody Gyn	Cupressac eae	*Platycladu s*	*Platycladus orientalis*	5/27/1948	1948	Songni-San	36.5332	127.90001	310.3	-7.04	-25.51	18.95		1249	10.3		361	1.01	46.02	53.14	45.56435644
ESS Lab	et al. 2020	CSPT1939	660	#8310	Clokey	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1939	1939	Kyle Canyo	36.27722	-115.4835	310.3	-6.99	-26.74	20.29		275	12.6		1524	3.54	50.91	16.77	14.38136
ESS Lab	et al. 2020	MHPS1966A	274	#15183	Cody & Moo	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	6/20/1966	1956	Ontario, No further information provid			323.75	-7.23	-26.56	19.85						1.26	52.19	48.30	41.42063
ESS Lab	et al. 2020	MHPS1966B	275	#15183	Cody & Moo	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	6/20/1966	1966	Ontario, No further information provid			323.75	-7.23	-26.84	20.15						1.03	44.19	50.03	42.90291
ESS Lab	et al. 2020	UMPT1896	430	#6713	Cole	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	4/10/1896	1896	Grand Rapi	42.9699	-85.66318	294.9	-6.80	-26.42	20.15		691	7.7		227	2.28	53.09	27.15	23.28508772
ESS Lab	et al. 2020	MHTO1936	187	S.N.	Cormack &	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	8/4/1936	1936	Ontario, No further information provid			309.8	-6.94	-24.55	18.05						1.22	1.02	49.20	0.831967
ESS Lab	et al. 2020	KKPT1909	619	S.N.	Crisp	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/31/1909	1909	Gilpin, Tolla	39.90812	-105.5863	299.3	-6.85	-25.94	19.60		751	2.7		2705	3.05	49.91	19.08	16.36393
ESS Lab	et al. 2020	CUBPT191	653	#4935	Cusick	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1919	1919	Jimmy Cree	42.86397	-122.5149	302.7	-6.88	-23.47	16.99		1221	8.3		915	3.35	50.31	17.51	15.01791045
ESS Lab	et al. 2020	MHTO1968A	210	#6720	D. J. Hagen	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/2/1968	1968	Michigan, No further information prov			325.36	-7.24	-26.15	19.41						0.88	45.18	59.87	51.34091
ESS Lab	et al. 2020	Gink_CT1	n/a	n/a	Dana Roye	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sep-11	2011	Middletown,	41.55	-72.65493	389	-8.15	-28.61	21.06		1137	9.7		43.59				
ESS Lab	et al. 2020	Gink_FRC 1	n/a	n/a	Dario De Fr	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/25/2011	2011	Paris, Franc	48.84	2.3595917	388.93	-8.17	-28.34	20.76		642	11.2		35.05				
ESS Lab	et al. 2020	CUBPT195	669	#30	Dave Murra	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1959	1959	Tetlin Lake,	63.08333	-143.25	318.15	-7.07	-27.11	20.60			-2.2		671	1.61	48.84	35.38	30.3354
ESS Lab	et al. 2020	Gink_ON_ Toronto1	n/a	n/a	Derek Lars	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sept/oct 2011	2011	Toronto, Or	43.65	-79.38296	389	-8.17	-27.71	20.10		784	8.2		81.08				
ESS Lab	et al. 2020	UMPT1956	458	#1595	Dieterle	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	5/29/1956	1956	Traverse C	44.7619	-85.61599	313.6	-7.01	-26.23	19.73		733	8.5		181	4.48	48.51	12.63	10.828125
ESS Lab	et al. 2020	UMPT1895	428	S.N.	Dodge	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	5/10/1895	1895	Port Huron,	42.98723	-82.4285	294.8	-6.80	-25.57	19.26		676	6.9		183	3.32	58.45	20.53	17.60542169
ESS Lab	et al. 2020	UMPT1892	426	S.N.	Dodge	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	5/8/1892	1892	Port Huron,	42.98723	-82.4285	294.5	-6.79	-28.28	22.12		676	6.9		183	2.73	47.53	20.30	17.41025641
ESS Lab	et al. 2020	MHPS1961B	272	#10644	E. G. Voss	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	8/6/1961	1961	Algoma Dis	47.08397	-84.45418	316.79	-7.07	-25.83	19.26					389	1.03	48.29	54.67	46.8835
ESS Lab	et al. 2020	MHPS1952B	267	#1474	E. G. Voss	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	9/27/1952	1952	Michigan, No further information prov			311.5	-7.00	-28.43	22.06						0.83	45.54	63.99	54.86747
ESS Lab	et al. 2020	YUTP1962	370	#1377	Elihnor Leht	Gymnosper	Woody	C3	Woody Gyn	Cupressac eae	*Thuja*	*Thuja plicata*	8/29/1962	1962	Vancouver,	49.27922	-123.1201	317.4	-7.09	-24.97	18.33		1153	11.0		25	1.23	47.64	45.17	38.73170732
ESS Lab	et al. 2020	Gink_NC1	n/a	n/a	Elizabeth W	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/1/2011	2011	Raleigh, No	35.77	-78.6384	389	-8.15	-26.85	19.22		1145	15.0		95.10				
ESS Lab	et al. 2020	Gink_OH1	n/a	n/a	Ellen D. Cur	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sept/oct 2011	2011	Miami, Ohio	39.51	-84.7631	389	-8.17	-27.93	20.32		1000	10.9		299.31				
ESS Lab	et al. 2020	C-KHTS200	488	#9282V01	Ellen Kanga	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja standishii*	7/11/2001	2001	Morton Arbo	41.79311	-88.0775	371.62	-8.05	-25.15	17.54		1018	11.3		202	0.90	43.47	56.33	48.3
ESS Lab	et al. 2020	UMPT1922	437	#435	Erlanson	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/31/1922	1922	Copeland, I	48.90316	-116.3884	303.8	-6.89	-24.79	18.35		458	6.2		547	2.21	49.11	25.91	22.22171946
ESS Lab	et al. 2020	Gink_Tokyo	n/a	70	Ewing Elliot	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/17/1946	1946	Tokyo, Japa	35.67	139.46	310.1	-6.98	-29.27	22.96		1407	15.4		0.00				
ESS Lab	et al. 2020	MHTO1937	189	#9256	F J Herman	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja occidentalis*	9/13/1937	1937	Michigan, No further information prov			310	-6.95	-24.94	18.45						1.11	51.24	53.83	46.16216
ESS Lab	et al. 2020	MHPS1965	273	#697	F. V. Brunet	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	7/1/1965	1965	Michigan, No further information prov			321.21	-7.17	-27.01	20.40						1.19	46.78	45.84	39.31092
ESS Lab	et al. 2020	C-SHTS19	494	12272	Fan	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja standishii*	9/14/1991	1991	Shanghai Bo	31.14998	121.44947	352.15	-7.67	-24.36	17.10						1.51	43.94	33.94	29.09933775
ESS Lab	et al. 2020	UMPT1912	435	#3248	Farwell	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	10/27/1912	1912	Parkedale, I	42.68586	-83.10828	300.4	-6.86	-25.92	19.57		798	9.7		215	1.82	51.72	33.14	28.41758242
ESS Lab	et al. 2020	KKPT1999	627	#12536	Freeman &	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/4/1999	1999	Larimer, Co	40.61318	-105.4786	370.35	-8.14	-26.94	19.32		631	5.3		3075	3.19	50.17	18.34	15.72727273
ESS Lab	et al. 2020	UMPT1983	475	#407	Freudenste	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	5/26/1983	1983	Murphi Lake	43.30124	-83.45747	345.76	-7.86	-27.38	20.07		782	8.5		264	3.52	52.34	17.34	14.86931818
ESS Lab	et al. 2020	UMPT1983	476	#1020	Freudenste	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/26/1983	1983	Alpena, Mic	45.06878	-83.44746	342.38	-7.58	-28.61	21.65		832	7.1		184	3.12	53.40	19.96	17.11538462
ESS Lab	et al. 2020	UMPT1988	479	#507	Fritsch	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	5/8/1988	1988	Jonesville, M	41.97766	-84.66893	354.22	-7.97	-26.38	18.91		817	8.4		329	6.14	49.43	9.39	8.050488599
ESS Lab	et al. 2020	UMPT1936	447	#8226	Fritz	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/20/1936	1934	Plumas Cou	40.17547	-120.8893	309.8	-6.94	-26.94	20.55		697	10.2		1473	2.40	50.90	24.73	21.20833333
ESS Lab	et al. 2020	Gink_OR_ Music1	n/a	n/a	G. J. Retalla	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/16/2009	2009	Eugene, Or	44.04	-123.14	384.33	-8.11	-27.38	19.81		1253	11.4		142.34				
ESS Lab	et al. 2020	Gink_OR_ Music5	n/a	n/a	G. J. Retalla	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/21/2011	2011	Eugene, Or	44.04	-123.0786	388.93	-8.17	-29.08	21.54		1253	11.4		142.34				
ESS Lab	et al. 2020	Gink_OR_ Silv	n/a	n/a	G. J. Retalla	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	12/17/2011	2011	Eugene, Or	44.99	-122.7922	391.8	-8.29	-29.35	21.70		1304	10.7		100.58				
ESS Lab	et al. 2020	Gink_OR_ Music4	n/a	n/a	G. J. Retalla	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/8/2007	2007	Eugene, Or	44.04	-123.14	380.86	-8.11	-29.43	21.97		1253	11.4		142.34				
ESS Lab	et al. 2020	Gink_OR_ Vill3	n/a	n/a	G. J. Retalla	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/16/2009	2009	Eugene, Or	44.05	-123.14	384.33	-8.11	-29.51	22.05		1253	11.4		134.42				
ESS Lab	et al. 2020	Gink_OR_ Vill1	n/a	n/a	G. J. Retalla	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/17/2007	2007	Eugene, Or	44.05	-123.14	380.86	-8.11	-29.87	22.43		1253	11.4		134.42				
ESS Lab	et al. 2020	Gink_OR_M	n/a	n/a	G. J. Retalla	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/22/2010	2010	Eugene, Or	44.04	-123.14	387.16	-8.18	-29.98	22.47		1253	11.4		142.34				
ESS Lab	et al. 2020	Gink_OR_ Vill2	n/a	n/a	G. J. Retalla	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/17/2008	2008	Eugene, Or	44.05	-123.14	382.78	-8.12	-29.98	22.54		1253	11.4		134.42				
ESS Lab	et al. 2020	Gink_OR_ Vill4	n/a	n/a	G. J. Retalla	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/22/2010	2010	Eugene, Or	44.05	-123.14	387.16	-8.18	-30.19	22.70		1253	11.4		134.42				
ESS Lab	et al. 2020	Gink_OR_ Vill5	n/a	n/a	G. J. Retalla	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/21/2011	2011	Eugene, Or	44.05	-87.62838	388.93	-8.17	-31.61	24.21		1253	11.4		134.42				
ESS Lab	et al. 2020	Gink_OH2	n/a	n/a	Gar Rothwe	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sept/oct 2011	2011	Athens, Ohi	39.33	-82.10125	389	-8.17	-28.47	20.89		1022	11.3		211.84				
ESS Lab	et al. 2020	Gink_OH3	n/a	n/a	Gar Rothwe	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	11/4/2011	2011	Athens, Ohi	39.33	-82.10138	390.24	-8.24	-29.55	21.96		1022	11.3		217.02				
ESS Lab	et al. 2020	MHPS1981	287	#20585	Garton	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	8/30/1981	1981	Thunder Ba	49.0445	-87.9998	338.43	-7.49	-26.85	19.89					350	0.84	48.72	67.64	58
ESS Lab	et al. 2020	YUPS1914	385	#55	George E N	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	7/14/1914	1914	Cape Breto	46.23861	-60.76918	301.1	-6.87	-27.71	21.43					138	0.81	46.46	66.89	57.35802
ESS Lab	et al. 2020	Gink_MN1	n/a	n/a	Greg Retalla	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/10/2011	2011	Minneapolis	44.97	-93.27132	388.93	-8.17	-28.21	20.62		710	6.7		259.38				
ESS Lab	et al. 2020	C-PHTS196	517	S.N.	Guofang Zh	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja standishii*	9/2/1963	1963	Lushu Botan	29.54759	115.98191	316.7	-7.06	-24.62	18.01					1100	1.45	48.02	38.62	33.11724138
ESS Lab	et al. 2020	C-PHTS196	516	37	Guofang Zh	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja standishii*	8/31/1963	1963	Lushan Bota	29.54759	115.98191	317.77	-7.06	-26.48	19.95					1100	1.25	49.79	46.45	39.832
ESS Lab	et al. 2020	YUTP1980	371	#10032-1	H D Hamm	Gymnosper	Woody	C3	Woody Gyn	Cupressac eae	*Thuja*	*Thuja plicata*	7/14/1980	1980	New Denve	49.99057	-117.3743	339.56	-7.59	-25.16	18.03		830	6.9		549	0.95	45.94	56.39	48.35789474
ESS Lab	et al. 2020	C-KHTS198	486	S.N.	H. Ohba & S	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja standishii*	6/12/1980	1980	Japan, Honshu Gunma Prefecture, T			341.17	-7.69	-25.11	17.87						0.74	46.69	73.58	63.09459459
ESS Lab	et al. 2020	CSPT1945	661	#1537	Harrington	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1945	1945	Hillside on I	40.94972	-108.8783	310.1	-7.03	-26.47	19.96		491	2.6		1974	2.08	48.69	27.30	23.40865
ESS Lab	et al. 2020	KKPT1983	623	#5244	Hartman	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/2/1983	1983	Hinsdale Co	37.88225	-107.3441	343.98	-7.71	-27.53	20.39		1383	-1.2		3766	2.76	49.89	21.08	18.07608696
ESS Lab	et al. 2020	UMPT1982	473	#1626	Hazlett	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/22/1982	1982	South Manit	45.0193	-86.12142	342.06	-7.67	-28.53	21.47		809	6.8		182	2.71	49.12	21.14	18.12546125
ESS Lab	et al. 2020	UMPT1984	477	#2826	Hazlett	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/11/1984	1984	Cleveland T	44.91262	-85.87381	343.28	-7.66	-28.80	21.76		882	8.0		232	2.42	48.38	23.31	19.99173554
ESS Lab	et al. 2020	UMPT1980	471	#1152	Hazlett	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/1/1980	1980	Round Islan	45.84068	-84.60575	337.6	-7.47	-28.63	21.78		564	5.0		184	2.70	48.03	20.75	17.78888889
ESS Lab	et al. 2020	UMPT1982	474	#1817	Hazlett	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/30/1982	1982	South Manit	45.0193	-86.12142	339.81	-7.46	-28.73	21.90		809	6.8		182	2.67	48.79	21.31	18.27340824
ESS Lab	et al. 2020	MHPS1979	285	#918	Hazlett	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	9/21/1979	1979	Michigan, No further information prov			333.91	-7.54	-29.89	23.04						1.04	46.67	52.33	44.875
ESS Lab	et al. 2020	MHTO1959	204	n/a	Heidenreich	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	7/6/1959	1959	Lake Simco	44.4636	-79.3353	316.54	-7.07	-24.36	17.73		885	4.4		295.0000	1.40	47.58	39.63	33.98571
ESS Lab	et al. 2020	MHTP1926	237	S.N.	Herb J M G	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	4/9/1905	1905	Washington			297.6	-6.83	-25.17	18.82						0.94	55.22	68.51	58.7483
ESS Lab	et al. 2020	UMPT1926	439	#387	Hermann	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/28/1926	1926	Houghton C	46.65399	-88.85951	305.4	-6.91	-26.23	19.84		755	3.2		321	2.92	58.47	23.35	20.0239726
ESS Lab	et al. 2020	UMPT1993	482	#139	Higman	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/25/1993	1993	Crawford, M	44.68907	-84.60738	359.6	-7.90	-28.08	20.77		909	5.1		369	4.43	50.88	13.39	11.48532731
ESS Lab	et al. 2020	C-PHTS193	512	#06766	Hwong & Su	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja standishii*	10/1/1930	1930	Japan, No further information provide			307.2	-6.92	-26.21	19.81						1.47	47.79	37.91	32.51020408
ESS Lab	et al. 2020	Gink_IL1	n/a	n/a	Ian Glasspo	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/21/2011	2011	Chicago, Illi	41.87	-123.0769	388.93	-8.17	-29.10	21.55		918	9.6		179.83				
ESS Lab	et al. 2020	Gink_IL2	n/a	n/a	Ian Glasspo	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/23/2011	2011	Chicago, Illi	41.87	-83.73443	388.93	-8.17	-29.11	21.57		936	9.3		237.74				
ESS Lab	et al. 2020	CUBPT193	657	#4012	ImCer	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1937	1937	SW Denver	39.66918	-105.0412	310	-6.95	-24.31	17.79		337	10.1		2057.4	4.28	49.13	13.39	11.47897196
ESS Lab	et al. 2020	CSPT1893A	642	#902	J H Cowen	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1893	1893	Pitkin Count	39.25573	-107.0438	294.6	-6.79	-24.78	18.45		680	3.5		1981.2	2.39	48.31	23.57	20.21338912
ESS Lab	et al. 2020	CSPT1893B	643	#2325	J H Cowen	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1893	1893	Red Stone,	39.17995	-107.2413	294.6	-6.79	-25.21	18.89		822	4.2		2192	2.99	50.35	19.64	16.83946488
ESS Lab	et al. 2020	MHTP1903	236	S.N.	J. W. Blank	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	8/28/1903	1903	Montana, No further information prov			296.8	-6.77	-24.68	18.37						0.98	53.89	64.13	54.98751
ESS Lab	et al. 2020	C-PHTK198	497	3392	Jiaju Qian	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja koraiensis*	4/2/1982	1982	Changbai M	41.74435	127.96504	343.57	-7.74	-22.00	14.58						0.93	48.99	61.43	52.67742
ESS Lab	et al. 2020	C-PHTK194	495	n/a	Jiaju Qian	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja koraiensis*	4/12/1942	1942	No further information provided			310.3	-6.96	-28.34	22.00						0.94	54.94	68.16	58.44681
ESS Lab	et al. 2020	Gink_AZ1	n/a	n/a	John Bened	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/28/2011	2011	Tempe, Ariz	33.42	-111.9328	389	-8.15	-26.44	18.78		837	12.8		357.23				
ESS Lab	et al. 2020	MHTO1957	404	S.N.	John Wright	Gymnosper	Woody	C3	Woody Gyn	Cupressac eae	*Thuja*	*Thuja occidentalis*	8/20/1957	1957	No further information provided			314.2	-7.07	-22.71	16.00						0.85	48.95	67.16	57.58823529
ESS Lab	et al. 2020	CUBPT193	658	#706	Johnson	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1937	1937	Trappers La	39.99055	-107.236	310	-6.95	-25.51	19.04		985	1.6		2250	3.57	49.37	16.13	13.82913165
ESS Lab	et al. 2020	CUBPT193	659	#733	Johnson	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1937	1937	Aldrich Lake	40.17485	-107.7023	310	-6.95	-27.49	21.12		542	4.7		2353	1.99	48.61	28.49	24.42713568
ESS Lab	et al. 2020	UMPT1949	456	#1918	Jordal	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/21/1949	1949	Brooks Ran	68.1999	-152.2498	310.5	-6.99	-28.45	22.09					523	4.36	58.08	15.53	13.32110092
ESS Lab	et al. 2020	FMTP1876	325	S.N.	Joseph Hov	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	9/1876	1876	Oregon, No further information provid			289	-6.73	-24.12	17.81						0.91	48.58	62.26	53.38461538
ESS Lab	et al. 2020	FMTO1945	314	#3620	Juvenal Val	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	12/27/1945	1945	Par Valle Te	14.0810	-87.20016	310.1	-7.03	-25.69	19.15		1002	22.3		980	2.09	48.06	26.82	22.99521531
ESS Lab	et al. 2020	C-PHTS196	515	71938	K. Inanaki	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja standishii*	7/25/1961	1961	Kashima-gu	36.97094	136.91548	318.57	-7.07	-23.03	16.34					62	1.19	50.46	49.45	42.40336134
ESS Lab	et al. 2020	UMPT1928	440	S.N.	Kauffmann	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/23/1928	1928	Echo Lake,	46.23293	-113.2613	306.3	-6.91	-25.41	18.98		699	3.3		1606	2.67	51.86	22.65	19.42322097
ESS Lab	et al. 2020	UMPT1900	431	#397	Kauffmann	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/25/1900	1900	Adams Cou	40.76977	-84.93593	295.8	-6.75	-26.37	20.15		742	7.1		250	2.30	49.82	25.26	21.66086957
ESS Lab	et al. 2020	UMPT1934	445	#4824	KcKelsey	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	5/30/1934	1934	Huerfano C	37.61369	-105.1893	309	-6.94	-24.41	17.91		292	7.2		2871	3.52	50.43	16.71	14.32670455
ESS Lab	et al. 2020	MSTO1843	409	#6819	Kessler	Gymnosper	Woody	C3	Woody Gyn	Cupressac eae	*Thuja*	*Thuja occidentalis*	1/16/1905	1905	Michigan, No further information prov			297.6	-6.83	-24.04	17.64						0.76	52.92	81.20	69.63157895
ESS Lab	et al. 2020	UMPT1970	465	S.N.	Ketvelo	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/5/1970	1970	7th St. Winn	49.36589	-99.94733	327.67	-7.29	-25.94	19.14		521	3.0		491	4.58	49.54	12.61	10.81659389
ESS Lab	et al. 2020	MSTST192	421	S.N.	Koidzumi	Gymnosper	Woody	C3	Woody Gyn	Cupressac eae	*Thuja*	*Thuja standishii*	6/11/1922	1922	Mt. Gozaish	35.02034	136.41871	303.8	-6.89	-22.38	15.84						0.62	47.70	89.72	76.93548387
ESS Lab	et al. 2020	KKPT2007	628	#5282	Legler	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	2007	2007	Taos, New	36.38862	-105.5831	385.87	-8.35	-26.97	19.14		364	9.0		2118	2.88	48.81	19.76	16.94791667
ESS Lab	et al. 2020	Gink_TX2	n/a	n/a	Lisa Bouche	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sept/oct 2011	2011	Austin, Texa	30.29	-97.74157	389	-8.17	-27.54	19.91		803	20.0		179.53				
ESS Lab	et al. 2020	Gink_TX3	n/a	n/a	Lisa Bouche	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sept/oct 2011	2011	Austin, Texa	30.29	-97.74157	389	-8.17	-27.96	20.36		803	20.0		179.53				
ESS Lab	et al. 2020	Gink_UK6	n/a	n/a	Margaret C	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sept/oct 2011	2011	Egham, Uni	51.43	-0.564811	389	-8.17	-26.84	19.18		642	10.0		57.61				
ESS Lab	et al. 2020	Gink_UK5	n/a	n/a	Margaret C	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sept/oct 2011	2011	Egham, Uni	51.43	-0.564811	389	-8.17	-26.89	19.24		642	10.0		57.61				
ESS Lab	et al. 2020	Gink_UK1	n/a	n/a	Margaret C	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sept/oct 2011	2011	Egham, Uni	51.43	-0.564811	389	-8.17	-28.66	21.09		642	10.0		57.61				
ESS Lab	et al. 2020	Gink_UK2	n/a	n/a	Margaret C	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sept/oct 2011	2011	Egham, Uni	51.43	-0.564811	389	-8.17	-29.43	21.91		642	10.0		57.61				
ESS Lab	et al. 2020	Gink_UK3	n/a	n/a	Margaret C	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sept/oct 2011	2011	Egham, Uni	51.43	-0.564811	389	-8.17	-30.14	22.65		642	10.0		57.61				
ESS Lab	et al. 2020	Gink_UK4	n/a	n/a	Margaret C	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sept/oct 2011	2011	Egham, Uni	51.43	-0.564811	389	-8.17	-30.94	23.49		642	10.0		57.61				

ESS Lab	et al. 2020	BHTP1990	558	#5501	Mary Clay M	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Thuja*	*Thuja plicata*	8/14/1990	1990	Prince of W	55.03299	-132.5942	352.91	-7.72	-24.70	17.40					486	1.35	50.18	43.35	37.17037037
ESS Lab	et al. 2020	UMPT1930	441	#2064	McFarlin	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/3/1930	1930	Isle Royale,	47.98018	-88.88849	307.2	-6.92	-28.22	21.92		815	2.5		189	2.96	49.18	19.38	16.61486486
ESS Lab	et al. 2020	UMPT1953	457	#14474	McVaugh	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/7/1953	1953	Garfield Co	37.88682	-111.377	311.9	-7.00	-23.77	17.18		283	8.5		2229	4.14	52.18	14.70	12.60386473
ESS Lab	et al. 2020	UMPT1970	467	#70-40	Merkle	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/4/1970	1970	Lapeer Gar	43.10995	-83.22778	326.34	-7.29	-26.93	20.17		726	8.4		265	3.04	49.66	19.05	16.33552632
ESS Lab	et al. 2020	UMPT1970	469	#70-371	Merkle	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	9/26/1970	1970	Clare, Mich	43.83189	-84.77718	323.1	-7.29	-27.57	20.85		830	7.6		254	2.05	49.12	27.94	23.96097561
ESS Lab	et al. 2020	UMPT1970	468	#70-290	Merkle	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/31/1970	1970	Rifle River,	44.01915	-83.81561	324.69	-7.29	-28.81	22.15		720	7.7		189	3.00	48.87	19.00	16.29
ESS Lab	et al. 2020	MHPS1970B	280	#70-462	Merkle	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Pinus*	*Pinus strobus*	8/11/1970	1970	Michigan, No further information prov			324.69	-7.29	-31.04	24.51						0.78	48.58	72.63	62.28205
ESS Lab	et al. 2020	C-PHTS19	513	#15109	Miyoshi Fur	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja standishii*	9/19/1932	1932	Mt. Surikogi	Ohdaira Ihida-shi, Prov. S		308.2	-6.91	-23.00	16.48						1.56	51.46	38.47	32.98717949
ESS Lab	et al. 2020	C-PHTS19	514	#31289	Miyoshi Fur	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja standishii*	8/12/1956	1956	halfway up M	36.31442	137.55013	313.6	-7.01	-24.49	17.91					1108	1.45	52.47	42.20	36.1862069
ESS Lab	et al. 2020	MN17-15	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	7/17/2017	2017	Chengdu Bo	30.76708	104.12115	407.2	-8.56	-26.35	18.27		938	29.2			1.88	49.35	30.69	26.31733
ESS Lab	et al. 2020	MN17-32	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	7/17/2017	2017	Beijing, Chir	39.99053	116.20797	407.2	-8.56	-27.08	19.04		542	32.1						
ESS Lab	et al. 2020	MN17-19	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	7/17/2017	2017	Enshi, Hube	30.27893	109.50225	407.2	-8.56	-27.15	19.11		1461	30.5						
ESS Lab	et al. 2020	MN17-13	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	7/17/2017	2017	Kunming Ins	25.14743	102.74092	407.2	-8.56	-27.24	19.20		921	25.6			1.84	46.78	29.65	25.4212
ESS Lab	et al. 2020	MN17-44	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	8/17/2017	2017	Charlottenlu	55.74947	12.57132	405.24	-8.55	-27.47	19.46		605	19.1			1.81	46.81	30.16	25.86188
ESS Lab	et al. 2020	MN17-36	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	8/17/2017	2017	Folehavesk	55.86728	12.50437	405.24	-8.55	-27.47	19.46		608	18.4						
ESS Lab	et al. 2020	MN17-24	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	7/17/2017	2017	Jiangjiajie, H	29.35325	110.5318	407.2	-8.56	-27.55	19.53		1386	30.5			2.24	47.72	24.84	21.30357
ESS Lab	et al. 2020	MN17-33	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	7/17/2017	2017	Beijing, Chir	39.99048	116.20788	407.2	-8.56	-27.63	19.61		542	32.1			2.62	47.79	21.27	18.24046
ESS Lab	et al. 2020	MN17-34	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	8/17/2017	2017	Folehavesk	55.8673	12.50461	405.24	-8.55	-27.68	19.67		608	18.4						
ESS Lab	et al. 2020	MN16-04	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	7/5/2016	2016	National Arb	38.90868	-76.97105	404.5	-8.55	-27.69	19.69		1073	13.3			2.28	44.83	22.93	19.66228
ESS Lab	et al. 2020	MN17-40	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	8/17/2017	2017	Bregnegard	55.75109	12.57353	405.24	-8.55	-28.03	20.04		605	18.9			1.66	48.34	34.06	29.20846
ESS Lab	et al. 2020	MN17-22	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	7/17/2017	2017	Jiangjiajie, H	29.35325	110.5318	407.2	-8.56	-28.12	20.12		1386	30.5			1.46	48.76	39.08	33.51203
ESS Lab	et al. 2020	MN17-17	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	7/17/2017	2017	Chengdu Bo	30.66273	104.04227	407.2	-8.56	-28.13	20.14		961	29.0			2.91	47.52	19.04	16.32818
ESS Lab	et al. 2020	MN16-02	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	7/3/2016	2016	Philadelphia	39.94725	-75.14886	404.5	-8.55	-28.14	20.16		1126	12.4						
ESS Lab	et al. 2020	MN17-18	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	7/17/2017	2017	Enshi, Hube	30.27925	109.50145	407.2	-8.56	-28.26	20.28		1461	30.5			1.13	49.18	50.98	43.71556
ESS Lab	et al. 2020	MN17-14	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	7/17/2017	2017	Chengdu Bo	30.76533	104.12477	407.2	-8.56	-28.41	20.44		931	29.2			1.80	49.39	32.00	27.43889
ESS Lab	et al. 2020	MN17-16	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	7/17/2017	2017	Chengdu Bo	30.66248	104.04188	407.2	-8.56	-28.55	20.58		961	29.0			1.34	48.63	42.48	36.42322
ESS Lab	et al. 2020	MN16-07	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	7/5/2016	2016	National Arb	38.91428	-76.95757	404.5	-8.55	-28.54	20.58		1075	13.3						
ESS Lab	et al. 2020	MN17-47	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	8/17/2017	2017	Brussels, Be	50.84832	4.38462	405.24	-8.55	-28.77	20.82		816	20.9			2.41	49.26	23.84	20.43983
ESS Lab	et al. 2020	MN17-01	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	7/17/2017	2017	Guangzhou	23.17868	113.35307	407.2	-8.56	-28.87	20.92		1673	22.0			2.71	47.71	20.53	17.60332
ESS Lab	et al. 2020	MN17-20	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	7/17/2017	2017	Enshi, Hube	30.27848	109.5018	407.2	-8.56	-28.90	20.95		1461	30.5			1.42	49.45	40.61	34.82394
ESS Lab	et al. 2020	MN17-42	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	8/17/2017	2017	Charlottenlu	55.75087	12.57298	405.24	-8.55	-28.93	20.98		605	18.9						
ESS Lab	et al. 2020	MN17-80	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	8/17/2017	2017	Uppsala, Sv	59.8508	17.62732	405.24	-8.55	-28.96	21.02		576	20.1						
ESS Lab	et al. 2020	MN17-37	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	8/17/2017	2017	Folehavesk	55.86899	12.50537	405.24	-8.55	-28.97	21.03		608	18.4			1.81	48.17	31.04	26.61326
ESS Lab	et al. 2020	MN17-41	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	8/17/2017	2017	Bregnegard	55.75087	12.57326	405.24	-8.55	-29.00	21.06		605	18.9			2.07	49.10	27.66	23.71981
ESS Lab	et al. 2020	MN17-02	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	7/17/2017	2017	Guangzhou	23.17868	113.35307	407.2	-8.56	-29.15	21.21		1673	22.0			2.49	48.33	22.68	19.44668
ESS Lab	et al. 2020	MN17-03	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	7/17/2017	2017	Guangzhou	23.17868	113.35307	407.2	-8.56	-29.32	21.39		1673	22.0			2.28	47.61	24.41	20.92747
ESS Lab	et al. 2020	MN17-21	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	7/17/2017	2017	Jiangjiajie, H	29.35328	110.53168	407.2	-8.56	-29.35	21.42		1386	30.5			1.55	47.10	35.55	30.48544
ESS Lab	et al. 2020	MN17-58	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	8/17/2017	2017	London, Un	51.51504	-0.11293	405.24	-8.55	-29.58	21.68		605	20.8			2.02	44.15	25.55	21.91067
ESS Lab	et al. 2020	MN17-30	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	7/17/2017	2017	Shanghai, C	31.21537	121.4383	407.2	-8.56	-30.56	22.69		1072	31.7						
ESS Lab	et al. 2020	MN17-38	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	8/17/2017	2017	Arboretvej,	55.86894	12.50529	405.24	-8.55	-30.68	22.83		608	18.4			2.49	47.37	22.23	19.06237
ESS Lab	et al. 2020	MN17-52	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	8/17/2017	2017	Roath Park,	51.50539	-3.17446	405.24	-8.55					20.2			2.04	48.12	27.51	23.58824
ESS Lab	et al. 2020	MN17-56	n/a	n/a	Molly Ng	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Metasequoia*	*Metasequoia glyptostro*	8/17/2017	2017	Hyde Park,	51.50425	0.16005	405.24	-8.55				605	20.8			1.82	47.49	30.51	26.16253
ESS Lab	et al. 2020	KKPT1957	622	S.N.	Montgomery	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	9/25/1957	1957	Montandon,	40.96535	-76.8528	314.2	-7.07	-28.25	21.80		899	10.5		142	1.98	48.02	28.28	24.25252525
ESS Lab	et al. 2020	KKPT1940	621	#12948	Moore	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/12/1940	1940	Ravine Rive	45.51165	-94.15359	310.4	-6.94	-27.10	20.73		643	5.5		308	2.87	50.56	20.54	17.61672474
ESS Lab	et al. 2020	UMPT1933	442	S.N.	Murle	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	9/17/1933	1933	Pacific Cree	43.8578	-110.5105	308.6	-6.91	-26.05	19.65		544	1.8		2246	0.75	48.51	75.43	64.68
ESS Lab	et al. 2020	Gink_CA_Berk_herb		2374	N. Floy Brad	Gymnosper	Woody	C3	Woody Gym	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	11/29/1942	1942	El Cerrito, C	37.91	-122.2881	310.3	-6.96	-25.85	19.38		693	13.9		173.43				
ESS Lab	et al. 2020	Gink_AUS RL1	n/a	n/a	Nathalie Na	Gymnosper	Woody	C3	Woody Gym	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/10/2011	2011	Sydney, Aus	-33.86	151.21698	388.93	-8.17	-28.93	21.38		1272	18.0		5.49				
ESS Lab	et al. 2020	UMPT1993	481	#14683	Oldham	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	5/19/1993	1993	Lobo, Ontar	43.00038	-81.42229	360.28	-7.99	-25.06	17.51		1012	7.8		277	4.00	49.52	14.44	12.38
ESS Lab	et al. 2020	UMPT1993	480	#14677	Oldham	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	5/19/1993	1993	Lobo, Ontar	43.00038	-81.42229	360.28	-7.99	-27.52	20.09		1012	7.8		277	3.82	47.88	14.62	12.53403141
ESS Lab	et al. 2020	UMPT1993	483	#15485	Oldham	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/24/1993	1993	London, On	42.97794	-81.24588	355.52	-7.71	-28.93	21.85		1012	7.8		248	2.06	49.57	28.06	24.0631068
ESS Lab	et al. 2020	KKPT1998B	626	#814	Orthner	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/17/1998	1998	Buffalo Pea	39.02483	-106.134	365.78	-7.97	-28.24	20.86		575	1.7		2593	3.85	49.81	15.09	12.93766234
ESS Lab	et al. 2020	FMTOND3	323	#13	Pamela Her	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Thuja*	*Thuja occidentalis*	No date		Pacayas, C	9.913031	-83.80886	n/a	n/a	-28.60			3002	19.2		1703	2.17	47.55	25.55	21.9124424
ESS Lab	et al. 2020	FMTOND2	322	#7	Pamela Her	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Thuja*	*Thuja occidentalis*	No date		Tres Rios, C	9.90688	-83.98425	n/a	n/a	-25.51			2031	19.2		1344	1.50	48.41	37.64	32.27333333
ESS Lab	et al. 2020	FMTOND1	321	#3	Pamela Her	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Thuja*	*Thuja occidentalis*	No date		San Jose, C	9.932902	-84.11975	n/a	n/a	-26.70			1901	20.4		1078	1.28	51.01	46.47	39.8515625
ESS Lab	et al. 2020	FMTOND4	324	#14	Pamela Her	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Thuja*	*Thuja occidentalis*	No date		Volcan Irazu	9.979791	-83.34904	n/a	n/a	-24.61						386	1.36	48.78	41.83	35.86764706
ESS Lab	et al. 2020	UMPT1940	450	S.N.	Parenteau	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/12/1940	1940	Wilson, Wis	44.95863	-92.16959	310.4	-6.94	-27.49	21.13		668	6.7		362	2.86	52.81	21.53	18.46503497
ESS Lab	et al. 2020	MHTOR187	405	S.N.	Peking	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Platycladus*	*Platycladus orientalis*	10-28-1878	1878	No further information provided			289.8	-6.74	-26.43	20.22						0.81	49.62	71.44	61.25925926
ESS Lab	et al. 2020	CO_PC220	973	n/a	Peter Blank	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Pinus*	*Pinus contorta*	10/11/2019	2019		40.04966	-105.617	408.53	-8.24	-27.62	19.92									
ESS Lab	et al. 2020	CO_PP220	967	n/a	Peter Blank	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Picea*	*Picea pungens*	10/11/2019	2019		40.04966	-105.617	408.53	-8.24	-28.47	20.81									
ESS Lab	et al. 2020	CO_PP120	956	n/a	Peter Blank	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Picea*	*Picea pungens*	10/11/2019	2019		40.04966	-105.617	408.53	-8.24	-28.80	21.17									
ESS Lab	et al. 2020	CO_PC220	971	n/a	Peter Blank	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Pinus*	*Pinus contorta*	10/11/2019	2019		40.04966	-105.617	408.53	-8.24	-29.18	21.56									
ESS Lab	et al. 2020	CO_PC220	972	n/a	Peter Blank	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Pinus*	*Pinus contorta*	10/11/2019	2019		40.04966	-105.617	408.53	-8.24	-29.25	21.64									
ESS Lab	et al. 2020	CO_PP120	958	n/a	Peter Blank	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Picea*	*Picea pungens*	10/11/2019	2019		40.04966	-105.617	408.53	-8.24	-29.44	21.84									
ESS Lab	et al. 2020	CO_PP220	959	n/a	Peter Blank	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Picea*	*Picea pungens*	10/11/2019	2019		40.04966	-105.617	408.53	-8.24	-29.62	22.02									
ESS Lab	et al. 2020	CO_PC120	969	n/a	Peter Blank	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Pinus*	*Pinus contorta*	10/11/2019	2019		40.04966	-105.617	408.53	-8.24	-29.68	22.09									
ESS Lab	et al. 2020	CO_PP120	957	n/a	Peter Blank	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Picea*	*Picea pungens*	10/11/2019	2019		40.04966	-105.617	408.53	-8.24	-29.96	22.39									
ESS Lab	et al. 2020	CO_PP220	960	n/a	Peter Blank	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Picea*	*Picea pungens*	10/11/2019	2019		40.04966	-105.617	408.53	-8.24	-30.10	22.53									
ESS Lab	et al. 2020	CO_PC120	968	n/a	Peter Blank	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Pinus*	*Pinus contorta*	10/11/2019	2019		40.04966	-105.617	408.53	-8.24	-30.13	22.57									
ESS Lab	et al. 2020	CO_PM120	961	n/a	Peter Blank	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Pseudotsug*	*Pseudotsuga menziesii*	10/11/2019	2019		40.04966	-105.617	408.53	-8.24	-30.29	22.73									
ESS Lab	et al. 2020	CO_PM120	963	n/a	Peter Blank	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Pseudotsug*	*Pseudotsuga menziesii*	10/11/2019	2019		40.04966	-105.617	408.53	-8.24	-30.92	23.39									
ESS Lab	et al. 2020	CO_PM220	966	n/a	Peter Blank	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Pseudotsug*	*Pseudotsuga menziesii*	10/11/2019	2019		40.04966	-105.617	408.53	-8.24	-30.96	23.44									
ESS Lab	et al. 2020	CO_PM220	965	n/a	Peter Blank	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Pseudotsug*	*Pseudotsuga menziesii*	10/11/2019	2019		40.04966	-105.617	408.53	-8.24	-31.27	23.77									
ESS Lab	et al. 2020	CO_PM220	964	n/a	Peter Blank	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Pseudotsug*	*Pseudotsuga menziesii*	10/11/2019	2019		40.04966	-105.617	408.53	-8.24	-31.28	23.78									
ESS Lab	et al. 2020	CO_PM120	962	n/a	Peter Blank	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Pseudotsug*	*Pseudotsuga menziesii*	10/11/2019	2019		40.04966	-105.617	408.53	-8.24	-32.06	24.60									
ESS Lab	et al. 2020	CO_PC120	970	n/a	Peter Blank	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Pinus*	*Pinus contorta*	10/11/2019	2019		40.04966	-105.617	408.53	-8.24											
ESS Lab	et al. 2020	MHPS1993	293	#442	Phyllis J Hig	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Pinus*	*Pinus strobus*	9/28/1993	1993	Michigan, No further information prov			353.69	-7.60	-30.73	23.86						0.52	47.36	106.21	91.07692
ESS Lab	et al. 2020	MHTO1993B	229	181	Phyllis J Hig	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Thuja*	*Thuja occidentalis*	6/10/1993	1993	Michigan, No further information prov			359.6	-7.90	-25.76	18.33						1.43	34.35	28.01	24.02073
ESS Lab	et al. 2020	UMPT1934	443	#7895	R Dreisbac	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	5/11/1934	1934	Midland, Mic	43.64583	-84.24204	309	-6.94	-24.42	17.92		672	9.5		192	5.79	51.43	10.36	8.882556131
ESS Lab	et al. 2020	UMPT1934	444	#7922	R Dreisbac	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	5/15/1934	1934	Greendale,	43.59917	-84.5506	309	-6.94	-27.47	21.11		564	8.7		202	3.55	49.76	16.35	14.01690141
ESS Lab	et al. 2020	C-PHTS198	520	S.N.	Racz & Deb	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja standishii*	7/16/1985	1985	Beijing, China			346.56	-7.68	-24.02	16.75						1.25	47.91	44.70	38.328
ESS Lab	et al. 2020	CUBPT192	654	#11742	Ramaley	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1920	1920	Sand Dunes	37.81626	-105.5075	303	-6.93	-22.57	16.00		739	1.2		2613	3.59	49.26	16.00	13.72144847
ESS Lab	et al. 2020	CSPT1934	655	#11423	Ramaley	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1934	1934	Great Sand	37.81626	-105.5075	309	-6.94	-26.03	19.60		504	3.3		2438.4	2.64	48.60	21.47	18.40909091
ESS Lab	et al. 2020	CUBPT190	649	#5355	Ramaley &	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1908	1908	Mammoth C	39.87842	-105.6058	298.9	-6.85	-24.66	18.27		715	2.2		3049	5.47	50.23	10.71	9.182815356
ESS Lab	et al. 2020	CUBPT190	647	#1745	Ramaley &	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1906	1906	Sugarloaf M	40.02243	-105.4191	298.1	-6.81	-26.45	20.17		644	6.2		2515	2.12	51.01	28.06	24.06132075
ESS Lab	et al. 2020	UMPT1944	453	S.N.	Raup	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/17/1944	1944	Pine Creek,	64.6751	-140.6393	310.1	-6.97	-27.18	20.77		324	-4.1		1216	4.64	51.66	12.98	11.13362069
ESS Lab	et al. 2020	WA_GWPT	877	n/a	Rebecca D	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja plicata*	8/29/2018	2018	Seattle, Wa	47.64522	-122.3343	407.1	-8.42	-26.70	18.78		1112	11.2		52	0.97	50.48	60.69	52.04124
ESS Lab	et al. 2020	MI_FTO201	919	n/a	Rebecca D	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja occidentalis*	11/10/2018	2018	Frankfort, M	44.65138	-86.2524	408.12	-8.42	-26.90	18.99						1.15	49.93	50.63	43.41739
ESS Lab	et al. 2020	WA_SJITP	878	n/a	Rebecca D	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja plicata*	8/24/2018	2018	Seattle, Wa	48.5324	-123.013	407.1	-8.42	-27.29	19.40		646	10.0		1369.3	0.96	47.79	58.05	49.78125
ESS Lab	et al. 2020	WA_LCTP	875	n/a	Rebecca D	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja plicata*	8/28/2018	2018	La Connor,	48.38596	-122.5006	407.1	-8.42	-27.74	19.87		645	10.3			1.25	47.84	44.63	38.272
ESS Lab	et al. 2020	WA_BTP20	876	n/a	Rebecca D	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja plicata*	8/29/2018	2018	Seattle, Wa	47.66629	-122.3973	407.1	-8.42	-28.61	20.78		1112	11.2			0.80	49.83	72.64	62.2875
ESS Lab	et al. 2020	C_SHBGT	610	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja koraiensis*	7/14/2017	2017	Shanghai B	31.14875	121.434	407.2	-8.56	-26.35	18.27		1066	16.1		5	2.11	47.68	26.35	22.59716
ESS Lab	et al. 2020	CO_MHPT	631	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/15/2017	2017	39°57.699,	39.96165	-105.3446	405.24	-8.55	-26.95	18.91		700	8.9		2238.5	3.00	50.53	19.64	16.84333333
ESS Lab	et al. 2020	CO_MEPT	636	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/16/2017	2017	39°06.034,	39.10057	-105.3902	405.24	-8.55	-27.04	19.01		561	6.1		3521.4	3.00	49.84	19.37	16.61333333
ESS Lab	et al. 2020	C_SCBGT	579	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja sutchuenensis*	6/30/2017	2017	South China	23.17868	113.3531	409.12	-8.70	-27.24	19.06		1736	22.0		28	2.07	45.83	25.82	22.14009662
ESS Lab	et al. 2020	CO_LCPT	635	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/15/2017	2017	39°05.862,	39.0977	-105.362	405.24	-8.55	-27.15	19.12		561	6.1		2900.2	2.53	48.67	22.43	19.23715415
ESS Lab	et al. 2020	CO_MHPT	632	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/15/2017	2017	39°57.692,	39.96153	-105.3446	405.24	-8.55	-27.43	19.42		700	8.9		2224.7	2.73	49.53	21.16	18.14285714
ESS Lab	et al. 2020	CO_MEPT	637	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/16/2017	2017	39°06.802,	39.11337	-105.404	405.24	-8.55	-27.57	19.56		661	4.6		3331.8	2.94	50.19	19.91	17.07142857
ESS Lab	et al. 2020	C_SCBGT	578	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja sutchuenensis*	6/30/2017	2017	South China	23.17868	113.3531	409.12	-8.70	-27.96	19.82		1736	22.0		28	1.36	47.56	40.78	34.97058824
ESS Lab	et al. 2020	CO_MEPT	638	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/16/2017	2017	39°06.800,	39.11333	-105.4046	405.24	-8.55	-27.85	19.85		661	4.6		3299.5	3.08	51.03	19.32	16.56818182
ESS Lab	et al. 2020	C_PBGTSU	614	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja sutchuenensis*	7/15/2017	2017	Beijing Bota	39.99122	116.2055	407.2	-8.56	-27.94	19.94		610	12.1		80	1.80	46.74	30.28	25.96666667
ESS Lab	et al. 2020	C_PBGJC2	612	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Juniperus*	*Juniperus c hybrid*	7/15/2017	2017	31°12.934',	39.9915	121.4338	407.2	-8.56	-27.95	19.95		610	12.1		24				
ESS Lab	et al. 2020	C_EGCTSU	603	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja sutchuenensis*	7/9/2017	2017	Enshi Gran	30.40717	109.1914	407.2	-8.56	-28.00	20.00		1399	17.0		418	1.45	49.13	39.51	33.88275862
ESS Lab	et al. 2020	CO_MEPT	641	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/16/2017	2017	39°06.620,	39.11033	-105.3934	405.24	-8.55	-28.06	20.07		661	4.6		2851	3.17	50.41	18.54	15.9022082
ESS Lab	et al. 2020	C_PBGTSU	615	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja sutch* (Chamaecy	7/15/2017	2017	Beijing Bota	39.99065	116.2077	407.2	-8.56	-28.07	20.07		610	12.1		77	2.78	45.48	19.08	16.35971223
ESS Lab	et al. 2020	CO_BRPT	952	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	9/4/2019	2019		39.7265	-106.1356	408.54	-8.33	-28.01	20.24					2574				
ESS Lab	et al. 2020	C_PBGTSU	613	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja sutch* (Chamaecy	7/15/2017	2017	Beijing Bota	39.9915	116.205	407.2	-8.56	-28.27	20.28		610	12.1		85	2.10	45.71	25.38	21.76666667
ESS Lab	et al. 2020	C_SHBGT	611	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja occidentalis*	7/14/2017	2017	Shanghai B	31.14953	121.4346	407.2	-8.56	-28.31	20.33		1066	16.1		6	1.79	46.79	30.48	26.1396648
ESS Lab	et al. 2020	C_SCBGT	576	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja sutchuenensis*	6/30/2017	2017	South China	23.17868	113.3531	409.12	-8.70	-28.54	20.42		1736	22.0		28	1.90	42.16	25.88	22.18947368
ESS Lab	et al. 2020	CO_BRPT	953	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	9/4/2019	2019		39.7265	-106.1356	408.54	-8.33	-28.20	20.45					2574				
ESS Lab	et al. 2020	C_ZJJTSU	606	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja sutchuenensis*	7/10/2017	2017	Zhangjiajie	29.34928	110.4568	407.2	-8.56	-28.62	20.65		1387	17.4		320	1.23	46.43	44.02	37.74796748
ESS Lab	et al. 2020	C_CCPTS2	597	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja standishii*	7/7/2017	2017	Chengdu C	30.66237	104.0403	407.2	-8.56	-28.74	20.78		961	16.4		497	2.02	47.75	27.57	23.63861386
ESS Lab	et al. 2020	C_LO2017	954	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Pinaceae	*Larix*	*Larix occidentalis*	8/1/2017	2019		29.34928	110.4568	405.24	-8.55	-28.80	20.85									
ESS Lab	et al. 2020	CO_MHPT	633	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/15/2017	2017	39°58.068,	39.9678	-105.3464	405.24	-8.55	-28.93	20.99		700	8.9		2265.3	2.07	47.86	26.96	23.12077295
ESS Lab	et al. 2020	CO_MHPT	634	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/15/2017	2017	39°57.437,	39.95728	-105.3458	405.24	-8.55	-28.96	21.02		700	8.9		2175.1	2.35	49.56	24.59	21.0893617
ESS Lab	et al. 2020	C_SCBGT	577	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja sutchuenensis*	6/30/2017	2017	South China	23.17868	113.3531	409.12	-8.70	-29.34	21.26		1736	22.0		28	1.36	44.70	38.33	32.86764706
ESS Lab	et al. 2020	CO_MEPT	639	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/16/2017	2017	39°06.847,	39.11412	-105.3973	405.24	-8.55	-29.28	21.35		661	4.6		3206.5	1.86	48.26	30.26	25.94623656
ESS Lab	et al. 2020	C_KBGTOR	583	S.N.	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Platycladus*	*Platycladus orientalis*	7/5/2017	2017	25°08.341',	25.13902	102.7422	407.2	-8.56	-29.35	21.42		915	15.0		1911	2.09	48.15	26.87	23.03827751
ESS Lab	et al. 2020	CO_MEPT	640	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/16/2017	2017	39°06.812,	39.11353	-105.396	405.24	-8.55	-29.38	21.46		661	4.6		2851	2.22	47.90	25.16	21.57657658
ESS Lab	et al. 2020	C_TK2017	955	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja koraiensis*	8/1/2017	2019		29.34928	110.4568	405.24	-8.55	-29.38	21.46									
ESS Lab	et al. 2020	C_EGCTSU	602	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja sutchuenensis*	7/8/2017	2017	Enshi Gran	30.40713	109.1914	407.2	-8.56	-29.59	21.68		1399	17.0		418	1.42	51.70	42.46	36.4084507
ESS Lab	et al. 2020	C_CCPTS2	595	n/a	Rebekah St	Gymnosper	Woody	C3	Woody Gym	Cupressace	*Thuja*	*Thuja standishii*	7/7/2017	2017	Chengdu C	30.6625	104.0407	407.2	-8.56	-29.95	22.05		961	16.4		497	1.85	46.84	29.53	25.31891892
ESS Lab	et al. 2020	CO_SSPT2	948	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	9/4/2019	2019		40.3612	-106.7786	408.54	-8.33							2471.93				
ESS Lab	et al. 2020	CO_SSPT2	949	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	9/4/2019	2019		40.34928	-106.7512	408.54	-8.33							2471.93				
ESS Lab	et al. 2020	CO_SSPT2	951	n/a	Rebekah St	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	9/4/2019	2019		40.38553	-106.5946	408.54	-8.33											
ESS Lab	et al. 2020	CUBPT190	648	#4966	Robbins	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1908	1908	Bulah, Colo	38.0747	-104.9863	298.9	-6.85	-24.45	18.04		410	9.1		1946	3.08	49.20	18.63	15.97402597
ESS Lab	et al. 2020	CUBPT190	646	#1641	Robbins	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1906	1906	Boulder, S.	39.99165	-105.1878	298.1	-6.81	-24.60	18.23		556	10.2		1619	3.38	50.11	17.29	14.82544379
ESS Lab	et al. 2020	CUBPT191	650	#8274	Robbins	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1910	1910	Rito de los	35.75544	-106.2565	299.7	-6.89	-24.84	18.41		338	10.1		2205	2.16	49.46	26.70	22.89814815
ESS Lab	et al. 2020	CUBPT191	651	#7055	Robbins	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1910	1910	Rio Blanco	39.98983	-108.3779	299.7	-6.89	-25.52	19.12		286	8.0		1219.2	3.10	50.69	19.07	16.3516129
ESS Lab	et al. 2020	MHTOR194	397	#405	Robert L Fle	Gymnosper	Woody	C3	Woody Gym	Cupressaceae	*Platycladus*	*Platycladus orientalis*	4/25/1948	1948	Mussoorrie	30.45502	78.081761	310.3	-7.04	-26.04	19.50					2002	1.22	44.70	42.73	36.63934426

ESS Lab	et al. 2020	UMPT1968	463	S.N.	Roedel	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	9/19/1968	1968	Logan, Utah	41.73838	-111.8511	320.33	-7.24	-28.29	21.66		470	8.6		1366	2.67	46.70	20.40	17.4906367
ESS Lab	et al. 2020	CUBPT194	665	#6077	Rogers	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1948	1948	Mesa de Ma	37.1226	-103.5838	310.3	-7.04	-25.96	19.42		431	9.5		3048	1.32	50.47	44.59	38.23485
ESS Lab	et al. 2020	MHPS1948	262	#112	Roulaeu	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	7/6/1948	1948	Wild Cove,	51.42155	-57.60903	310.3	-7.04	-26.49	19.98					120	0.94	49.01	60.80	52.1383
ESS Lab	et al. 2020	KKPT2014	630	#1650	Rregensber	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/17/2014	2014	Rio Grande	37.79295	-106.9158	401.31	-8.59	-27.64	19.59		455	3.3		2865	3.33	49.57	17.36	14.88588589
ESS Lab	et al. 2020	CUBPT191	652	#179	Rydberg	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	1913	1913	Deadwood,	44.38572	-103.7182	300.8	-6.87	-27.37	21.08		584	6.3		1369	1.81	50.03	32.23	27.64088398
ESS Lab	et al. 2020	C-PHTSU2	522	#11304	S Zhenyu Li	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja sutchuenensis*	9/16/2000	2000	Longmen Vi	31.73214	108.81398	366.62	-7.90	-24.47	16.98						1.31	51.43	45.78	39.25954198
ESS Lab	et al. 2020	Gink12_IL3b	n/a	n/a	S.Y. Smith	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	6/1/2012	2012	Westmont,	41.80	-87.97561	395.88	-8.45	-26.35	18.38		937	9.4		228.60				
ESS Lab	et al. 2020	Gink12_IL3a	n/a	n/a	S.Y. Smith	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	6/1/2012	2012	Westmont,	41.80	-87.97561	395.88	-8.45	-26.55	18.59		937	9.4		228.60				
ESS Lab	et al. 2020	Gink12_AAJackdr	n/a	n/a	S.Y. Smith	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	7/4/2012	2012	Ann Arbor,	42.29	-83.845	394.52	-8.38	-26.93	19.06		825	9.3		265.00				
ESS Lab	et al. 2020	Gink_MI_Wash6a	n/a	n/a	S.Y. Smith	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/30/2011	2011	Ann Arbor,	42.28	-83.748	388.93	-8.17	-26.82	19.16		827	9.5		251.16				
ESS Lab	et al. 2020	Gink_MI_Wash6b	n/a	n/a	S.Y. Smith	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/30/2011	2011	Ann Arbor,	42.28	-83.748	388.93	-8.17	-26.96	19.31		827	9.5		251.16				
ESS Lab	et al. 2020	Gink_MI_AAJack1b	n/a	n/a	S.Y. Smith	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	11/12/2011	2011	Ann Arbor,	42.29	-83.84528	390.24	-8.24	-27.96	20.29		825	9.3		265.18				
ESS Lab	et al. 2020	Gink_MO_2a	n/a	n/a	S.Y. Smith	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	7/1/2011	2011	St. Louis, M	35.60	-90.36288	392.59	-8.36	-28.30	20.52		1217	15.9		158.19				
ESS Lab	et al. 2020	Gink_MI_AAJack1a	n/a	n/a	S.Y. Smith	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	11/12/2011	2011	Ann Arbor,	42.29	-83.84528	390.24	-8.24	-28.21	20.55		825	9.3		265.18				
ESS Lab	et al. 2020	Gink_MO_2c	n/a	n/a	S.Y. Smith	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	7/1/2011	2011	St. Louis, M	35.60	-90.36288	392.59	-8.36	-28.46	20.69		1217	15.9		158.19				
ESS Lab	et al. 2020	Gink_MO_1	n/a	n/a	S.Y. Smith	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	7/10/2011	2011	St. Louis, M	38.63	-122.2548	392.59	-8.36	-28.85	21.10		933	13.1		140.51				
ESS Lab	et al. 2020	Gink_MN2	n/a	n/a	S.Y. Smith a	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/11/2011	2011	Minneapolis	44.97	-93.277	388.93	-8.17	-28.28	20.69		711	6.7		259.99				
ESS Lab	et al. 2020	Gink12_Ma	n/a	n/a	S.Y. Smith,	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	6/15/2012	2012	University o	42.30	-83.663	395.88	-8.45	-24.15	16.09		801	9.5		247.50				
ESS Lab	et al. 2020	Gink12_Ma	n/a	n/a	S.Y. Smith,	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	6/15/2012	2012	University o	42.30	-83.663	395.88	-8.45	-24.58	16.53		801	9.5		247.50				
ESS Lab	et al. 2020	Gink12_Ma	n/a	n/a	S.Y. Smith,	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	6/15/2012	2012	University o	42.30	-83.663	395.88	-8.45	-24.68	16.64		801	9.5						
ESS Lab	et al. 2020	Gink12_Ma	n/a	n/a	S.Y. Smith,	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	6/15/2012	2012	University o	42.30	-83.663	395.88	-8.45	-24.75	16.72		801	9.5		247.50				
ESS Lab	et al. 2020	Gink12_Ma	n/a	n/a	S.Y. Smith,	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	6/15/2012	2012	University o	42.30	-83.663	395.88	-8.45	-24.76	16.72		802	9.5		247.50				
ESS Lab	et al. 2020	Gink12_Ma	n/a	n/a	S.Y. Smith,	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	6/15/2012	2012	University o	42.30	-83.663	395.88	-8.45	-24.99	16.96		802	9.5		247.50				
ESS Lab	et al. 2020	Gink12_Ma	n/a	n/a	S.Y. Smith,	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	6/15/2012	2012	University o	42.30	-83.663	395.88	-8.45	-25.13	17.11		801	9.5		247.50				
ESS Lab	et al. 2020	Gink12_Ma	n/a	n/a	S.Y. Smith,	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	6/15/2012	2012	University o	42.30	-83.663	395.88	-8.45	-25.20	17.18		801	9.5		247.50				
ESS Lab	et al. 2020	Gink12_Ma	n/a	n/a	S.Y. Smith,	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	6/15/2012	2012	University o	42.30	-83.663	395.88	-8.45	-25.25	17.23		801	9.5		247.50				
ESS Lab	et al. 2020	Gink12_Ma	n/a	n/a	S.Y. Smith,	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	6/15/2012	2012	University o	42.30	-83.663	395.88	-8.45	-25.61	17.61		801	9.5		247.50				
ESS Lab	et al. 2020	Gink12_Ma	n/a	n/a	S.Y. Smith,	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	6/15/2012	2012	University o	42.30	-83.663	395.88	-8.45	-25.68	17.68		801	9.5		247.50				
ESS Lab	et al. 2020	Gink12_Ma	n/a	n/a	S.Y. Smith,	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	6/15/2012	2012	University o	42.30	-83.663	395.88	-8.45	-25.71	17.72		801	9.5		247.50				
ESS Lab	et al. 2020	Gink12_Ma	n/a	n/a	S.Y. Smith,	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	6/15/2012	2012	University o	42.30	-83.663	395.88	-8.45	-25.72	17.72		802	9.5		247.50				
ESS Lab	et al. 2020	Gink12_Ma	n/a	n/a	S.Y. Smith,	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	6/15/2012	2012	University o	42.30	-83.663	395.88	-8.45	-25.84	17.86		801	9.5		247.50				
ESS Lab	et al. 2020	Gink12_Ma	n/a	n/a	S.Y. Smith,	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	6/15/2012	2012	University o	42.30	-83.663	395.88	-8.45	-26.19	18.21		801	9.5		247.50				
ESS Lab	et al. 2020	Gink12_Ma	n/a	n/a	S.Y. Smith,	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	6/15/2012	2012	University o	42.30	-83.663	395.88	-8.45	-26.21	18.24		802	9.5		247.50				
ESS Lab	et al. 2020	Gink12_Ma	n/a	n/a	S.Y. Smith,	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	6/15/2012	2012	University o	42.30	-83.663	395.88	-8.45	-26.53	18.58		801	9.5		247.50				
ESS Lab	et al. 2020	UMPT1893	427	#391	Sandberg &	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	7/5/1893	1893	Egbert Sprir	47.71771	-119.6442	294.6	-6.79	-25.65	19.35		226	8.5		802	1.23	48.97	46.43	39.81300813
ESS Lab	et al. 2020	UMPT1941	451	#122	Scholes & F	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/13/1941	1941	Clinton, Mic	42.06829	-83.97256	310.4	-7.00	-24.93	18.39		813	8.3		252	3.04	51.52	19.76	16.94736842
ESS Lab	et al. 2020	Gink_BC5b	n/a	n/a	Sean Graha	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sept/oct 2011	2011	Vancouver,	49.25	-123.2508	389	-8.17	-27.03	19.38		1757	9.3		74.68				
ESS Lab	et al. 2020	Gink_BC5a	n/a	n/a	Sean Graha	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sept/oct 2011	2011	Vancouver,	49.25	-123.2508	389	-8.17	-28.62	21.05		1757	9.3		74.68				
ESS Lab	et al. 2020	Gink_BC2	n/a	n/a	Sean Graha	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sept/oct 2011	2011	Vancouver,	49.25	-123.2508	389	-8.17	-29.85	22.35		1757	9.3		74.68				
ESS Lab	et al. 2020	Gink_BC3a	n/a	n/a	Sean Graha	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sept/oct 2011	2011	Vancouver,	49.25	-123.2508	389	-8.17	-29.88	22.38		1757	9.3		74.68				
ESS Lab	et al. 2020	Gink_BC3b	n/a	n/a	Sean Graha	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sept/oct 2011	2011	Vancouver,	49.25	-123.2508	389	-8.17	-30.13	22.64		1757	9.3		74.68				
ESS Lab	et al. 2020	Gink_BC4b	n/a	n/a	Sean Graha	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sept/oct 2011	2011	Vancouver,	49.25	-123.2508	389	-8.17	-30.74	23.29		1757	9.3		74.68				
ESS Lab	et al. 2020	Gink_BC4a	n/a	n/a	Sean Graha	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	Sept/oct 2011	2011	Vancouver,	49.25	-123.2508	389	-8.17	-31.29	23.87		1757	9.3		74.68				
ESS Lab	et al. 2020	MHTOR1936	396	#5801	Seoul Chon	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Platycladus*	*Platycladus orientalis*	9/1/1936	1936	National Fo	38.01284	128.08227	309.8	-6.94	-26.05	19.63					182	1.18	44.23	43.71	37.48305085
ESS Lab	et al. 2020	UMPT1948	455	#3109	Shacklette	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	8/5/1948	1948	Yellowknife,	62.47057	-114.4241	310.3	-7.04	-27.15	20.66		289	-4.3		206	2.58	49.14	22.21	19.04651163
ESS Lab	et al. 2020	MHTP1958	243	#4897	Shaclette	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja plicata*	6/9/1958	1958	Mahoney C	60.0117	-151.6860	317.24	-7.02	-23.41	16.78		3586	7.3		56.0000	0.69	51.36	86.80	74.43478
ESS Lab	et al. 2020	C-PHTK19	496	9444	She'e Liu,,	Gymnosper	Woody	C3	Woody Gyn	Cupressace	*Thuja*	*Thuja koraiensis*	9/29/1962	1962	Onjong, Mo	38.65628	128.10479	316.25	-7.09	-24.61	17.96						0.63	43.98	81.41	69.80952
ESS Lab	et al. 2020	UMPT1895	429	#41402	Skeels	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/16/1895	1895	Agricultural	42.73028	-84.47877	294.8	-6.80	-24.93	18.60		661	7.5		258	4.07	53.49	15.33	13.14250614
ESS Lab	et al. 2020	FMPS1895	333	S.N.	Small	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	*Pinus*	*Pinus strobus*	8/13/1895	1895	Georgia			294.8	-6.80	-24.73	18.38						1.05	49.13	54.57	46.79048
ESS Lab	et al. 2020	FMTO1892	298	S.N.	Small	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	7/23/1892	1892	No further information provided			294.5	-6.79	-24.76	18.43						1.27	50.38	46.26	39.66929
ESS Lab	et al. 2020	FMTO1908	304	#623	Smith	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	5/25/1908	1908	Missouri, No further information provi			298.9	-6.85	-25.97	19.64						1.87	50.15	31.27	26.81818182
ESS Lab	et al. 2020	UMPT2001	484	#29131	Smith	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	5/1/2001	2001	LeSeur, Min	44.46804	-93.91774	374.02	-8.22	-28.43	20.80		619	7.9		258	4.76	49.34	12.09	10.36554622
ESS Lab	et al. 2020	Gink_CA_Dav7c	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-25.04	17.32		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav8c	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-25.51	17.81		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav9b	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-25.65	17.96		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav7b	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-25.76	18.07		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav8b	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-25.86	18.18		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav9c	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-25.94	18.26		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav6c	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-25.98	18.31		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav12b	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-25.99	18.31		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav6b	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-26.03	18.36		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav1c	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-26.11	18.44		475	15.7		15.85				
ESS Lab	et al. 2020	Gink_CA_Dav6a	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-26.20	18.53		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav13c	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-26.26	18.60		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav11a	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-26.37	18.71		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav5a	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-26.44	18.79		474	15.7		17.37				
ESS Lab	et al. 2020	Gink_CA_Dav2b	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-26.45	18.80		475	15.7		247.50				
ESS Lab	et al. 2020	Gink_CA_Dav2a	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-26.47	18.82		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav2c	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-26.50	18.85		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav12c	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-26.51	18.86		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav9a	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-26.63	18.99		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav1a	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-26.87	19.24		475	15.7		15.85				
ESS Lab	et al. 2020	Gink_CA_Dav7a	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-26.96	19.33		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav8a	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-27.03	19.40		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav10a	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	7/1/2011	2011	Davis, Calif	38.54	-121.7507	392.59	-8.36	-27.24	19.41		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav14d	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-27.09	19.47		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav5b	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-27.32	19.71		474	15.7		17.37				
ESS Lab	et al. 2020	Gink_CA_Dav14c	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-27.33	19.72		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav4b	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-27.37	19.76		475	15.7		15.85				
ESS Lab	et al. 2020	Gink_CA_Sonoma1a	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/3/2011	2011	Sonoma, Ca	38.26	-122.458	389	-8.15	-27.47	19.86		773	14.1		25.30				
ESS Lab	et al. 2020	Gink_CA_Auburn1a	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/3/2011	2011	Auburn, Cal	38.90	-121.0769	389	-8.15	-27.56	19.96		864	15.4		370.94				
ESS Lab	et al. 2020	Gink_CA_Dav4c	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-27.71	20.12		475	15.7		15.85				
ESS Lab	et al. 2020	Gink_CA_Auburn1b	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/3/2011	2011	Auburn, Cal	38.90	-121.0769	389	-8.15	-27.80	20.21		864	15.4		370.94				
ESS Lab	et al. 2020	Gink_CA_Green4	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/10/2011	2011	Berkeley, C	37.88	-122.2592	389	-8.15	-27.87	20.29		642	14.0		186.54				
ESS Lab	et al. 2020	Gink_CA_Dav3c	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-27.92	20.34		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav10b	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	7/1/2011	2011	Davis, Calif	38.54	-121.7507	392.59	-8.36	-28.20	20.41		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Berk2	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	7/1/2011	2011	Berkeley, C	37.86	-122.2548	392.59	-8.36	-28.21	20.42		609	14.2		79.55				
ESS Lab	et al. 2020	Gink_CA_Dav3a	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-28.05	20.47		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav5c	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-28.08	20.51		474	15.7		17.37				
ESS Lab	et al. 2020	Gink_CA_Dav10c	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	7/1/2011	2011	Davis, Calif	38.54	-121.7507	392.59	-8.36	-28.29	20.51		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Dav3b	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-28.11	20.54		475	15.7		15.54				
ESS Lab	et al. 2020	Gink_CA_Green3	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/10/2011	2011	Berkeley, C	37.88	-122.2592	389	-8.15	-28.30	20.74		642	14.0		186.54				
ESS Lab	et al. 2020	Gink_CA_Auburn1c	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/3/2011	2011	Auburn, Cal	38.90	-121.0769	389	-8.15	-28.61	21.06		864	15.4		370.94				
ESS Lab	et al. 2020	Gink_CA_Dav4a	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/8/2011	2011	Davis, Calif	38.54	-121.7507	389	-8.15	-28.61	21.06		475	15.7		15.85				
ESS Lab	et al. 2020	Gink_CA_Berk7	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/10/2011	2011	Berkeley, C	37.86	-122.2548	389	-8.15	-28.66	21.11		609	14.2		79.55				
ESS Lab	et al. 2020	Gink_CA_Berk5	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/10/2011	2011	Berkeley, C	37.86	-122.2548	389	-8.15	-28.68	21.14		609	14.2		79.55				
ESS Lab	et al. 2020	Gink_CA_Berk3	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/10/2011	2011	Berkeley, C	37.86	-122.2548	389	-8.15	-28.82	21.29		609	14.2		79.55				
ESS Lab	et al. 2020	Gink_CA_Berk6	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/10/2011	2011	Berkeley, C	37.86	-122.2548	389	-8.15	-28.98	21.45		609	14.2		79.55				
ESS Lab	et al. 2020	Gink_CA_Green2	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/10/2011	2011	Berkeley, C	37.88	-122.2592	389	-8.15	-29.05	21.52		642	14.0		186.54				
ESS Lab	et al. 2020	Gink_CA_Sonoma1b	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/3/2011	2011	Sonoma, Ca	38.26	-122.458	389	-8.15	-29.33	21.82		773	14.1		25.30				
ESS Lab	et al. 2020	Gink_CA_Green1	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/10/2011	2011	Berkeley, C	37.88	-122.2592	389	-8.15	-29.77	22.29		642	14.0		186.54				
ESS Lab	et al. 2020	Gink_CA_Berk8	n/a	n/a	Stefan Little	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	7/1/2011	2011	Berkeley, C	37.86	-122.2548	392.59	-8.36	-31.18	23.55		609	14.2		79.55				
ESS Lab	et al. 2020	Gink_AR1	n/a	n/a	Steven J. K	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	sept/oct 2011	2011	Conway, Ar	35.08	-92.45419	389	-8.17	-27.70	20.08		1218	16.2		93.88				
ESS Lab	et al. 2020	Gink_SC1_Leaf		19093	Steven R. H	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	4/8/1988	1988	Clemson, S	34.68	-82.83697	353.59	-7.95	-25.07	17.56		1366	15.7		226.47				
ESS Lab	et al. 2020	MHTO1968C	212	#6356	Stuckey	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	3/31/1968	1968	Ohio, No further information provided			323.89	-7.24	-25.01	18.23						1.14	47.36	48.45	41.54386
ESS Lab	et al. 2020	CUBPT196	671	#214	Swan	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	5/15/1905	1905	Candle Lak	53.81419	-105.4006	297.6	-6.83	-28.77	22.59					3352.8	2.73	50.31	21.49	18.42857
ESS Lab	et al. 2020	MHTO1968B	211	#134	T. Reznicek	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	*Thuja*	*Thuja occidentalis*	3/13/1968	1968	Ontario, No further information provid			323.89	-7.24	-24.17	17.34						1.37	48.84	41.57	35.64964
ESS Lab	et al. 2020	Gink_Seoul1		5753	Tae-Hyon C	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/5/1933	1933	Seoul, Sout	37.57	126.97819	308.6	-6.91	-27.27	20.93		1339	12.0		52.73				
ESS Lab	et al. 2020	KKPT1998A	625	#7706	Taylor	Angiosperm	Woody	C3	Woody Ang	Salicaceae	*Populus*	*Populus tremuloides*	6/2/1998	1998	Gunnison, C	38.5477	-106.9253	368.88	-8.20	-25.57	17.82		575	1.7		2351	4.62	51.62	13.03	11.17316017
ESS Lab	et al. 2020	Gink_FL1	n/a	n/a	Terry A. Lot	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/27/2011	2011	Gainesville,	29.64	-82.3701	389	-8.15	-26.56	18.91		515	7.9		25.60				
ESS Lab	et al. 2020	Gink_FL2	n/a	n/a	Terry A. Lot	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	9/27/2011	2011	Gainesville,	29.65	-82.34371	389	-8.15	-28.09	20.52		1323	20.4		50.29				
ESS Lab	et al. 2020	Gink_MI_Wash3	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/31/2011	2011	Ann Arbor,	42.28	-83.748	388.93	-8.17	-24.64	16.89		826	9.5		258.17				
ESS Lab	et al. 2020	Gink_MI_AAMill1	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	11/13/2011	2011	Ann Arbor,	42.28	-83.75	390.24	-8.24	-24.84	17.02		827	9.5		248.41				
ESS Lab	et al. 2020	Gink_MI_Will2	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/31/2011	2011	Ann Arbor,	42.28	-83.748	388.93	-8.17	-27.33	19.69		825	9.4		266.40				
ESS Lab	et al. 2020	Gink_MI_Union1	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/7/2011	2011	Ann Arbor,	42.28	-83.75337	388.93	-8.17	-27.43	19.80		827	9.4		266.09				
ESS Lab	et al. 2020	Gink_MI_Will1a	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	*Ginkgo*	*Ginkgo biloba*	10/31/2011	2011	Ann Arbor,	42.28	-83.748	388.93	-8.17	-27.47	19.85		825	9.4		266.70				

ESS Lab	et al. 2020	Gink_MI_ Wash2	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	10/31/2011	2011	Ann Arbor, I	42.28	-83.748	388.93	-8.17	-27.49	19.86		826	9.5		258.17				
ESS Lab	et al. 2020	Gink_MI_ Wash4ai	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	10/31/2011	2011	Ann Arbor, I	42.28	-83.748	388.93	-8.17	-27.52	19.89		826	9.5		257.00				
ESS Lab	et al. 2020	Gink_MI_ Mus1	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	10/23/2011	2011	Ann Arbor, I	42.28	-88.061	388.93	-8.17	-28.21	20.62		822	9.4		270.05				
ESS Lab	et al. 2020	Gink_MI_ Will1b	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	10/31/2011	2011	Ann Arbor, I	42.28	-83.74233	388.93	-8.17	-28.26	20.68		825	9.4		266.70				
ESS Lab	et al. 2020	Gink_MI_ Wash4aii	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	10/31/2011	2011	Ann Arbor, I	42.28	-83.748	388.93	-8.17	-28.54	20.97		826	9.5		257.25				
ESS Lab	et al. 2020	Gink_MI_ Wash4b	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	10/31/2011	2011	Ann Arbor, I	42.28	-83.748	388.93	-8.17	-29.49	21.97		826	9.5		257.25				
ESS Lab	et al. 2020	Gink_MI_ Wash1	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	10/31/2011	2011	Ann Arbor, I	42.28	-83.748	388.93	-8.17	-29.93	22.43		826	9.5		258.17				
ESS Lab	et al. 2020	Gink_MI_ Wash5	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	10/31/2011	2011	Ann Arbor, I	42.28	-83.748	388.93	-8.17	-30.05	22.56		826	9.5		257.25				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-25.80	18.12		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-25.93	18.25		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-26.11	18.44		801	9.5		247.50				
ESS Lab	et al. 2020	Gink(11)_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-26.32	18.66		801	9.5		247.50				
ESS Lab	et al. 2020	Gink(11)_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-26.36	18.70		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-26.38	18.72		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-26.42	18.77		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-26.44	18.79		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-26.54	18.90		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-26.55	18.90		801	9.5		247.50				
ESS Lab	et al. 2020	Gink(11)_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-82.3701	389	-8.15	-26.60	18.96		801	9.5		247.50				
ESS Lab	et al. 2020	Gink(11)_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-26.71	19.07		802	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.66636	389	-8.15	-26.72	19.08		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-26.75	19.12		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-26.76	19.12		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-26.87	19.24		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-26.88	19.25		801	9.5		247.50				
ESS Lab	et al. 2020	Gink(11)_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-26.96	19.33		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-26.98	19.35		801	9.5		247.50				
ESS Lab	et al. 2020	Gink(11)_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.66636	389	-8.15	-26.99	19.36		802	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.02	19.39		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.02	19.40		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.04	19.42		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.05	19.42		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.07	19.45		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.07	19.45		801	9.5		247.50				
ESS Lab	et al. 2020	Gink(11)_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.14	19.52		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.17	19.56		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.18	19.56		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.18	19.57		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.20	19.58		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.24	19.62		801	9.5		247.50				
ESS Lab	et al. 2020	Gink(11)_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.29	19.68		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.35	19.74		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.35	19.74		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.35	19.74		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.36	19.75		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.37	19.76		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.39	19.78		801	9.5		247.50				
ESS Lab	et al. 2020	Gink(11)_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.40	19.79		801	9.5		247.50				
ESS Lab	et al. 2020	Gink(11)_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.44	19.83		801	9.5		247.50				
ESS Lab	et al. 2020	Gink(11)_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.44	19.84		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.51	19.91		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.51	19.91		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.52	19.92		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.52	19.92		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.56	19.96		801	9.5		247.50				
ESS Lab	et al. 2020	Gink(11)_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.60	20.00		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.61	20.01		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.62	20.03		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.67	20.07		801	9.5		247.50				
ESS Lab	et al. 2020	Gink(11)_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.68	20.09		801	9.5		247.50				
ESS Lab	et al. 2020	Gink(11)_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.74	20.15		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.74	20.15		801	9.5		247.50				
ESS Lab	et al. 2020	Gink(11)_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.75	20.16		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.81	20.22		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.86	20.28		801	9.5		247.50				
ESS Lab	et al. 2020	Gink(11)_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.86	20.28		801	9.5		247.50				
ESS Lab	et al. 2020	Gink(11)_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.87	20.29		801	9.5		247.50				
ESS Lab	et al. 2020	Gink(11)_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.90	20.31		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.92	20.34		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.6604	389	-8.15	-27.96	20.38		282	-2.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.97	20.39		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-27.99	20.42		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-28.03	20.45		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-28.04	20.46		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-82.34371	389	-8.15	-28.10	20.52		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-28.13	20.56		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-28.16	20.59		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-28.16	20.59		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-28.17	20.60		282	-2.5		247.50				
ESS Lab	et al. 2020	Gink(11)_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.66636	389	-8.15	-28.22	20.65		802	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-28.36	20.80		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-28.40	20.84		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-28.51	20.95		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-28.56	21.01		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-28.57	21.02		801	9.5		247.50				
ESS Lab	et al. 2020	Gink_MI_M	n/a	n/a	Tess Nuger	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	9/27/2011	2011	University o	42.30	-83.663	389	-8.15	-29.09	21.57		801	9.5		247.50				
ESS Lab	et al. 2020	FMTP1881	326	S.N.	Thomas J H	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	Thuja	Thuja plicata	8/15/1881	1881	Oregon, no further information provid			291.2	-6.80	-25.89	19.60						1.42	49.66	40.78	34.97183099
ESS Lab	et al. 2020	UMPT1908	432	S.N.	Thurston	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides	8/8/1908	1908	St. Coestia, Mis. California			298.9	-6.85	-27.98	21.74						2.25	50.77	26.31	22.56444444
ESS Lab	et al. 2020	UMPT1909	433	#3037	Tidestrom	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides	9/28/1909	1909	Mt. Carbon,	39.64937	-105.1363	299.3	-6.85	-26.63	20.32		434	9.6		1744	0.75	50.34	78.27	67.12
ESS Lab	et al. 2020	UMPT1939	449	#3077	Train	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides	6/12/1939	1939	Snow Creek	41.41259	-116.0578	310.3	-6.99	-26.61	20.15		469	6.5		2512	3.10	53.55	20.14	17.27419355
ESS Lab	et al. 2020	CUBPT194	662	#218	Tryon & Da	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides	1946	1946	Nelson Rive	56.42299	-94.97708	310.1	-6.98	-27.00	20.57					2194.56	2.66	48.29	21.17	18.15414
ESS Lab	et al. 2020	C-PHTS188	511	S.N.	Tschonoski	Gymnosper	Woody	C3	Woody Gyn	Cupressace	Thuja	Thuja standishii	2/28/1886	1886	Japan, No further information provide			293.3	-6.77	-23.69	17.33						1.46	50.44	40.29	34.54794521
ESS Lab	et al. 2020	FMTO1804	296	#4217	Unknown	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	Thuja	Thuja occidentalis	12/8/1804	1804	Castillo et M	21.3721	-77.8520	283.4	-6.48	-22.31	16.19		1334	25.0		120.0000	1.81	48.65	31.35	26.87845
ESS Lab	et al. 2020	C-KHTSU2	490	YISR20130808009	Unknown	Gymnosper	Woody	C3	Woody Gyn	Cupressace	Thuja	Thuja sutchuenensis	10/25/2013	2013	Kaizhou, Ch	31.61639	108.6725	393.7	-8.28	-24.24	16.36		1100	14.8		756	0.83	46.52	65.36	56.04819277
ESS Lab	et al. 2020	C-KHTSU2	489	YISR20130808009	Unknown	Gymnosper	Woody	C3	Woody Gyn	Cupressace	Thuja	Thuja sutchuenensis	8/8/2013	2013	Kaizhou, Ch	31.61639	108.6725	395.41	-8.29	-24.75	16.87		1100	14.8		756	0.70	49.48	82.43	70.68571429
ESS Lab	et al. 2020	C-SHTS198	493	S.N.	Unknown	Gymnosper	Woody	C3	Woody Gyn	Cupressace	Thuja	Thuja standishii	10/27/1986	1986	Shanghai Botanical Garden, Shangha			344.17	-7.48	-25.15	18.12						0.79	46.29	68.33	58.59493671
ESS Lab	et al. 2020	UMPT1987	478	S.N.	Unknown	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides	8/20/1987	1987	East Humbo	41.03314	-115.1667	348.1	-7.62	-25.38	18.22		392	6.8		1621	2.04	46.91	26.82	22.99509804
ESS Lab	et al. 2020	C-SHTS198	491	S.N.	Unknown	Gymnosper	Woody	C3	Woody Gyn	Cupressace	Thuja	Thuja standishii	6/5/1986	1986	Shanghai Bo	31.14998	121.44947	349.55	-7.71	-26.53	19.33						0.84	41.91	58.18	49.89285714
ESS Lab	et al. 2020	CUBPT195	668	#1712	Venick	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides	8/17/1956	1956	Wonder Lak	63.48242	-150.8679	313.6	-7.01	-27.85	21.44		459	-5.6		2286	2.36	51.13	25.27	21.66525
ESS Lab	et al. 2020	MHPS1952A	266	#12689	Virginius H	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	Pinus	Pinus strobus	6/21/1952	1952	Michigan, No further information prov			311.5	-7.00	-27.83	21.43						1.24	48.36	45.48	39
ESS Lab	et al. 2020	MHTO1962A	207	#10998	Voss	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	Thuja	Thuja occidentalis	7/18/1962	1962	Michigan, No further information prov			319.61	-7.09	-25.28	18.67						1.26	49.46	45.78	39.25397
ESS Lab	et al. 2020	UMPT1975	470	#14788	Voss	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides	8/31/1975	1975	Deer Park,	46.67434	-85.6163	330.06	-7.42	-28.67	21.88		857	5.8		191	2.51	47.70	22.16	19.00398406
ESS Lab	et al. 2020	UMPT1970	466	#13396	Voss	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides	7/4/1970	1970	Summer Isla	45.56262	-86.6397	326.34	-7.29	-28.72	22.06		738	5.2		185	4.07	51.18	14.66	12.57493857
ESS Lab	et al. 2020	UMPT1970	464	#13119	Voss	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides	6/2/1970	1970	Gaylord, Mi	45.01717	-84.6767	327.67	-7.29	-28.47	21.80		856	6.4		408	4.40	51.47	13.64	11.69772727
ESS Lab	et al. 2020	Gink_Omei2_SS		7907	W.P. Fang	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	7/23/1930	1930	Emei Mount	29.51	103.31223	307.2	-6.92	-25.33	18.88		1258	12.2		2637.13				
ESS Lab	et al. 2020	Gink_Omei2_leaf		7907	W.P. Fang	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	7/23/1930	1930	Emei Mount	29.51	103.31223	307.2	-6.92	-26.22	19.82		1258	12.2		2637.13				
ESS Lab	et al. 2020	UMPT1960	459	#9288	Wagner	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides	8/13/1960	1960	Saginaw, M	43.38268	-83.96435	315.9	-7.04	-27.17	20.69		736	7.1		177	3.71	48.84	15.35	13.16442049
ESS Lab	et al. 2020	UMPT1961	460	#9404	Wagner	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides	6/1/1961	1961	Lodi Towns	42.2265	-83.84755	319.77	-7.07	-28.67	22.24		696	8.8		285	2.76	50.21	21.22	18.19202899
ESS Lab	et al. 2020	UMPT1948	454	#1	Wahrhaftig	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides	6/30/1948	1948	Healy, Alas	63.89742	-149.0373	310.3	-7.04	-26.63	20.12		459	-5.6		454	3.14	52.78	19.60	16.8089172
ESS Lab	et al. 2020	CUBPT194	663	#260	Ward	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides	1946	1946	Chelan Cou	48.0805	-120.9109	310.1	-6.98	-24.75	18.21		2388	0.6		806	2.44	50.05	23.92	20.5123
ESS Lab	et al. 2020	CUBPT194	664	#7140	Warnock	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides	8/3/1947	1947	Mt. Emory,	29.24405	-103.3046	310.2	-7.01	-26.09	19.58		390	14.1		1569	0.76	49.83	76.46	65.56579
ESS Lab	et al. 2020	MHPS1911A	253	#4415	Wiegand	Gymnosper	Woody	C3	Woody Gyn	Pinaceae	Pinus	Pinus strobus	7/24/1911	1911	Division No	54.65521	-60.97086	300.1	-6.86	-26.66	20.34						1.18	48.09	47.53	40.75424
ESS Lab	et al. 2020	C-SHTS198	492	6700	Xingfu Yang	Gymnosper	Woody	C3	Woody Gyn	Cupressace	Thuja	Thuja standishii	10/27/1986	1986	Shanghai Bo	31.14998	121.44947	344.17	-7.48	-24.75	17.71						1.00	45.46	53.01	45.46
ESS Lab	et al. 2020	KKPT2009	629	#5778	Yeatts	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides	7/15/2009	2009	El Paso, Co	38.76463	-104.5552	388.07	-8.29	-29.18	21.52		443	9.1		1845	2.15	48.42	26.26	22.52093023
ESS Lab	et al. 2020	Gink_HOP1			Yin daing?	Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	UNKNOWN		Piche, Neva	38.03	-114.479			-23.33			541	13.4		134.72				
ESS Lab	et al. 2020	MHTO1950	198	#1029	Yves Desm	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	Thuja	Thuja occidentalis	7/28/1950	1950	Quebec, No further information provi			310.7	-7.01	-23.86	17.27						1.46	51.94	41.49	35.57534
ESS Lab	et al. 2020	MSTST192	422	S.N.	Z. Tashiro	Gymnosper	Woody	C3	Woody Gyn	Cupressaceae	Thuja	Thuja standishii	8/23/1927	1927	Shikoku, Pr	33.87005	133.3792	305.8	-6.91	-23.47	16.96		1619	16.0		692	1.09	50.25	53.76	46.10091743
ESS Lab	et al. 2020	UMPT1891	425	S.N.	S	Angiosperm	Woody	C3	Woody Ang	Salicaceae	Populus	Populus tremuloides	5/4/1891	1891	SE Oberlin,	41.26952	-82.20834	294.3	-6.79	-24.30	17.95		720	9.2		244	5.00	55.76	13.01	11.152
ESS Lab	et al. 2020	C-PHTK198	498			Gymnosper	Woody	C3	Woody Gyn	Cupressace	Thuja	Thuja koraiensis	8/21/1986	1986	Fu Song Co	42.10441	127.85808	345.9	-7.52	-26.92	19.94					689	0.81	49.32	71.01	60.88889
ESS Lab	et al. 2020	Gink_Omei1				Gymnosper	Woody	C3	Woody Gyn	Ginkgoacea	Ginkgo	Ginkgo biloba	july-sep 1938	1938	Emei Mount	29.51	103.31223	310.2	-6.94	-26.52	20.11		1258	12.2		2637.13				

Study	Secondary Source	Study ID	RS Sample #	Accession #	Collector	Higher Plant Group	Plant Functional Typ	Photosynth	Sort	Family	Genus	Species	note	Date	Year	$[CO_2]$ (ppm)[A,B]	$\delta^{13}C_{CO2}$ (‰)[C,D]	$\delta^{13}C_{plant}$ (‰)	$\Delta^{13}C$ (‰; Eq.	Δ13C (‰; as listed in Diefendorf et al. 2010)[F]
Arens et al. 2000	Araus et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-7.85	-24.53	17.10	
Arens et al. 2000	Araus et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-7.85	-24.91	17.50	
Arens et al. 2000	Araus et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-7.85	-25.20	17.80	
Arens et al. 2000	Araus et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-7.85	-25.20	17.80	
Arens et al. 2000	Araus et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-7.85	-25.49	18.10	
Arens et al. 2000	Araus et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-7.85	-25.87	18.50	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Onagraceae	*Epilobium*	*Epilobium hirsutum*		n/a	n/a	n/a	-17.90	-33.46	16.10	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Brachypodium*	*Brachypodium pinnatum*		n/a	n/a	n/a	-17.90	-34.22	16.90	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Onagraceae	*Epilobium*	*Epilobium hirsutum*		n/a	n/a	n/a	-9.40	-26.05	17.10	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Bromus*	*Bromus erectus*		n/a	n/a	n/a	-9.40	-26.53	17.60	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Plantaginaceae	*Digitalis*	*Digitalis purpurea*		n/a	n/a	n/a	-9.40	-26.72	17.80	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Plantaginaceae	*Digitalis*	*Digitalis purpurea*		n/a	n/a	n/a	-21.60	-38.71	17.80	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Bromus*	*Bromus sterilis*		n/a	n/a	n/a	-9.40	-27.11	18.20	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Brachypodium*	*Brachypodium pinnatum*		n/a	n/a	n/a	-9.40	-27.30	18.40	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Brachypodium*	*Brachypodium pinnatum*		n/a	n/a	n/a	-21.60	-39.28	18.40	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Dactylis*	*Dactylis glomerata*		n/a	n/a	n/a	-17.90	-35.74	18.50	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Anthoxanthum*	*Anthoxanthum odoratum*		n/a	n/a	n/a	-9.40	-27.58	18.70	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Urticaceae	*Urtica*	*Urtica dioica*		n/a	n/a	n/a	-9.40	-27.58	18.70	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Urticaceae	*Urtica*	*Urtica dioica*		n/a	n/a	n/a	-21.60	-39.56	18.70	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Plantaginaceae	*Digitalis*	*Digitalis purpurea*		n/a	n/a	n/a	-17.90	-36.02	18.80	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Arrhenatherun*	*Arrhenatherum elatius*		n/a	n/a	n/a	-17.90	-36.21	19.00	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Bromus*	*Bromus erectus*		n/a	n/a	n/a	-17.90	-36.31	19.10	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Plantaginaceae	*Plantago*	*Plantago lanceolata*		n/a	n/a	n/a	-9.40	-27.97	19.10	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Onagraceae	*Epilobium*	*Epilobium angustifolium*		n/a	n/a	n/a	-9.40	-28.25	19.40	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Helianthus*	*Helianthus annuus*		n/a	n/a	n/a	-17.90	-36.59	19.40	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Urticaceae	*Urtica*	*Urtica dioica*		n/a	n/a	n/a	-17.90	-36.59	19.40	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Onagraceae	*Epilobium*	*Epilobium angustifolium*		n/a	n/a	n/a	-17.90	-36.68	19.50	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Bromus*	*Bromus sterilis*		n/a	n/a	n/a	-21.60	-40.31	19.50	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Poa*	*Poa annua*		n/a	n/a	n/a	-9.40	-28.35	19.50	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Arrhenatherun*	*Arrhenatherum elatius*		n/a	n/a	n/a	-9.40	-28.44	19.60	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Dactylis*	*Dactylis glomerata*		n/a	n/a	n/a	-9.40	-28.44	19.60	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Anthoxanthum*	*Anthoxanthum odoratum*		n/a	n/a	n/a	-17.90	-36.87	19.70	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Onagraceae	*Epilobium*	*Epilobium hirsutum*		n/a	n/a	n/a	-21.60	-40.60	19.80	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Agrostis*	*Agrostis capillaris*		n/a	n/a	n/a	-17.90	-37.16	20.00	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Bromus*	*Bromus sterilis*		n/a	n/a	n/a	-17.90	-37.16	20.00	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Holcus*	*Holcus lanatus*		n/a	n/a	n/a	-17.90	-37.35	20.20	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Poa*	*Poa trivialis*		n/a	n/a	n/a	-9.40	-29.20	20.40	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Arrhenatherun*	*Arrhenatherum elatius*		n/a	n/a	n/a	-21.60	-41.25	20.50	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Onagraceae	*Epilobium*	*Epilobium angustifolium*		n/a	n/a	n/a	-21.60	-41.25	20.50	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Helianthus*	*Helianthus annuus*		n/a	n/a	n/a	-9.40	-29.39	20.60	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Holcus*	*Holcus lanatus*		n/a	n/a	n/a	-21.60	-41.35	20.60	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Dactylis*	*Dactylis glomerata*		n/a	n/a	n/a	-21.60	-41.44	20.70	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Agrostis*	*Agrostis capillaris*		n/a	n/a	n/a	-9.40	-29.58	20.80	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Bromus*	*Bromus erectus*		n/a	n/a	n/a	-21.60	-41.54	20.80	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Helianthus*	*Helianthus annuus*		n/a	n/a	n/a	-21.60	-41.82	21.10	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Holcus*	*Holcus lanatus*		n/a	n/a	n/a	-9.40	-29.96	21.20	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Plantaginaceae	*Plantago*	*Plantago lanceolata*		n/a	n/a	n/a	-17.90	-38.29	21.20	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Poa*	*Poa trivialis*		n/a	n/a	n/a	-17.90	-38.38	21.30	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Anthoxanthum*	*Anthoxanthum odoratum*		n/a	n/a	n/a	-21.60	-42.10	21.40	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Poa*	*Poa trivialis*		n/a	n/a	n/a	-21.60	-42.10	21.40	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Lolium*	*Lolium perenne*		n/a	n/a	n/a	-9.40	-30.53	21.80	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Lolium*	*Lolium perenne*		n/a	n/a	n/a	-17.90	-38.85	21.80	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Agrostis*	*Agrostis capillaris*		n/a	n/a	n/a	-21.60	-42.66	22.00	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Lolium*	*Lolium perenne*		n/a	n/a	n/a	-21.60	-42.85	22.20	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Poa*	*Poa annua*		n/a	n/a	n/a	-21.60	-42.85	22.20	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Plantaginaceae	*Plantago*	*Plantago lanceolata*		n/a	n/a	n/a	-21.60	-43.69	23.10	
Arens et al. 2000	erling & Woodward 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Poa*	*Poa annua*		n/a	n/a	n/a	-17.90	-41.29	24.40	
Arens et al. 2000	Beerling 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Salicaceae	*Salix*	*Salix herbacea*		n/a	n/a	n/a	-6.52	-27.79	21.88	
Arens et al. 2000	Beerling 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Salicaceae	*Salix*	*Salix herbacea*		n/a	n/a	n/a	-6.52	-28.26	22.37	
Arens et al. 2000	Beerling 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Salicaceae	*Salix*	*Salix herbacea*		n/a	n/a	n/a	-6.52	-28.36	22.48	
Arens et al. 2000	Beerling 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Salicaceae	*Salix*	*Salix herbacea*		n/a	n/a	n/a	-6.52	-28.45	22.57	
Arens et al. 2000	Beerling 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Salicaceae	*Salix*	*Salix herbacea*		n/a	n/a	n/a	-6.52	-28.74	22.88	
Arens et al. 2000	Beerling 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Salicaceae	*Salix*	*Salix herbacea*		n/a	n/a	n/a	-6.52	-29.21	23.37	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Araceae	*Philodendron*	*Philodendron krugii*		n/a	n/a	n/a	-7.85	-25.40	18.01	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Meliaceae	*Swietenia*	*Swietenia macrophylla*		n/a	n/a	n/a	-7.85	-25.80	18.43	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Melastomataceae	*Miconia*	*Miconia affinis*		n/a	n/a	n/a	-8.65	-26.80	18.65	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Bignoniaceae	*Lundia*	*Lundia corymbifera*		n/a	n/a	n/a	-7.85	-26.30	18.95	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Moraceae	*Brosimum*	*Brosimum alicastrum*		n/a	n/a	n/a	-8.70	-27.20	19.02	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Moraceae	*Brosimum*	*Brosimum alicastrum*		n/a	n/a	n/a	-7.85	-26.50	19.16	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Bignoniaceae	*Lundia*	*Lundia corymbifera*		n/a	n/a	n/a	-8.70	-27.90	19.75	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Araceae	*Philodendron*	*Philodendron krugii*		n/a	n/a	n/a	-8.70	-27.90	19.75	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Clathrotropis*	*Clathrotropis brachypetala*		n/a	n/a	n/a	-8.65	-28.20	20.12	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Meliaceae	*Swietenia*	*Swietenia macrophylla*		n/a	n/a	n/a	-8.70	-28.70	20.59	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Salicaceae	*Casearia*	*Casearia guianensis*		n/a	n/a	n/a	-7.85	-28.30	21.05	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Salicaceae	*Ryania*	*Ryania speciosa*		n/a	n/a	n/a	-8.65	-29.10	21.06	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Salicaceae	*Casearia*	*Casearia guianensis*		n/a	n/a	n/a	-8.70	-29.60	21.54	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Apocynaceae	*Tabernaemon*	*Tabernaemontana attenuata*		n/a	n/a	n/a	-7.85	-28.90	21.68	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Calliandra*	*Calliandra guildingii*		n/a	n/a	n/a	-8.65	-29.70	21.69	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Apocynaceae	*Calliandra*	*Calliandra guildingii*		n/a	n/a	n/a	-9.55	-31.00	22.14	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Apocynaceae	*Tabernaemon*	*Tabernaemontana attenuata*		n/a	n/a	n/a	-8.70	-30.20	22.17	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Clathrotropis*	*Clathrotropis brachypetala*		n/a	n/a	n/a	-9.55	-31.80	22.98	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Melastomataceae	*Miconia*	*Miconia affinis*		n/a	n/a	n/a	-9.55	-31.80	22.98	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Salicaceae	*Ryania*	*Ryania speciosa*		n/a	n/a	n/a	-9.55	-32.00	23.19	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Araceae	*Philodendron*	*Philodendron lingulatum*		n/a	n/a	n/a	-8.65	-31.60	23.70	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Acanthaceae	*Aphelandra*	*Aphelandra pulcherrima*		n/a	n/a	n/a	-7.85	-31.10	24.00	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Arecaceae	*Bactris*	*Bactris gasipaes*		n/a	n/a	n/a	-8.65	-31.90	24.02	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Acanthaceae	*Aphelandra*	*Aphelandra pulcherrima*		n/a	n/a	n/a	-8.70	-32.40	24.49	
Arens et al. 2000	roadmeadow et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Herbaceous Angiosperm	Araceae	*Philodendron*	*Philodendron lingulatum*		n/a	n/a	n/a	-9.55	-35.90	27.33	
Arens et al. 2000	Condon et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-7.85	-23.76	16.30	
Arens et al. 2000	Condon et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-7.85	-24.24	16.80	
Arens et al. 2000	Condon et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-7.85	-24.63	17.20	
Arens et al. 2000	Condon et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-7.85	-24.63	17.20	
Arens et al. 2000	Condon et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-7.85	-24.82	17.40	
Arens et al. 2000	Condon et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-7.85	-24.91	17.50	
Arens et al. 2000	Condon et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-7.85	-25.01	17.60	
Arens et al. 2000	Condon et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-7.85	-25.30	17.90	
Arens et al. 2000	wson & Ehleringer 1993	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	*Acer*	*Acer negundo*		n/a	n/a	n/a	-7.85	-24.63	17.20	
Arens et al. 2000	wson & Ehleringer 1993	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	*Acer*	*Acer negundo*		n/a	n/a	n/a	-7.85	-24.63	17.20	
Arens et al. 2000	wson & Ehleringer 1993	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	*Acer*	*Acer negundo*		n/a	n/a	n/a	-7.85	-25.34	17.94	
Arens et al. 2000	wson & Ehleringer 1993	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	*Acer*	*Acer negundo*		n/a	n/a	n/a	-7.85	-26.05	18.69	
Arens et al. 2000	wson & Ehleringer 1993	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	*Acer*	*Acer negundo*		n/a	n/a	n/a	-7.85	-27.23	19.92	
Arens et al. 2000	wson & Ehleringer 1993	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	*Acer*	*Acer negundo*		n/a	n/a	n/a	-7.85	-27.94	20.67	
Arens et al. 2000	wson & Ehleringer 1993	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	*Acer*	*Acer negundo*		n/a	n/a	n/a	-7.85	-28.65	21.41	
Arens et al. 2000	wson & Ehleringer 1993	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	*Acer*	*Acer negundo*		n/a	n/a	n/a	-7.85	-28.89	21.67	
Arens et al. 2000	novan & Ehleringer 1991	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Ericameria*	*Ericameria nauseosa*		n/a	n/a	n/a	-8.00	-27.46	20.01	
Arens et al. 2000	novan & Ehleringer 1991	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Artemisia*	*Artemisia tridentata*		n/a	n/a	n/a	-8.00	-27.61	20.17	
Arens et al. 2000	novan & Ehleringer 1991	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Artemisia*	*Artemisia tridentata*		n/a	n/a	n/a	-8.00	-27.87	20.44	
Arens et al. 2000	novan & Ehleringer 1991	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Ericameria*	*Ericameria nauseosa*		n/a	n/a	n/a	-8.00	-28.01	20.59	
Arens et al. 2000	novan & Ehleringer 1991	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Ericameria*	*Ericameria nauseosa*		n/a	n/a	n/a	-8.00	-26.02	18.50	
Arens et al. 2000	novan & Ehleringer 1991	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Ericameria*	*Ericameria nauseosa*		n/a	n/a	n/a	-8.00	-27.36	19.90	
Arens et al. 2000	novan & Ehleringer 1991	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Ericameria*	*Ericameria nauseosa*		n/a	n/a	n/a	-8.00	-27.74	20.30	
Arens et al. 2000	novan & Ehleringer 1991	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Ericameria*	*Ericameria nauseosa*		n/a	n/a	n/a	-8.00	-29.30	21.94	
Arens et al. 2000	Dupouey et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Fagus*	*Fagus sylvatica*		n/a	n/a	n/a	-8.00	-27.00	19.53	
Arens et al. 2000	Dupouey et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Fagus*	*Fagus sylvatica*		n/a	n/a	n/a	-7.84	-26.95	19.64	
Arens et al. 2000	Dupouey et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Fagus*	*Fagus sylvatica*		n/a	n/a	n/a	-7.68	-26.90	19.75	
Arens et al. 2000	Dupouey et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Fagus*	*Fagus sylvatica*		n/a	n/a	n/a	-7.51	-26.85	19.87	
Arens et al. 2000	Dupouey et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Fagus*	*Fagus sylvatica*		n/a	n/a	n/a	-7.35	-26.80	19.99	
Arens et al. 2000	Dupouey et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Fagus*	*Fagus sylvatica*		n/a	n/a	n/a	-7.19	-26.70	20.05	
Arens et al. 2000	Dupouey et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Fagus*	*Fagus sylvatica*		n/a	n/a	n/a	-7.03	-26.60	20.10	
Arens et al. 2000	Dupouey et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Fagus*	*Fagus sylvatica*		n/a	n/a	n/a	-6.86	-26.50	20.17	
Arens et al. 2000	Dupouey et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Fagus*	*Fagus sylvatica*		n/a	n/a	n/a	-6.70	-26.40	20.23	
Arens et al. 2000	hleringer & Cerling 1995	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	*Juniperus*	*Juniperus osteosperma*		n/a	n/a	n/a	-7.85	-23.86	16.40	
Arens et al. 2000	hleringer & Cerling 1995	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus ponderosa*		n/a	n/a	n/a	-7.85	-25.39	18.00	
Arens et al. 2000	Ehleringer et al. 1991	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Phaseolus*	*Phaseolus vulgaris*		n/a	n/a	n/a	-7.85	-21.45	13.90	
Arens et al. 2000	Ehleringer et al. 1991	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Phaseolus*	*Phaseolus vulgaris*		n/a	n/a	n/a	-7.85	-25.39	18.00	
Arens et al. 2000	Ehleringer et al. 1991	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Phaseolus*	*Phaseolus vulgaris*		n/a	n/a	n/a	-7.85	-27.30	20.00	
Arens et al. 2000	Ehleringer et al. 1991	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Phaseolus*	*Phaseolus vulgaris*		n/a	n/a	n/a	-7.85	-29.97	22.80	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Ambrosia*	*Ambrosia monogyra*		n/a	n/a	n/a	-8.00	-23.14	15.50	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Senecio*	*Senecio flaccidus var. douglasii*	Senecio flaccidus Less. is valid	n/a	n/a	n/a	-8.00	-23.43	15.80	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Lamiaceae	*Scutellaria*	*Scutellaria mexicana*		n/a	n/a	n/a	-8.00	-23.53	15.90	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Ambrosia*	*Ambrosia salsola*		n/a	n/a	n/a	-8.00	-23.72	16.10	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Bebbia*	*Bebbia juncea*		n/a	n/a	n/a	-8.00	-23.91	16.30	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Gutierrezia*	*Gutierrezia sarothrae*		n/a	n/a	n/a	-8.00	-24.01	16.40	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Encelia*	*Encelia farinosa*		n/a	n/a	n/a	-8.00	-24.29	16.70	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Ambrosia*	*Ambrosia dumosa*		n/a	n/a	n/a	-8.00	-24.39	16.80	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Ericameria*	*Ericameria paniculata*		n/a	n/a	n/a	-8.00	-24.68	17.10	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Malvaceae	*Sphaeralcea*	*Sphaeralcea parvifolia*		n/a	n/a	n/a	-8.00	-24.77	17.20	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Porophyllum*	*Porophyllum gracile*		n/a	n/a	n/a	-8.00	-24.87	17.30	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Psilostrophe*	*Psilostrophe cooperi*		n/a	n/a	n/a	-8.00	-24.87	17.30	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Stephanomeri*	*Stephanomeria pauciflora*		n/a	n/a	n/a	-8.00	-25.06	17.50	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Encelia*	*Encelia farinosa*		n/a	n/a	n/a	-8.00	-25.35	17.80	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Ambrosia*	*Ambrosia eriocentra*		n/a	n/a	n/a	-8.00	-25.73	18.20	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Ambrosia*	*Ambrosia monogyra*		n/a	n/a	n/a	-8.00	-26.02	18.50	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Bebbia*	*Bebbia juncea*		n/a	n/a	n/a	-8.00	-26.02	18.50	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Senecio*	*Senecio flaccidus var. douglasii*	Senecio flaccidus Less. is valid	n/a	n/a	n/a	-8.00	-26.11	18.60	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Lamiaceae	*Scutellaria*	*Scutellaria mexicana*		n/a	n/a	n/a	-8.00	-26.31	18.80	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Ambrosia*	*Ambrosia dumosa*		n/a	n/a	n/a	-8.00	-26.59	19.10	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Ambrosia*	*Ambrosia salsola*		n/a	n/a	n/a	-8.00	-26.59	19.10	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Gutierrezia*	*Gutierrezia sarothrae*		n/a	n/a	n/a	-8.00	-26.78	19.30	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Acamptopapp*	*Acamptopappus sphaerocephalus*		n/a	n/a	n/a	-8.00	-26.97	19.50	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Ambrosia*	*Ambrosia eriocentra*		n/a	n/a	n/a	-8.00	-27.07	19.60	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Porophyllum*	*Porophyllum gracile*		n/a	n/a	n/a	-8.00	-27.26	19.80	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Acamptopapp*	*Acamptopappus sphaerocephalus*		n/a	n/a	n/a	-8.00	-27.45	20.00	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Malvaceae	*Sphaeralcea*	*Sphaeralcea parvifolia*		n/a	n/a	n/a	-8.00	-27.64	20.20	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Stephanomeri*	*Stephanomeria pauciflora*		n/a	n/a	n/a	-8.00	-27.74	20.30	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Psilostrophe*	*Psilostrophe cooperi*		n/a	n/a	n/a	-8.00	-27.83	20.40	
Arens et al. 2000	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Ericameria*	*Ericameria paniculata*		n/a	n/a	n/a	-8.00	-27.93	20.50	
Arens et al. 2000	Ehleringer et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Encelia*	*Encelia farinosa*		n/a	n/a	n/a	-7.85	-24.43	17.00	
Arens et al. 2000	Ehleringer et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Encelia*	*Encelia farinosa*		n/a	n/a	n/a	-7.85	-25.39	18.00	
Arens et al. 2000	Ehleringer et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Encelia*	*Encelia farinosa*		n/a	n/a	n/a	-7.85	-26.35	19.00	
Arens et al. 2000	Friend et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Nardus*	*Nardus stricta*		n/a	n/a	n/a	-7.85	-24.00	16.55	
Arens et al. 2000	Friend et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Nardus*	*Nardus stricta*		n/a	n/a	n/a	-7.85	-26.00	18.63	
Arens et al. 2000	Friend et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Ericaceae	*Vaccinium*	*Vaccinium myrtillus*		n/a	n/a	n/a	-7.85	-27.20	19.89	
Arens et al. 2000	Friend et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Ericaceae	*Vaccinium*	*Vaccinium myrtillus*		n/a	n/a	n/a	-7.85	-27.50	20.21	
Arens et al. 2000	utiérrez & Meinzer 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rubiaceae	*Coffea*	*Coffea arabica*		n/a	n/a	n/a	-8.00	-27.11	19.64	
Arens et al. 2000	utiérrez & Meinzer 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rubiaceae	*Coffea*	*Coffea arabica*		n/a	n/a	n/a	-8.00	-27.40	19.95	
Arens et al. 2000	utiérrez & Meinzer 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rubiaceae	*Coffea*	*Coffea arabica*		n/a	n/a	n/a	-8.00	-27.40	19.95	
Arens et al. 2000	utiérrez & Meinzer 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rubiaceae	*Coffea*	*Coffea arabica*		n/a	n/a	n/a	-8.00	-27.49	20.04	
Arens et al. 2000	utiérrez & Meinzer 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rubiaceae	*Coffea*	*Coffea arabica*		n/a	n/a	n/a	-8.00	-27.49	20.04	
Arens et al. 2000	utiérrez & Meinzer 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rubiaceae	*Coffea*	*Coffea arabica*		n/a	n/a	n/a	-8.00	-27.59	20.15	
Arens et al. 2000	utiérrez & Meinzer 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rubiaceae	*Coffea*	*Coffea arabica*		n/a	n/a	n/a	-8.00	-27.88	20.45	
Arens et al. 2000	utiérrez & Meinzer 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rubiaceae	*Coffea*	*Coffea arabica*		n/a	n/a	n/a	-8.00	-28.26	20.85	
Arens et al. 2000	Guy & Reid 1986	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Puccinellia*	*Puccinellia nuttalliana*		n/a	n/a	n/a	-46.90	-63.90	18.16	
Arens et al. 2000	Guy & Reid 1986	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Puccinellia*	*Puccinellia nuttalliana*		n/a	n/a	n/a	-46.90	-66.10	20.56	
Arens et al. 2000	Guy & Reid 1986	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Puccinellia*	*Puccinellia nuttalliana*		n/a	n/a	n/a	-46.90	-68.30	22.97	
Arens et al. 2000	Guy & Reid 1986	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Puccinellia*	*Puccinellia nuttalliana*		n/a	n/a	n/a	-43.50	-65.40	23.43	
Arens et al. 2000	Guy & Reid 1986	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Puccinellia*	*Puccinellia nuttalliana*		n/a	n/a	n/a	-43.50	-66.40	24.53	
Arens et al. 2000	Guy & Reid 1986	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Puccinellia*	*Puccinellia nuttalliana*		n/a	n/a	n/a	-43.50	-66.60	24.75	
Arens et al. 2000	Guy & Reid 1986	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Puccinellia*	*Puccinellia nuttalliana*		n/a	n/a	n/a	-46.90	-70.00	24.84	
Arens et al. 2000	Guy & Reid 1986	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Puccinellia*	*Puccinellia nuttalliana*		n/a	n/a	n/a	-43.50	-67.80	26.07	
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.35	21.10	
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.54	21.30	
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.54	21.30	
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.54	21.30	
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.54	21.30	
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.54	21.30	
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.54	21.30	
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.64	21.40	

Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.64	21.40
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.64	21.40
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.64	21.40
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.64	21.40
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.64	21.40
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.83	21.60
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.83	21.60
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.83	21.60
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.92	21.70
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.92	21.70
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.92	21.70
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.92	21.70
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.92	21.70
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-28.92	21.70
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-29.02	21.80
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-29.02	21.80
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-29.11	21.90
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-29.11	21.90
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-29.11	21.90
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-29.11	21.90
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-29.11	21.90
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-29.11	21.90
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-29.11	21.90
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-29.11	21.90
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-29.11	21.90
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-29.21	22.00
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-29.21	22.00
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-29.30	22.10
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-29.40	22.20
Arens et al. 2000	Hall et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-7.85	-29.49	22.30
Arens et al. 2000	Hansen & Steig 1993	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Acacia*	*Acacia koa*		n/a	n/a	n/a	-8.00	-25.44	17.90
Arens et al. 2000	Hansen & Steig 1993	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Acacia*	*Acacia koa*		n/a	n/a	n/a	-8.00	-27.16	19.69
Arens et al. 2000	Huc et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Eperua*	*Eperua falcata*		n/a	n/a	n/a	-8.00	-26.81	19.33
Arens et al. 2000	Huc et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Dicorynia*	*Dicorynia guianensis*		n/a	n/a	n/a	-8.00	-27.82	20.39
Arens et al. 2000	Huc et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Jacaranda*	*Jacaranda copaia*		n/a	n/a	n/a	-8.00	-29.52	22.17
Arens et al. 2000	Huc et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Goupia*	*Goupia glabra*		n/a	n/a	n/a	-8.00	-29.57	22.23
Arens et al. 2000	Huc et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Woody Angiosperm	Meliaceae	*Carapa*	*Carapa guianensis*		n/a	n/a	n/a	-8.00	-30.49	23.20
Arens et al. 2000	Ismail & Hall 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-8.00	-26.44	18.94
Arens et al. 2000	Ismail & Hall 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-8.00	-26.44	18.94
Arens et al. 2000	Ismail & Hall 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-8.00	-26.54	19.05
Arens et al. 2000	Ismail & Hall 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-8.00	-26.60	19.11
Arens et al. 2000	Ismail & Hall 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-8.00	-26.73	19.24
Arens et al. 2000	Ismail & Hall 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-8.00	-27.30	19.84
Arens et al. 2000	Ismail & Hall 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-8.00	-27.88	20.45
Arens et al. 2000	Ismail et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-8.00	-25.01	17.45
Arens et al. 2000	Ismail et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-8.00	-25.49	17.95
Arens et al. 2000	Ismail et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-8.00	-25.49	17.95
Arens et al. 2000	Ismail et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-8.00	-25.58	18.04
Arens et al. 2000	Ismail et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-8.00	-25.78	18.25
Arens et al. 2000	Ismail et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-8.00	-26.73	19.24
Arens et al. 2000	Ismail et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-8.00	-26.83	19.35
Arens et al. 2000	Ismail et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-8.00	-26.92	19.44
Arens et al. 2000	Ismail et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-8.00	-27.11	19.64
Arens et al. 2000	Ismail et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vigna*	*Vigna unguiculata*		n/a	n/a	n/a	-8.00	-27.59	20.15
Arens et al. 2000	Johnson & Tieszen 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Festuca*	*Festuca arundinacea*		n/a	n/a	n/a	-7.85	-24.43	17.00
Arens et al. 2000	Johnson & Tieszen 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Dactylis*	*Dactylis glomerata*		n/a	n/a	n/a	-7.85	-24.53	17.10
Arens et al. 2000	Johnson & Tieszen 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Lolium*	*Lolium perenne*		n/a	n/a	n/a	-7.85	-24.72	17.30
Arens et al. 2000	Johnson & Tieszen 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Agropyron*	*Agropyron desertorum*		n/a	n/a	n/a	-7.85	-26.16	18.80
Arens et al. 2000	rtin & Thorstenson 1988	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Solanaceae	*Lycopersicon*	*Lycopersicon esculentum x pennellii*		n/a	n/a	n/a	-7.85	-24.50	17.07
Arens et al. 2000	rtin & Thorstenson 1988	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Solanaceae	*Lycopersicon*	*Lycopersicon pennellii*		n/a	n/a	n/a	-7.85	-24.70	17.28
Arens et al. 2000	rtin & Thorstenson 1988	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Solanaceae	*Lycopersicon*	*Lycopersicon pennellii*		n/a	n/a	n/a	-7.85	-25.00	17.59
Arens et al. 2000	rtin & Thorstenson 1988	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Solanaceae	*Lycopersicon*	*Lycopersicon esculentum*		n/a	n/a	n/a	-7.85	-25.10	17.69
Arens et al. 2000	rtin & Thorstenson 1988	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Solanaceae	*Lycopersicon*	*Lycopersicon esculentum x pennellii*		n/a	n/a	n/a	-7.85	-25.40	18.01
Arens et al. 2000	rtin & Thorstenson 1988	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Solanaceae	*Lycopersicon*	*Lycopersicon pennellii*		n/a	n/a	n/a	-7.85	-26.10	18.74
Arens et al. 2000	rtin & Thorstenson 1988	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Solanaceae	*Lycopersicon*	*Lycopersicon esculentum*		n/a	n/a	n/a	-7.85	-26.40	19.05
Arens et al. 2000	rtin & Thorstenson 1988	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Solanaceae	*Lycopersicon*	*Lycopersicon esculentum x pennellii*		n/a	n/a	n/a	-7.85	-26.60	19.26
Arens et al. 2000	rtin & Thorstenson 1988	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Solanaceae	*Lycopersicon*	*Lycopersicon esculentum*		n/a	n/a	n/a	-7.85	-27.90	20.63
Arens et al. 2000	Martin et al. 1988	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Lactuca*	*Lactuca sativa*		n/a	n/a	n/a	-7.85	-25.91	18.54
Arens et al. 2000	Martin et al. 1988	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Phaseolus*	*Phaseolus vulgaris*		n/a	n/a	n/a	-7.85	-26.24	18.89
Arens et al. 2000	Martin et al. 1988	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Picea*	*Picea abies*		n/a	n/a	n/a	-7.85	-26.42	19.07
Arens et al. 2000	Martin et al. 1988	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Picea*	*Picea abies*		n/a	n/a	n/a	-7.85	-26.59	19.25
Arens et al. 2000	Martin et al. 1988	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Abies*	*Abies alba*		n/a	n/a	n/a	-7.85	-26.91	19.59
Arens et al. 2000	Martin et al. 1988	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Fagus*	*Fagus sylvatica*		n/a	n/a	n/a	-7.85	-27.43	20.13
Arens et al. 2000	Martin et al. 1988	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-7.85	-28.00	20.73
Arens et al. 2000	Martin et al. 1988	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus pinaster*		n/a	n/a	n/a	-7.85	-28.92	21.70
Arens et al. 2000	Martin et al. 1988	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Brassica*	*Brassica oleracea*		n/a	n/a	n/a	-7.85	-28.97	21.75
Arens et al. 2000	Martin et al. 1988	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-7.85	-29.27	22.07
Arens et al. 2000	Mayland et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Agropyron*	*Agropyron desertorum*		n/a	n/a	n/a	-7.85	-23.95	16.50
Arens et al. 2000	Mayland et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Agropyron*	*Agropyron desertorum*		n/a	n/a	n/a	-7.85	-26.83	19.50
Arens et al. 2000	Mayland et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Agropyron*	*Agropyron desertorum*		n/a	n/a	n/a	-7.85	-26.83	19.50
Arens et al. 2000	Mole et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Carex*	*Carex inops subsp. heliophila*		n/a	n/a	n/a	-8.00	-25.70	18.17
Arens et al. 2000	Mole et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Stipa*	*Stipa comata*		n/a	n/a	n/a	-8.00	-25.70	18.17
Arens et al. 2000	Mole et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Agropyron*	*Elymus smithii*		n/a	n/a	n/a	-8.00	-26.50	19.00
Arens et al. 2000	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Apocynaceae	*Stemmadenia*	*Stemmadenia sp.*		n/a	n/a	n/a	-7.85	-28.80	21.57
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-23.93	16.32
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-24.13	16.53
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-24.37	16.78
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-24.37	16.78
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-24.37	16.78
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-24.40	16.81
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-24.42	16.83
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-24.45	16.86
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-24.52	16.94
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-24.54	16.96
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-24.58	17.00
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-24.58	17.00
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-24.62	17.04
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-24.66	17.08
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-24.72	17.14
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-24.84	17.27
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-24.85	17.28
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-24.92	17.35
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-24.93	17.36
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-24.93	17.36
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-25.00	17.44
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-25.01	17.45
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-25.04	17.48
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-25.06	17.50
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-25.11	17.55
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-25.15	17.59
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-25.35	17.80
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-25.63	18.09
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-25.79	18.26
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-25.86	18.33
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-25.89	18.37
Arens et al. 2000	Morgan et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Triticum*	*Triticum aestivum*		n/a	n/a	n/a	-8.00	-26.28	18.77
Arens et al. 2000	geswara Roa et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Arachis*	*Arachis hypogaea*		n/a	n/a	n/a	-7.85	-26.01	18.64
Arens et al. 2000	geswara Roa et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Arachis*	*Arachis hypogaea*		n/a	n/a	n/a	-7.85	-26.05	18.69
Arens et al. 2000	geswara Roa et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Arachis*	*Arachis hypogaea*		n/a	n/a	n/a	-7.85	-26.19	18.83
Arens et al. 2000	geswara Roa et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Arachis*	*Arachis hypogaea*		n/a	n/a	n/a	-7.85	-26.21	18.85
Arens et al. 2000	geswara Roa et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Arachis*	*Arachis hypogaea*		n/a	n/a	n/a	-7.85	-26.23	18.88
Arens et al. 2000	geswara Roa et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Arachis*	*Arachis hypogaea*		n/a	n/a	n/a	-7.85	-26.32	18.97
Arens et al. 2000	geswara Roa et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Arachis*	*Arachis hypogaea*		n/a	n/a	n/a	-7.85	-26.34	18.99
Arens et al. 2000	geswara Roa et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Arachis*	*Arachis hypogaea*		n/a	n/a	n/a	-7.85	-26.39	19.04
Arens et al. 2000	geswara Roa et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Arachis*	*Arachis hypogaea*		n/a	n/a	n/a	-7.85	-26.44	19.09
Arens et al. 2000	geswara Roa et al. 1993	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Arachis*	*Arachis hypogaea*		n/a	n/a	n/a	-7.85	-26.53	19.19
Arens et al. 2000	Osório & Pereira 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Myrtaceae	*Eucalyptus*	*Eucalyptus globulus*		n/a	n/a	n/a	-7.85	-25.70	18.32
Arens et al. 2000	Osório & Pereira 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Myrtaceae	*Eucalyptus*	*Eucalyptus globulus*		n/a	n/a	n/a	-7.85	-26.80	19.47
Arens et al. 2000	Osório & Pereira 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Myrtaceae	*Eucalyptus*	*Eucalyptus globulus*		n/a	n/a	n/a	-7.85	-26.80	19.47
Arens et al. 2000	Osório & Pereira 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Myrtaceae	*Eucalyptus*	*Eucalyptus globulus*		n/a	n/a	n/a	-7.85	-26.80	19.47
Arens et al. 2000	Osório & Pereira 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Myrtaceae	*Eucalyptus*	*Eucalyptus globulus*		n/a	n/a	n/a	-7.85	-26.80	19.47
Arens et al. 2000	Osório & Pereira 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Myrtaceae	*Eucalyptus*	*Eucalyptus globulus*		n/a	n/a	n/a	-7.85	-27.40	20.10
Arens et al. 2000	Panek 1996	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-7.85	-25.00	17.59
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Buxaceae	*Buxus*	*Buxus sempervirens*		n/a	n/a	n/a	-7.80	-23.67	16.25
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Buxaceae	*Buxus*	*Buxus sempervirens*		n/a	n/a	n/a	-6.80	-23.29	16.88
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	*Juniperus*	*Juniperus communis*		n/a	n/a	n/a	-6.50	-23.10	16.99
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Ranunculaceae	*Helleborus*	*Helleborus foetidus*		n/a	n/a	n/a	-7.80	-24.50	17.12
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	*Juniperus*	*Juniperus communis*		n/a	n/a	n/a	-6.40	-23.28	17.28
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Gentianaceae	*Gentiana*	*Gentiana alpina*		n/a	n/a	n/a	-7.80	-24.72	17.35
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus uncinata*		n/a	n/a	n/a	-6.50	-24.02	17.95
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus uncinata*		n/a	n/a	n/a	-7.80	-25.43	18.09
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Ericaceae	*Rhododendron*	*Rhododendron ferrugineum*		n/a	n/a	n/a	-7.80	-25.54	18.20
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Gentianaceae	*Gentiana*	*Gentiana alpina*		n/a	n/a	n/a	-6.80	-24.62	18.27
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Ceratonia*	*Ceratonia siliqua*		n/a	n/a	n/a	-6.50	-24.41	18.36
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Buxaceae	*Buxus*	*Buxus sempervirens*		n/a	n/a	n/a	-6.40	-24.34	18.39
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	*Juniperus*	*Juniperus communis*		n/a	n/a	n/a	-7.80	-25.77	18.45
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Betulaceae	*Betula*	*Betula pendula*		n/a	n/a	n/a	-7.80	-25.96	18.64
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Betulaceae	*Betula*	*Betula pendula*		n/a	n/a	n/a	-6.80	-25.22	18.90
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Papaveraceae	*Papaver*	*Papaver alpinum*		n/a	n/a	n/a	-6.40	-25.06	19.14
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Betulaceae	*Betula*	*Betula pendula*		n/a	n/a	n/a	-6.40	-25.08	19.16
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Ranunculaceae	*Helleborus*	*Helleborus foetidus*		n/a	n/a	n/a	-6.80	unk	19.48
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Ranunculaceae	*Helleborus*	*Helleborus foetidus*		n/a	n/a	n/a	-6.40	-25.39	19.48
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Ceratonia*	*Ceratonia siliqua*		n/a	n/a	n/a	-7.80	-26.84	19.57
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Ceratonia*	*Ceratonia siliqua*		n/a	n/a	n/a	-6.80	-26.05	19.76
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	*Juniperus*	*Juniperus communis*		n/a	n/a	n/a	-6.80	-26.07	19.79
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Papaveraceae	*Papaver*	*Papaver alpinum*		n/a	n/a	n/a	-6.80	-26.16	19.88
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Gentianaceae	*Gentiana*	*Gentiana alpina*		n/a	n/a	n/a	-6.50	-25.88	19.89
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Buxaceae	*Buxus*	*Buxus sempervirens*		n/a	n/a	n/a	-6.50	-25.90	19.92
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Ericaceae	*Rhododendron*	*Rhododendron ferrugineum*		n/a	n/a	n/a	-6.50	-25.93	19.95
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Ericaceae	*Rhododendron*	*Rhododendron ferrugineum*		n/a	n/a	n/a	-6.40	-25.87	19.99
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Betulaceae	*Alnus*	*Alnus glutinosa*		n/a	n/a	n/a	-6.40	-26.06	20.19
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Ceratonia*	*Ceratonia siliqua*		n/a	n/a	n/a	-6.40	-26.18	20.31
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus pinea*		n/a	n/a	n/a	-7.80	-27.61	20.37
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Anacardiaceae	*Pistacia*	*Pistacia lentiscus*		n/a	n/a	n/a	-7.80	-27.61	20.37
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Ranunculaceae	*Helleborus*	*Helleborus foetidus*		n/a	n/a	n/a	-6.50	-26.53	20.58
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Anacardiaceae	*Pistacia*	*Pistacia lentiscus*		n/a	n/a	n/a	-6.50	-26.55	20.60
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Betulaceae	*Alnus*	*Alnus glutinosa*		n/a	n/a	n/a	-6.50	-26.56	20.61
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Papaveraceae	*Papaver*	*Papaver alpinum*		n/a	n/a	n/a	-6.50	-26.56	20.61
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Gentianaceae	*Gentiana*	*Gentiana alpina*		n/a	n/a	n/a	-6.40	-26.48	20.63
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus uncinata*		n/a	n/a	n/a	-6.80	-26.90	20.66
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus pinea*		n/a	n/a	n/a	-6.80	-26.94	20.70
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Anacardiaceae	*Pistacia*	*Pistacia lentiscus*		n/a	n/a	n/a	-6.80	-27.05	20.81
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus pinea*		n/a	n/a	n/a	-6.40	-26.81	20.97
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Betulaceae	*Alnus*	*Alnus glutinosa*		n/a	n/a	n/a	-6.80	-27.21	20.98
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus pinea*		n/a	n/a	n/a	-6.50	-26.92	20.98
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Betulaceae	*Betula*	*Betula pendula*		n/a	n/a	n/a	-6.50	-26.95	21.02
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus uncinata*		n/a	n/a	n/a	-6.40	-26.91	21.08
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Anacardiaceae	*Pistacia*	*Pistacia lentiscus*		n/a	n/a	n/a	-6.40	-27.00	21.17
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Betulaceae	*Alnus*	*Alnus glutinosa*		n/a	n/a	n/a	-7.80	-28.82	21.64
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Ericaceae	*Rhododendron*	*Rhododendron ferrugineum*		n/a	n/a	n/a	-6.80	-28.68	22.53
Arens et al. 2000	elas & Azcón-Bieto 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Papaveraceae	*Papaver*	*Papaver alpinum*		n/a	n/a	n/a	-7.80	-29.94	22.82
Arens et al. 2000	Polley et al. 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Bromus*	*Bromus tectorum*		n/a	n/a	n/a	-9.60	-28.00	18.93
Arens et al. 2000	Polley et al. 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Bromus*	*Bromus tectorum*		n/a	n/a	n/a	-9.60	-28.00	18.93
Arens et al. 2000	Polley et al. 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Bromus*	*Bromus tectorum*		n/a	n/a	n/a	-3.50	-23.00	19.96
Arens et al. 2000	Polley et al. 1995	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Bromus*	*Bromus tectorum*		n/a	n/a	n/a	-3.50	-23.00	19.96
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Balsamorhiza*	*Balsamorhiza macrophylla*		n/a	n/a	n/a	-8.00	-25.54	18.00
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Polemoniaceae	*Phlox*	*Phlox longifolia*		n/a	n/a	n/a	-8.00	-25.54	18.00
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Stipa*	*Stipa comata*		n/a	n/a	n/a	-8.00	-25.54	18.00
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Melanthiaceae	*Toxicoscordion*	*Toxicoscordion paniculatum*		n/a	n/a	n/a	-8.00	-25.54	18.00

Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Cirsium*	*Cirsium undulatum*		n/a	n/a	n/a	-8.00	-25.92	18.40	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Gutierrezia*	*Gutierrezia sarothrae*		n/a	n/a	n/a	-8.00	-26.02	18.50	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Plantaginaceae	*Linaria*	*Linaria dalmatica*		n/a	n/a	n/a	-8.00	-26.11	18.60	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Ambrosia*	*Ambrosia psilostachya*		n/a	n/a	n/a	-8.00	-26.21	18.70	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Astragalus*	*Astragalus cibarius*		n/a	n/a	n/a	-8.00	-26.21	18.70	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Vicia*	*Vicia americana*		n/a	n/a	n/a	-8.00	-26.21	18.70	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Poa*	*Poa bulbosa*		n/a	n/a	n/a	-8.00	-26.31	18.80	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Balsamorhiza*	*Balsamorhiza macrophylla*		n/a	n/a	n/a	-8.00	-26.40	18.90	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Lactuca*	*Lactuca serriola*		n/a	n/a	n/a	-8.00	-26.40	18.90	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Hedysarum*	*Hedysarum boreale*		n/a	n/a	n/a	-8.00	-26.50	19.00	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Melica*	*Melica bulbosa*		n/a	n/a	n/a	-8.00	-26.59	19.10	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Symphyotrich*	*Symphyotrichum chilense*		n/a	n/a	n/a	-8.00	-26.59	19.10	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Artemisia*	*Artemisia ludoviciana*		n/a	n/a	n/a	-8.00	-26.69	19.20	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Apiaceae	*Cymopterus*	*Cymopterus longipes*		n/a	n/a	n/a	-8.00	-26.78	19.30	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Erigeron*	*Erigeron divergens*	Hook is illeg; Torr & A.Gray is l	n/a	n/a	n/a	-8.00	-26.78	19.30	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Grindelia*	*Grindelia squarrosa*		n/a	n/a	n/a	-8.00	-26.78	19.30	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Pseudoroegne*	*Elymus spicatus*		n/a	n/a	n/a	-8.00	-26.78	19.30	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Wyethia*	*Wyethia amplexicaulis*		n/a	n/a	n/a	-8.00	-26.78	19.30	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Lepidium*	*Lepidium perfoliatum*		n/a	n/a	n/a	-8.00	-26.88	19.40	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Lupinus*	*Lupinus argenteus*		n/a	n/a	n/a	-8.00	-26.88	19.40	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Tragopogon*	*Tragopogon dubius*		n/a	n/a	n/a	-8.00	-26.88	19.40	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Alyssum*	*Alyssum simplex*		n/a	n/a	n/a	-8.00	-26.97	19.50	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Lygodesmia*	*Lygodesmia grandiflora*		n/a	n/a	n/a	-8.00	-27.07	19.60	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Astragalus*	*Astragalus utahensis*		n/a	n/a	n/a	-8.00	-27.16	19.69	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Crepis*	*Crepis occidentalis*		n/a	n/a	n/a	-8.00	-27.16	19.69	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Senecio*	*Senecio integerrimus*		n/a	n/a	n/a	-8.00	-27.26	19.80	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Malvaceae	*Sphaeralcea*	*Sphaeralcea coccinea*		n/a	n/a	n/a	-8.00	-27.26	19.80	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Apiaceae	*Lomatium*	*Lomatium triternatum*		n/a	n/a	n/a	-8.00	-27.45	20.00	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Ranunculaceae	*Ceratocephala*	*Ceratocephala testiculata*		n/a	n/a	n/a	-8.00	-27.55	20.10	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Microseris*	*Microseris nutans*		n/a	n/a	n/a	-8.00	-27.55	20.10	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Boraginaceae	*Buglossoides*	*Buglossoides arvensis*		n/a	n/a	n/a	-8.00	-27.74	20.30	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Camelina*	*Camelina microcarpa*		n/a	n/a	n/a	-8.00	-27.93	20.50	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Sisymbrium*	*Sisymbrium altissimum*		n/a	n/a	n/a	-8.00	-28.12	20.70	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Boraginaceae	*Cryptantha*	*Cryptantha torreyana*		n/a	n/a	n/a	-8.00	-28.40	21.00	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Rubiaceae	*Galium*	*Galium aparine*		n/a	n/a	n/a	-8.00	-28.78	21.40	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Geraniaceae	*Erodium*	*Erodium cicutarium*		n/a	n/a	n/a	-8.00	-28.97	21.60	
Arens et al. 2000	Smedley et al. 1991	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Santalaceae	*Comandra*	*Comandra umbellata*		n/a	n/a	n/a	-8.00	-29.64	22.30	
Arens et al. 2000	Terwilliger 1997	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Urticaceae	*Cecropia*	*Cecropia peltata*		n/a	n/a	n/a	-7.85	-29.20	21.99	
Arens et al. 2000	Terwilliger 1997	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Malvaceae	*Apeiba*	*Apeiba tibourbou*		n/a	n/a	n/a	-7.85	-29.50	22.31	
Arens et al. 2000	Terwilliger 1997	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Urticaceae	*Cecropia*	*Cecropia peltata*		n/a	n/a	n/a	-7.85	-29.90	22.73	
Arens et al. 2000	Terwilliger 1997	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Malvaceae	*Apeiba*	*Apeiba membranacea*		n/a	n/a	n/a	-7.85	-30.30	23.15	
Arens et al. 2000	Terwilliger 1997	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Malvaceae	*Apeiba*	*Apeiba membranacea*		n/a	n/a	n/a	-7.85	-30.50	23.36	
Arens et al. 2000	Terwilliger 1997	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Malvaceae	*Apeiba*	*Apeiba tibourbou*		n/a	n/a	n/a	-7.85	-30.50	23.36	
Arens et al. 2000	Terwilliger 1997	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Urticaceae	*Cecropia*	*Cecropia insignis*		n/a	n/a	n/a	-7.85	-30.50	23.36	
Arens et al. 2000	Terwilliger 1997	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Urticaceae	*Cecropia*	*Cecropia insignis*		n/a	n/a	n/a	-7.85	-30.50	23.36	
Arens et al. 2000	Terwilliger 1997	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Malvaceae	*Apeiba*	*Apeiba membranacea*		n/a	n/a	n/a	-7.85	-31.10	24.00	
Arens et al. 2000	Terwilliger 1997	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Urticaceae	*Cecropia*	*Cecropia insignis*		n/a	n/a	n/a	-7.85	-31.40	24.31	
Arens et al. 2000	Terwilliger 1997	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Malvaceae	*Apeiba*	*Apeiba membranacea*		n/a	n/a	n/a	-7.85	-32.00	24.95	
Arens et al. 2000	Terwilliger 1997	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Urticaceae	*Cecropia*	*Cecropia insignis*		n/a	n/a	n/a	-7.85	-32.40	25.37	
Arens et al. 2000	Toft et al. 1989	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Elymus*	*Elymus lanceolatus*		n/a	n/a	n/a	-7.85	-24.20	16.76	
Arens et al. 2000	Toft et al. 1989	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Elymus*	*Elymus elymoides*		n/a	n/a	n/a	-7.85	-25.00	17.59	
Arens et al. 2000	Toft et al. 1989	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Elymus*	*Elymus lanceolatus*		n/a	n/a	n/a	-7.85	-25.20	17.80	
Arens et al. 2000	Toft et al. 1989	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Elymus*	*Elymus elymoides*		n/a	n/a	n/a	-7.85	-25.40	18.01	
Arens et al. 2000	Toft et al. 1989	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Artemisia*	*Artemisia tridentata*		n/a	n/a	n/a	-7.85	-25.80	18.43	
Arens et al. 2000	Toft et al. 1989	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Elymus*	*Elymus elymoides*		n/a	n/a	n/a	-7.85	-25.80	18.43	
Arens et al. 2000	Toft et al. 1989	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Artemisia*	*Artemisia tridentata*		n/a	n/a	n/a	-7.85	-25.90	18.53	
Arens et al. 2000	Toft et al. 1989	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Artemisia*	*Artemisia tridentata*		n/a	n/a	n/a	-7.85	-26.00	18.63	
Arens et al. 2000	Toft et al. 1989	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Elymus*	*Elymus lanceolatus*		n/a	n/a	n/a	-7.85	-26.00	18.63	
Arens et al. 2000	Toft et al. 1989	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Artemisia*	*Artemisia tridentata*		n/a	n/a	n/a	-7.85	-26.30	18.95	
Arens et al. 2000	Toft et al. 1989	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Elymus*	*Elymus elymoides*		n/a	n/a	n/a	-7.85	-26.40	19.05	
Arens et al. 2000	Toft et al. 1989	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Elymus*	*Elymus lanceolatus*		n/a	n/a	n/a	-7.85	-26.60	19.26	
Arens et al. 2000	Toft et al. 1989	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Amaranthaceae	*Kraschenninik*	*Krascheninnikovia ceratoides subsp. lanata*		n/a	n/a	n/a	-7.85	-27.60	20.31	
Arens et al. 2000	Toft et al. 1989	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Amaranthaceae	*Kraschenninik*	*Krascheninnikovia ceratoides subsp. lanata*		n/a	n/a	n/a	-7.85	-28.80	21.57	
Arens et al. 2000	Toft et al. 1989	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Amaranthaceae	*Kraschenninik*	*Krascheninnikovia ceratoides subsp. lanata*		n/a	n/a	n/a	-7.85	-28.90	21.68	
Arens et al. 2000	Toft et al. 1989	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Amaranthaceae	*Kraschenninik*	*Krascheninnikovia ceratoides subsp. lanata*		n/a	n/a	n/a	-7.85	-28.90	21.68	
Arens et al. 2000	Van de Water et al. 1994	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus flexilis*		n/a	n/a	n/a	-6.40	-23.30	17.30	
Arens et al. 2000	Van de Water et al. 1994	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus flexilis*		n/a	n/a	n/a	-6.40	-24.45	18.50	
Arens et al. 2000	Van de Water et al. 1994	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus flexilis*		n/a	n/a	n/a	-6.40	-25.21	19.30	
Arens et al. 2000	Welker et al. 1993	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Rosaceae	*Dryas*	*Dryas octopetala*		n/a	n/a	n/a	-7.90	-28.26	20.95	
Arens et al. 2000	Welker et al. 1993	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Rosaceae	*Dryas*	*Dryas octopetala*		n/a	n/a	n/a	-7.90	-29.02	21.75	
Arens et al. 2000	Welker et al. 1993	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Rosaceae	*Dryas*	*Dryas octopetala*		n/a	n/a	n/a	-7.90	-29.11	21.85	
Arens et al. 2000	Welker et al. 1993	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Rosaceae	*Dryas*	*Dryas octopetala*		n/a	n/a	n/a	-7.90	-29.21	21.95	
Arens et al. 2000	White et al. 1994	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Phaseolus*	*Phaseolus vulgaris*		n/a	n/a	n/a	-8.00	-25.58	18.04	
Arens et al. 2000	White et al. 1994	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Phaseolus*	*Phaseolus vulgaris*		n/a	n/a	n/a	-8.00	-26.46	18.96	
Arens et al. 2000	White et al. 1994	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Phaseolus*	*Phaseolus vulgaris*		n/a	n/a	n/a	-8.00	-27.02	19.55	
Arens et al. 2000	White et al. 1994	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Phaseolus*	*Phaseolus vulgaris*		n/a	n/a	n/a	-8.00	-27.16	19.69	
Arens et al. 2000	White et al. 1994	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Phaseolus*	*Phaseolus vulgaris*		n/a	n/a	n/a	-8.00	-27.37	19.92	
Arens et al. 2000	White et al. 1994	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Phaseolus*	*Phaseolus vulgaris*		n/a	n/a	n/a	-8.00	-27.88	20.45	
Arens et al. 2000	Wright et al. 1994	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Arachis*	*Arachis hypogaea*		n/a	n/a	n/a	-7.85	-25.97	18.60	
Arens et al. 2000	Wright et al. 1994	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Arachis*	*Arachis hypogaea*		n/a	n/a	n/a	-7.85	-26.16	18.80	
Arens et al. 2000	Wright et al. 1994	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Arachis*	*Arachis hypogaea*		n/a	n/a	n/a	-7.85	-26.73	19.40	
Arens et al. 2000	Wright et al. 1994	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Arachis*	*Arachis hypogaea*		n/a	n/a	n/a	-7.85	-26.73	19.40	
Arens et al. 2000	Wright et al. 1994	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Arachis*	*Arachis hypogaea*		n/a	n/a	n/a	-7.85	-27.21	19.90	
Arens et al. 2000	Wright et al. 1994	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Arachis*	*Arachis hypogaea*		n/a	n/a	n/a	-7.85	-27.97	20.70	
Arens et al. 2000	Wright et al. 1994	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Arachis*	*Arachis hypogaea*		n/a	n/a	n/a	-7.85	-28.16	20.90	
Arens et al. 2000	Wright et al. 1994	n/a	n/a	n/a		n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fabaceae	*Arachis*	*Arachis hypogaea*		n/a	n/a	n/a	-7.85	-28.35	21.10	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-27.02	19.55	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-27.10	19.63	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-27.25	19.79	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-27.25	19.79	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-27.35	19.89	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-27.37	19.92	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-27.40	19.95	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-27.48	20.03	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-27.51	20.06	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-27.61	20.17	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-27.69	20.25	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-27.89	20.46	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-28.09	20.67	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-28.22	20.81	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-28.24	20.83	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-28.49	21.09	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-28.53	21.13	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-28.72	21.33	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-28.76	21.37	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-28.79	21.41	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-28.81	21.43	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-28.83	21.45	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-28.93	21.55	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-28.99	21.62	
Arens et al. 2000	Zhang et al. 1993	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pseudotsuga*	*Pseudotsuga menziesii*		n/a	n/a	n/a	-8.00	-29.62	22.28	
Arens et al. 2000	Zhang et al. 1994	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Larix*	*Larix occidentalis*		n/a	n/a	n/a	-8.00	-26.33	18.83	
Arens et al. 2000	Zhang et al. 1994	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Larix*	*Larix occidentalis*		n/a	n/a	n/a	-8.00	-26.78	19.30	
Arens et al. 2000	Zhang et al. 1994	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Larix*	*Larix occidentalis*		n/a	n/a	n/a	-8.00	-27.15	19.68	
Arens et al. 2000	Zhang et al. 1994	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Larix*	*Larix occidentalis*		n/a	n/a	n/a	-8.00	-27.20	19.74	
Arens et al. 2000	Zhang et al. 1994	n/a	n/a	n/a		n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Larix*	*Larix occidentalis*		n/a	n/a	n/a	-8.00	-28.63	21.24	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Duclos		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Blysmus*	*Blysmus compressus*		1924	n/a	n/a	-6.89	-27.50	21.20	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Serre Orsay		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Afrotrilepis*	*Afrotrilepis pilosa*		1972	n/a	n/a	-7.36	-33.10	26.63	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Morrison		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Cyathochaeta*	*Cyathochaeta avenacea*		12/3/1903	n/a	n/a	-6.77	-26.30	20.06	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Ramos		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Paramapania*	*Paramapania radians*		Aug 1915	n/a	n/a	-6.87	-29.20	23.00	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Clifford		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Ficinia*	*Ficinia spiralis*		11/17/1973	n/a	n/a	-7.39	-24.60	17.64	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Eggers		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Rhynchospora*	*Rhynchospora holoschoenoides*		Jul 1881	n/a	n/a	-6.80	-25.50	19.19	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Smith		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Rhynchospora*	*Rhynchospora cephalantha*		8/17/1939	n/a	n/a	-6.99	-26.50	20.04	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Steyermark		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Lagenocarpus*	*Lagenocarpus amazonicus*		9/1/1961	n/a	n/a	-7.07	-26.90	20.38	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Lerman		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Carex*	*Carex ericetorum*		1970	n/a	n/a	-7.29	-25.90	19.10	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Lerman		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Carex*	*Carex flava*		1971	n/a	n/a	-7.35	-27.40	20.62	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Phytotron		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Carex*	*Carex setifolia*		1972	n/a	n/a	-7.36	-31.90	25.35	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Phytotron		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Carex*	*Carex pachystylis*		1972	n/a	n/a	-7.36	-33.10	26.63	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Duclos		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Carex*	*Carex bohemica*		1929	n/a	n/a	-6.83	-27.70	21.46	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Duclos		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Carex*	*Carex maritima*		1938	n/a	n/a	-6.94	-26.90	20.51	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Seyrat		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Carex*	*Carex pilulifera*		1912	n/a	n/a	-6.86	-30.30	24.17	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	De Vergnes		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Carex*	*Carex strigosa*		1902	n/a	n/a	-6.82	-30.10	24.00	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Le Guillou		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Carpha*	*Carpha alpina*		1840	n/a	n/a	-6.61	-26.60	20.54	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Dillon & Pettit		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Coleochloa*	*Coleochloa abyssinica*		1842	n/a	n/a	-6.62	-26.10	20.01	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Morrison		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Cyathochaeta*	*Cyathochaeta avenacea*		1915	n/a	n/a	-6.87	-25.90	19.54	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Hombron		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Capitularina*	*Capitularina involucrata*		1841	n/a	n/a	-6.61	-33.80	28.14	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	La Ferte Alais		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Scirpus*	*Scirpus sylvaticus*		1841	n/a	n/a	-6.61	-27.50	21.48	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Boivin		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Schoenoplecti*	*Schoenoplectiella articulata*		ca. 1850	n/a	n/a	-6.65	-29.20	23.23	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Buchet		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Eleocharis*	*Eleocharis palustris*		1853	n/a	n/a	-6.65	-27.30	21.23	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Halle		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Eleocharis*	*Eleocharis confervoides*		1960	n/a	n/a	-7.04	-23.30	16.65	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Hombron		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Ficinia*	*Ficinia spiralis*		1840	n/a	n/a	-6.61	-24.70	18.55	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Humbert		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Kobresia*	*Kobresia myosuroides*		1911	n/a	n/a	-6.86	-25.90	19.55	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Lerma		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Trichophorum*	*Trichophorum cespitosum*		1971	n/a	n/a	-7.35	-27.10	20.30	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Maximowicz		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Cyperus*	*Cyperus limosus*		1859	n/a	n/a	-6.68	-26.00	19.84	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Riedal		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Pleurostachys*	*Pleurostachys gaudichaudii*		1823	n/a	n/a	-6.55	-30.20	24.39	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Serre Orsay		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Cyperus*	*Cyperus fertilis*		1972	n/a	n/a	-7.36	-33.70	27.26	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Serre Orsay		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Cyperus*	*Cyperus gracilis*		1972	n/a	n/a	-7.36	-31.20	24.61	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Serre Orsay		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Cyperus*	*Cyperus laxus*		1972	n/a	n/a	-7.36	-32.70	26.20	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Serre Orsay		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Fuirena*	*Fuirena simplex*		1972	n/a	n/a	-7.36	-34.30	27.90	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Serre Orsay		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Hypolytrum*	*Hypolytrum heteromorphum*		1972	n/a	n/a	-7.36	-29.50	22.82	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Serre Orsay		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Isolepis*	*Isolepis prolifera*		1972	n/a	n/a	-7.36	-34.80	28.43	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Serre Orsay		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Mapania*	*Mapania baldwinii*		1972	n/a	n/a	-7.36	-33.50	27.05	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Serre Orsay		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Mapania*	*Mapania coriandrum*		1972	n/a	n/a	-7.36	-31.30	24.72	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Serre Orsay		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Mapania*	*Mapania macrantha*		1972	n/a	n/a	-7.36	-33.40	26.94	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Serre Orsay		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Mapania*	*Mapania soyauxii*		1972	n/a	n/a	-7.36	-35.80	29.50	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Serre Orsay		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Microdracoide*	*Microdracoides squamosa*		1972	n/a	n/a	-7.36	-33.70	27.26	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Serre Orsay		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Rhynchospora*	*Rhynchospora nervosa*		1972	n/a	n/a	-7.36	-34.10	27.69	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	n/a		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Tetraria*	*Tetraria capillaris*		1900	n/a	n/a	-6.75	-28.10	21.96	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Ducke		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Eleocharis*	*Eleocharis fluctuans*		7/20/1912	n/a	n/a	-6.86	-25.60	19.23	
Bruhl & Wilson 2007	n/a	n/a	n/a	S.N.	Ducke		Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Eleocharis*	*Eleocharis fluctuans*		7/20/1912	n/a	n/a	-6.86	-27.60	21.33	
Diefendorf et al. 2010	Bai et al. 2008	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rutaceae	*Zanthoxylum*	*Zanthoxylum fagara*		Apr-05	2005	382.05	-8.13	-27.40	19.81	19.81
Diefendorf et al. 2010	Bai et al. 2008	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rhamnaceae	*Condalia*	*Condalia hookeri*		Apr-05	2005	382.05	-8.13	-27.80	20.23	20.23
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Mimosaceae	*Balizia*	*Albizia pedicellaris*		n/a	n/a	n/a	-7.93	-27.50	20.12	20.12
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lecythidaceae	*Lecythis*	*Lecythis zabucajo*		n/a	n/a	n/a	-7.93	-27.70	20.33	20.33
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Peltogyne*	*Peltogyne venosa*		n/a	n/a	n/a	-7.93	-27.90	20.54	20.54
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Elaeocarpaceae	*Sloanea*	*Sloanea sp.*		n/a	n/a	n/a	-7.93	-27.90	20.54	20.54
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Caesalpiniaceae	*Dicorynia*	*Dicorynia guianensis*		n/a	n/a	n/a	-7.93	-28.00	20.65	20.65
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Clusiaceae	*Platonia*	*Platonia insignis*		n/a	n/a	n/a	-7.93	-28.00	20.65	20.65
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm		C3		Caesalpiniaceae	*Recordoxylon*	*Recordoxylon venosa*	No species with this name in th	n/a	n/a	n/a	-7.93	-28.00	20.65	20.65
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Vocysiaceae	*Ruizterania*	*Qualea albiflora*		n/a	n/a	n/a	-7.93	-28.20	20.86	20.86
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Mimosaceae	*Balizia*	*Albizia pedicellaris*		n/a	n/a	n/a	-7.93	-28.30	20.96	20.96
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Eperua*	*Eperua falcata*		n/a	n/a	n/a	-7.93	-28.30	20.96	20.96
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Mimosaceae	*Inga*	*Inga paraensis*		n/a	n/a	n/a	-7.93	-28.30	20.96	20.96
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Elaeocarpaceae	*Amanoa*	*Amanoa congesta*		n/a	n/a	n/a	-7.93	-28.40	21.07	21.07
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Swartzia*	*Swartzia polyphylla*		n/a	n/a	n/a	-7.93	-28.40	21.07	21.07
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Eperua*	*Eperua falcata*		n/a	n/a	n/a	-7.93	-28.50	21.17	21.17
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Caesalpiniaceae	*Dicorynia*	*Dicorynia guianensis*		n/a	n/a	n/a	-7.93	-28.60	21.28	21.28
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Eperua*	*Eperua falcata*		n/a	n/a	n/a	-7.93	-28.60	21.28	21.28
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Sclerolobium*	*Sclerolobium melinonii*		n/a	n/a	n/a	-7.93	-28.60	21.28	21.28
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Burseraceae	*Tetragastris*	*Tetragastris panamensis*		n/a	n/a	n/a	-7.93	-28.70	21.38	21.38
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	*Pouteria*	*Pouteria eugeniifolia*		n/a	n/a	n/a	-7.93	-28.80	21.49	21.49
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Apocynaceae	*Couma*	*Couma guianensis*		n/a	n/a	n/a	-7.93	-28.90	21.59	21.59
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Eperua*	*Eperua grandiflora*		n/a	n/a	n/a	-7.93	-28.90	21.59	21.59
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Eperua*	*Eperua grandiflora*		n/a	n/a	n/a	-7.93	-28.90	21.59	21.59
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rubiaceae	*Posoqueria*	*Posoqueria latifolia*		n/a	n/a	n/a	-7.93	-28.90	21.59	21.59
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Vocysiaceae	*Ruizterania*	*Qualea albiflora*		n/a	n/a	n/a	-7.93	-28.90	21.59	21.59
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Caesalpiniaceae	*Dicorynia*	*Dicorynia guianensis*		n/a	n/a	n/a	-7.93	-29.00	21.70	21.70
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Mimosaceae	*Pseudopiptad*	*Pseudopiptadenia suaveolens*		n/a	n/a	n/a	-7.93	-29.00	21.70	21.70
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Mimosaceae	*Abarema*	*Abarema jupunba*		n/a	n/a	n/a	-7.93	-29.10	21.80	21.80
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lauraceae	*Ocotea*	*Sextonia rubra*		n/a	n/a	n/a	-7.93	-29.10	21.80	21.80
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	*Pouteria*	*Pouteria melanopoda*		n/a	n/a	n/a	-7.93	-29.10	21.80	21.80
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Mimosaceae	*Abarema*	*Abarema curvicarpa*		n/a	n/a	n/a	-7.93	-29.20	21.91	21.91
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Meliaceae	*Carapa*	*Carapa procera*		n/a	n/a	n/a	-7.93	-29.20	21.91	21.91
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Elaeocarpaceae	*Hevea*	*Hevea guianensis*		n/a	n/a	n/a	-7.93	-29.20	21.91	21.91
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a		n/a	Angiosperm	Woody	C3	Woody Angiosperm	Olacaceae	*Minquartia*	*Minquartia guianensis*		n/a	n/a	n/a	-7.93	-29.20	21.91	21.91

Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Swartzia*	*Swartzia polyphylla*		n/a	n/a	n/a	-7.93	-29.20	21.91	21.91
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Meliaceae	*Carapa*	*Carapa procera*		n/a	n/a	n/a	-7.93	-29.30	22.02	22.02
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Mimosaceae	*Abarema*	*Abarema jupunba*		n/a	n/a	n/a	-7.93	-29.40	22.12	22.12
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Mimosaceae	*Abarema*	*Abarema jupunba*		n/a	n/a	n/a	-7.93	-29.40	22.12	22.12
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Caryocaraceae	*Caryocar*	*Caryocar glabrum*		n/a	n/a	n/a	-7.93	-29.40	22.12	22.12
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Caryocaraceae	*Caryocar*	*Caryocar glabrum*		n/a	n/a	n/a	-7.93	-29.40	22.12	22.12
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	*Chrysophyllum*	*Chrysophyllum sanguinolentum*		n/a	n/a	n/a	-7.93	-29.40	22.12	22.12
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	*Micropholis*	*Micropholis guyanensis*		n/a	n/a	n/a	-7.93	-29.40	22.12	22.12
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Melastomataceae	*Mouriri*	*Mouriri crassifolia*		n/a	n/a	n/a	-7.93	-29.40	22.12	22.12
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Mimosaceae	*Balizia*	*Albizia pedicellaris*		n/a	n/a	n/a	-7.93	-29.50	22.23	22.23
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Eperua*	*Eperua grandiflora*		n/a	n/a	n/a	-7.93	-29.50	22.23	22.23
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Moraceae	*Brosimum*	*Brosimum guianense*		n/a	n/a	n/a	-7.93	-29.60	22.33	22.33
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Chrysobalanaceae	*Couepia*	*Couepia caryophylloides*		n/a	n/a	n/a	-7.93	-29.60	22.33	22.33
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Caesalpiniaceae	*Bocoa*	*Bocoa prouacensis*		n/a	n/a	n/a	-7.93	-29.70	22.44	22.44
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	*Chrysophyllum*	*Chrysophyllum prieurii*		n/a	n/a	n/a	-7.93	-29.70	22.44	22.44
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Mimosaceae	*Inga*	*Inga thibaudiana*		n/a	n/a	n/a	-7.93	-29.70	22.44	22.44
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Peltogyne*	*Peltogyne venosa*		n/a	n/a	n/a	-7.93	-29.70	22.44	22.44
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lecythidaceae	*Eschweilera*	*Eschweilera decolorans*		n/a	n/a	n/a	-7.93	-29.80	22.54	22.54
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Chrysobalanaceae	*Parinari*	*Parinari montana*		n/a	n/a	n/a	-7.93	-29.80	22.54	22.54
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	*Ecclinusa*	*Ecclinusa guianensis*		n/a	n/a	n/a	-7.93	-29.90	22.65	22.65
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Celastraceae	*Goupia*	*Goupia glabra*		n/a	n/a	n/a	-7.93	-29.90	22.65	22.65
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	*Chrysophyllum*	*Chrysophyllum prieurii*		n/a	n/a	n/a	-7.93	-30.00	22.75	22.75
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Celastraceae	*Goupia*	*Goupia glabra*		n/a	n/a	n/a	-7.93	-30.00	22.75	22.75
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Sclerolobium*	*Sclerolobium albiflorum*		n/a	n/a	n/a	-7.93	-30.00	22.75	22.75
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Sclerolobium*	*Sclerolobium melinonii*		n/a	n/a	n/a	-7.93	-30.00	22.75	22.75
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Sclerolobium*	*Sclerolobium melinonii*		n/a	n/a	n/a	-7.93	-30.10	22.86	22.86
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Clusiaceae	*Symphonia*	*Symphonia sp.*		n/a	n/a	n/a	-7.93	-30.10	22.86	22.86
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Humiriaceae	*Vantanea*	*Vantanea parviflora*		n/a	n/a	n/a	-7.93	-30.10	22.86	22.86
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Araliaceae	*Schefflera*	*Schefflera decaphylla*		n/a	n/a	n/a	-7.93	-30.20	22.96	22.96
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Clusiaceae	*Symphonia*	*Symphonia sp.*		n/a	n/a	n/a	-7.93	-30.20	22.96	22.96
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Anacardiaceae	*Thyrsodium*	*Thyrsodium guianense*		n/a	n/a	n/a	-7.93	-30.20	22.96	22.96
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	*Chrysophyllum*	*Chrysophyllum sanguinolentum*		n/a	n/a	n/a	-7.93	-30.30	23.07	23.07
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Moraceae	*Helicostylis*	*Helicostylis pedunculata*		n/a	n/a	n/a	-7.93	-30.30	23.07	23.07
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Clusiaceae	*Moronobea*	*Moronobea coccinea*		n/a	n/a	n/a	-7.93	-30.30	23.07	23.07
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Bombacaceae	*Catostemma*	*Catostemma fragrans*		n/a	n/a	n/a	-7.93	-30.40	23.17	23.17
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	*Pouteria*	*Pouteria grandis*		n/a	n/a	n/a	-7.93	-30.40	23.17	23.17
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Clusiaceae	*Symphonia*	*Symphonia sp.*		n/a	n/a	n/a	-7.93	-30.40	23.17	23.17
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Chrysobalanaceae	*Licania*	*Licania sp. 1*		n/a	n/a	n/a	-7.93	-30.60	23.39	23.39
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	*Micropholis*	*Micropholis venulosa*		n/a	n/a	n/a	-7.93	-30.60	23.39	23.39
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	*Pradosia*	*Pradosia cochlearia*		n/a	n/a	n/a	-7.93	-30.60	23.39	23.39
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Caesalpiniaceae	*Bocoa*	*Bocoa prouacensis*		n/a	n/a	n/a	-7.93	-30.70	23.49	23.49
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Chrysobalanaceae	*Couepia*	*Couepia caryophylloides*		n/a	n/a	n/a	-7.93	-30.70	23.49	23.49
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Diplotropis*	*Diplotropis purpurea*		n/a	n/a	n/a	-7.93	-30.70	23.49	23.49
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lecythidaceae	*Eschweilera*	*Eschweilera parviflora*		n/a	n/a	n/a	-7.93	-30.70	23.49	23.49
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lecythidaceae	*Lecythis*	*Lecythis persistens*		n/a	n/a	n/a	-7.93	-30.70	23.49	23.49
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Caesalpiniaceae	*Vouacapoua*	*Vouacapoua americana*		n/a	n/a	n/a	-7.93	-30.70	23.49	23.49
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Andira*	*Andira coriacea*		n/a	n/a	n/a	-7.93	-30.80	23.60	23.60
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Elaeocarpaceae	*Glycydendron*	*Glycydendron amazonicum*		n/a	n/a	n/a	-7.93	-30.80	23.60	23.60
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lecythidaceae	*Lecythis*	*Lecythis chartacea*		n/a	n/a	n/a	-7.93	-30.80	23.60	23.60
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	*Micropholis*	*Micropholis obscura*		n/a	n/a	n/a	-7.93	-30.80	23.60	23.60
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Clusiaceae	*Moronobea*	*Moronobea coccinea*		n/a	n/a	n/a	-7.93	-30.80	23.60	23.60
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Chrysobalanaceae	*Parinari*	*Parinari excelsa*		n/a	n/a	n/a	-7.93	-30.80	23.60	23.60
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sterculiaceae	*Sterculia*	*Sterculia sp.*		n/a	n/a	n/a	-7.93	-30.80	23.60	23.60
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Meliaceae	*Trichilia*	*Trichilia sp.*		n/a	n/a	n/a	-7.93	-30.80	23.60	23.60
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lecythidaceae	*Couratari*	*Couratari guianensis*		n/a	n/a	n/a	-7.93	-30.90	23.70	23.70
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Melastomataceae	*Mouriri*	*Mouriri crassifolia*		n/a	n/a	n/a	-7.93	-30.90	23.70	23.70
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Melastomataceae	*Mouriri*	*Mouriri crassifolia*		n/a	n/a	n/a	-7.93	-30.90	23.70	23.70
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Elaeocarpaceae	*Drypetes*	*Drypetes variabilis*		n/a	n/a	n/a	-7.93	-31.00	23.81	23.81
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lecythidaceae	*Eschweilera*	*Eschweilera sp.*		n/a	n/a	n/a	-7.93	-31.00	23.81	23.81
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Chrysobalanaceae	*Licania*	*Licania granvillei*		n/a	n/a	n/a	-7.93	-31.00	23.81	23.81
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	*Micropholis*	*Micropholis obscura*		n/a	n/a	n/a	-7.93	-31.00	23.81	23.81
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Moraceae	*Brosimum*	*Brosimum rubescens*		n/a	n/a	n/a	-7.93	-31.10	23.91	23.91
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Meliaceae	*Carapa*	*Carapa procera*		n/a	n/a	n/a	-7.93	-31.10	23.91	23.91
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Icacinaceae	*Dendrobangia*	*Dendrobangia boliviana*		n/a	n/a	n/a	-7.93	-31.10	23.91	23.91
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Icacinaceae	*Dendrobangia*	*Dendrobangia boliviana*		n/a	n/a	n/a	-7.93	-31.10	23.91	23.91
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lecythidaceae	*Eschweilera*	*Eschweilera coriacea*		n/a	n/a	n/a	-7.93	-31.10	23.91	23.91
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lecythidaceae	*Eschweilera*	*Eschweilera decolorans*		n/a	n/a	n/a	-7.93	-31.10	23.91	23.91
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Burseraceae	*Protium*	*Protium subserratum*		n/a	n/a	n/a	-7.93	-31.10	23.91	23.91
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Caesalpiniaceae	*Vouacapoua*	*Vouacapoua americana*		n/a	n/a	n/a	-7.93	-31.10	23.91	23.91
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Diplotropis*	*Diplotropis purpurea*		n/a	n/a	n/a	-7.93	-31.20	24.02	24.02
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Myristicaceae	*Virola*	*Virola michelii*		n/a	n/a	n/a	-7.93	-31.20	24.02	24.02
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Elaeocarpaceae	*Chaetocarpus*	*Chaetocarpus schomburgkianus*		n/a	n/a	n/a	-7.93	-31.30	24.13	24.13
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lecythidaceae	*Eschweilera*	*Eschweilera micrantha*		n/a	n/a	n/a	-7.93	-31.30	24.13	24.13
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lecythidaceae	*Eschweilera*	*Eschweilera sagotiana*		n/a	n/a	n/a	-7.93	-31.30	24.13	24.13
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Flacourtiaceae	*Laetia*	*Laetia procera*		n/a	n/a	n/a	-7.93	-31.30	24.13	24.13
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Parkia*	*Parkia nitida*		n/a	n/a	n/a	-7.93	-31.30	24.13	24.13
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Humiriaceae	*Vantanea*	*Vantanea parviflora*		n/a	n/a	n/a	-7.93	-31.30	24.13	24.13
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Bombacaceae	*Catostemma*	*Catostemma fragrans*		n/a	n/a	n/a	-7.93	-31.40	24.23	24.23
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lecythidaceae	*Lecythis*	*Lecythis idatimon*		n/a	n/a	n/a	-7.93	-31.40	24.23	24.23
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	*Micropholis*	*Micropholis guyanensis*		n/a	n/a	n/a	-7.93	-31.40	24.23	24.23
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Icacinaceae	*Dendrobangia*	*Dendrobangia boliviana*		n/a	n/a	n/a	-7.93	-31.50	24.34	24.34
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lecythidaceae	*Lecythis*	*Lecythis idatimon*		n/a	n/a	n/a	-7.93	-31.50	24.34	24.34
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Chrysobalanaceae	*Licania*	*Licania alba*		n/a	n/a	n/a	-7.93	-31.50	24.34	24.34
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Chrysobalanaceae	*Parinari*	*Parinari sp.*		n/a	n/a	n/a	-7.93	-31.50	24.34	24.34
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Parkia*	*Parkia nitida*		n/a	n/a	n/a	-7.93	-31.50	24.34	24.34
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Moraceae	*Brosimum*	*Brosimum acutifolium*		n/a	n/a	n/a	-7.93	-31.60	24.44	24.44
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Bignoniaceae	*Jacaranda*	*Jacaranda copaia*		n/a	n/a	n/a	-7.93	-31.60	24.44	24.44
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Chrysobalanaceae	*Licania*	*Licania alba*		n/a	n/a	n/a	-7.93	-31.60	24.44	24.44
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Simaroubaceae	*Simaba*	*Simaba cedron*		n/a	n/a	n/a	-7.93	-31.60	24.44	24.44
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Chrysobalanaceae	*Couepia*	*Couepia guianensis*		n/a	n/a	n/a	-7.93	-31.70	24.55	24.55
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Burseraceae	*Dacryodes*	*Dacryodes nitens*		n/a	n/a	n/a	-7.93	-31.70	24.55	24.55
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Burseraceae	*Protium*	*Protium sp.*		n/a	n/a	n/a	-7.93	-31.70	24.55	24.55
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Myristicaceae	*Virola*	*Virola michelii*		n/a	n/a	n/a	-7.93	-31.70	24.55	24.55
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Caesalpiniaceae	*Bocoa*	*Bocoa prouacensis*		n/a	n/a	n/a	-7.93	-31.80	24.65	24.65
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lecythidaceae	*Eschweilera*	*Eschweilera micrantha*		n/a	n/a	n/a	-7.93	-31.80	24.65	24.65
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Hugoniaceae	*Hebepetalum*	*Hebepetalum humiriifolia*		n/a	n/a	n/a	-7.93	-31.80	24.65	24.65
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Chrysobalanaceae	*Licania*	*Licania ovalifolia*		n/a	n/a	n/a	-7.93	-31.80	24.65	24.65
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Elaeocarpaceae	*Chaetocarpus*	*Chaetocarpus schomburgkianus*		n/a	n/a	n/a	-7.93	-31.90	24.76	24.76
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lauraceae	*Ocotea*	*Sextonia rubra*		n/a	n/a	n/a	-7.93	-31.90	24.76	24.76
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Lecythidaceae	*Gustavia*	*Gustavia hexapetala*		n/a	n/a	n/a	-7.93	-32.00	24.87	24.87
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Myristicaceae	*Iryanthera*	*Iryanthera hostmannii*		n/a	n/a	n/a	-7.93	-32.00	24.87	24.87
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lecythidaceae	*Lecythis*	*Lecythis idatimon*		n/a	n/a	n/a	-7.93	-32.00	24.87	24.87
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Chrysobalanaceae	*Licania*	*Licania membranacea*		n/a	n/a	n/a	-7.93	-32.00	24.87	24.87
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Chrysobalanaceae	*Licania*	*Licania membranacea*		n/a	n/a	n/a	-7.93	-32.00	24.87	24.87
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lecythidaceae	*Lecythis*	*Lecythis persistens*		n/a	n/a	n/a	-7.93	-32.10	24.97	24.97
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Chrysobalanaceae	*Licania*	*Licania alba*		n/a	n/a	n/a	-7.93	-32.10	24.97	24.97
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Chrysobalanaceae	*Licania*	*Licania glabriflora*		n/a	n/a	n/a	-7.93	-32.10	24.97	24.97
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lecythidaceae	*Eschweilera*	*Eschweilera sagotiana*		n/a	n/a	n/a	-7.93	-32.20	25.08	25.08
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Myristicaceae	*Iryanthera*	*Iryanthera sagotiana*		n/a	n/a	n/a	-7.93	-32.20	25.08	25.08
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Mimosaceae	*Inga*	*Inga alba*		n/a	n/a	n/a	-7.93	-32.40	25.29	25.29
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Myristicaceae	*Iryanthera*	*Iryanthera hostmannii*		n/a	n/a	n/a	-7.93	-32.40	25.29	25.29
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	*Micropholis*	*Micropholis guyanensis*		n/a	n/a	n/a	-7.93	-32.40	25.29	25.29
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Olacaceae	*Minquartia*	*Minquartia guianensis*		n/a	n/a	n/a	-7.93	-32.40	25.29	25.29
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Caesalpiniaceae	*Vouacapoua*	*Vouacapoua americana*		n/a	n/a	n/a	-7.93	-32.40	25.29	25.29
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Chrysobalanaceae	*Licania*	*Licania sp. 2*		n/a	n/a	n/a	-7.93	-32.50	25.40	25.40
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Clusiaceae	*Tovomita*	*Tovomita sp.*		n/a	n/a	n/a	-7.93	-32.50	25.40	25.40
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Annonaceae	*Xylopia*	*Xylopia sp.*		n/a	n/a	n/a	-7.93	-32.50	25.40	25.40
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Myristicaceae	*Iryanthera*	*Iryanthera sagotiana*		n/a	n/a	n/a	-7.93	-32.60	25.50	25.50
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Humiriaceae	*Humiriastrum*	*Humiriastrum subcrenatum*		n/a	n/a	n/a	-7.93	-32.70	25.61	25.61
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Tiliaceae	*Lueheopsis*	*Lueheopsis rugosa*		n/a	n/a	n/a	-7.93	-32.70	25.61	25.61
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rubiaceae	*Posoqueria*	*Posoqueria latifolia*		n/a	n/a	n/a	-7.93	-32.70	25.61	25.61
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rubiaceae	*Posoqueria*	*Posoqueria latifolia*		n/a	n/a	n/a	-7.93	-32.70	25.61	25.61
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	*Pouteria*	*Pouteria guianensis*		n/a	n/a	n/a	-7.93	-32.80	25.71	25.71
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Icacinaceae	*Poraqueiba*	*Poraqueiba guianensis*		n/a	n/a	n/a	-7.93	-32.90	25.82	25.82
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Boraginaceae	*Cordia*	*Cordia sp.*		n/a	n/a	n/a	-7.93	-33.10	26.03	26.03
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lecythidaceae	*Eschweilera*	*Eschweilera parviflora*		n/a	n/a	n/a	-7.93	-33.20	26.14	26.14
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Myristicaceae	*Iryanthera*	*Iryanthera sagotiana*		n/a	n/a	n/a	-7.93	-33.20	26.14	26.14
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Chrysobalanaceae	*Licania*	*Licania membranacea*		n/a	n/a	n/a	-7.93	-33.40	26.35	26.35
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Elaeocarpaceae	*Chaetocarpus*	*Chaetocarpus schomburgkianus*		n/a	n/a	n/a	-7.93	-33.80	26.77	26.77
Diefendorf et al. 2010	Bonal et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Humiriaceae	*Humiriastrum*	*Humiriastrum subcrenatum*		n/a	n/a	n/a	-7.93	-34.80	27.84	27.84
Diefendorf et al. 2010	Brooks et al. 1997	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus banksiana*		n/a	n/a	n/a	-7.81	-24.80	17.42	17.42
Diefendorf et al. 2010	Brooks et al. 1997	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Picea*	*Picea mariana*		n/a	n/a	n/a	-7.81	-26.50	19.20	19.20
Diefendorf et al. 2010	Brooks et al. 1997	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Picea*	*Picea mariana*		n/a	n/a	n/a	-7.81	-26.50	19.20	19.20
Diefendorf et al. 2010	Brooks et al. 1997	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus banksiana*		n/a	n/a	n/a	-7.81	-26.60	19.30	19.30
Diefendorf et al. 2010	Brooks et al. 1997	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Salicaceae	*Populus*	*Populus tremuloides*		n/a	n/a	n/a	-7.81	-27.20	19.93	19.93
Diefendorf et al. 2010	Brooks et al. 1997	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Betulaceae	*Alnus*	*Alnus alnobetula subsp. crispa*		n/a	n/a	n/a	-7.81	-28.30	21.09	21.09
Diefendorf et al. 2010	Brooks et al. 1997	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Betulaceae	*Alnus*	*Alnus alnobetula subsp. crispa*		n/a	n/a	n/a	-7.81	-28.40	21.19	21.19
Diefendorf et al. 2010	Brooks et al. 1997	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Salicaceae	*Populus*	*Populus tremuloides*		n/a	n/a	n/a	-7.81	-28.65	21.45	21.45
Diefendorf et al. 2010	Brooks et al. 1997	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Salicaceae	*Salix*	*Salix sp.*		n/a	n/a	n/a	-7.81	-29.80	22.67	22.67
Diefendorf et al. 2010	Buchmann et al. 1997	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Picea*	*Picea engelmannii*		n/a	n/a	n/a	-7.80	-24.40	17.02	17.02
Diefendorf et al. 2010	Buchmann et al. 1997	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Abies*	*Abies lasiocarpa*		n/a	n/a	n/a	-7.80	-24.50	17.12	17.12
Diefendorf et al. 2010	Buchmann et al. 1997	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Salicaceae	*Populus*	*Populus tremuloides*		n/a	n/a	n/a	-7.80	-25.58	18.25	18.25
Diefendorf et al. 2010	Buchmann et al. 1997	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	*Acer*	*Acer grandidentatum*		n/a	n/a	n/a	-7.80	-26.03	18.72	18.72
Diefendorf et al. 2010	Buchmann et al. 1997	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus contorta*		n/a	n/a	n/a	-7.80	-26.77	19.49	19.49
Diefendorf et al. 2010	Buchmann et al. 1997	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	*Acer*	*Acer negundo*		n/a	n/a	n/a	-7.80	-27.35	20.10	20.10
Diefendorf et al. 2010	Chevillat et al. 2005	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Picea*	*Picea abies*		n/a	n/a	n/a	-7.98	-25.65	18.14	18.14
Diefendorf et al. 2010	Chevillat et al. 2005	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus sylvestris*		n/a	n/a	n/a	-7.98	-25.88	18.38	18.38
Diefendorf et al. 2010	Chevillat et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Betulaceae	*Carpinus*	*Carpinus betulus*		n/a	n/a	n/a	-7.98	-26.67	19.20	19.20
Diefendorf et al. 2010	Chevillat et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Quercus*	*Quercus petraea*		n/a	n/a	n/a	-7.98	-26.77	19.31	19.31
Diefendorf et al. 2010	Chevillat et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rosaceae	*Prunus*	*Prunus avium*		n/a	n/a	n/a	-7.98	-26.79	19.33	19.33
Diefendorf et al. 2010	Chevillat et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Malvaceae	*Tilia*	*Tilia platyphyllos*		n/a	n/a	n/a	-7.98	-26.89	19.43	19.43
Diefendorf et al. 2010	Chevillat et al. 2005	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Abies*	*Abies alba*		n/a	n/a	n/a	-7.98	-27.66	20.24	20.24
Diefendorf et al. 2010	Chevillat et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	*Acer*	*Acer campestre*		n/a	n/a	n/a	-7.98	-27.76	20.34	20.34
Diefendorf et al. 2010	Chevillat et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Fagus*	*Fagus sylvatica*		n/a	n/a	n/a	-7.98	-27.88	20.47	20.47
Diefendorf et al. 2010	Chevillat et al. 2005	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Larix*	*Larix decidua*		n/a	n/a	n/a	-7.98	-28.19	20.80	20.80
Diefendorf et al. 2010	Collister et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Magnoliaceae	*Magnolia*	*Magnolia delavayi*		n/a	n/a	n/a	-7.75	-28.70	21.57	21.57
Diefendorf et al. 2010	Collister et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Quercus*	*Quercus × hispanica*		n/a	n/a	n/a	-7.75	-28.80	21.67	21.67
Diefendorf et al. 2010	Collister et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Fagus*	*Fagus sylvatica*		n/a	n/a	n/a	-7.75	-29.80	22.73	22.73
Diefendorf et al. 2010	Collister et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	*Acer*	*Acer campestre*		n/a	n/a	n/a	-7.75	-30.40	23.36	23.36
Diefendorf et al. 2010	Collister et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Quercus*	*Quercus robur*		n/a	n/a	n/a	-7.75	-30.50	23.47	23.47
Diefendorf et al. 2010	De Lillis et al. 2004	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm		*Conifers*	*Conifers*		n/a	n/a	n/a	-7.82	-25.38	18.02	18.02
Diefendorf et al. 2010	De Lillis et al. 2004	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm		*Evergreen*	*Evergreen broadleaf*		n/a	n/a	n/a	-7.82	-26.65	19.35	19.35
Diefendorf et al. 2010	De Lillis et al. 2004	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm		*Deciduous*	*Deciduous broadleaf*		n/a	n/a	n/a	-7.82	-28.47	21.26	21.26
Diefendorf et al. 2010	Delucia & Schlesinger 199	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus monophylla*		n/a	n/a	n/a	-7.62	-21.36	14.04	14.04
Diefendorf et al. 2010	Delucia & Schlesinger 199	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus ponderosa*		n/a	n/a	n/a	-7.62	-21.55	14.24	14.24
Diefendorf et al. 2010	Delucia & Schlesinger 199	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus jeffreyi*		n/a	n/a	n/a	-7.62	-22.22	14.93	14.93
Diefendorf et al. 2010	Delucia & Schlesinger 199	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus ponderosa*		n/a	n/a	n/a	-7.62	-22.23	14.94	14.94
Diefendorf et al. 2010	Delucia & Schlesinger 199	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus ponderosa*		n/a	n/a	n/a	-7.62	-22.26	14.97	14.97
Diefendorf et al. 2010	Delucia & Schlesinger 199	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	*Juniperus*	*Juniperus osteosperma*		n/a	n/a	n/a	-7.62	-22.52	15.24	15.24
Diefendorf et al. 2010	Delucia & Schlesinger 199	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus jeffreyi*		n/a	n/a	n/a	-7.62	-22.97	15.71	15.71
Diefendorf et al. 2010	Delucia & Schlesinger 199	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	*Juniperus*	*Juniperus osteosperma*		n/a	n/a	n/a	-7.62	-23.05	15.79	15.79
Diefendorf et al. 2010	Delucia & Schlesinger 199	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Artemisia*	*Artemisia tridentata*		n/a	n/a	n/a	-7.62	-24.05	16.83	16.83
Diefendorf et al. 2010	Delucia & Schlesinger 199	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Rosaceae	*Purshia*	*Purshia tridentata*		n/a	n/a	n/a	-7.62	-24.15	16.94	16.94
Diefendorf et al. 2010	Delucia & Schlesinger 199	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Artemisia*	*Artemisia tridentata*		n/a	n/a	n/a	-7.62	-24.81	17.63	17.63
Diefendorf et al. 2010	Delucia & Schlesinger 199	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Artemisia*	*Artemisia tridentata*	genus misspelled	n/a	n/a	n/a	-7.62	-25.40	18.24	18.24
Diefendorf et al. 2010	Delucia & Schlesinger 199	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rosaceae	*Amelanchier*	*Amelanchier alnifolia*		n/a	n/a	n/a	-7.62	-25.74	18.60	18.60
Diefendorf et al. 2010	Delucia & Schlesinger 199	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Artemisia*	*Artemisia tridentata*		n/a	n/a	n/a	-7.62	-25.90	18.77	18.77
Diefendorf et al. 2010	Delucia & Schlesinger 199	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Ericaceae	*Arctostaphylos*	*Arctostaphylos patula*		n/a	n/a	n/a	-7.62	-26.50	19.39	19.39
Diefendorf et al. 2010	Dodd et al. 1998	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Salicaceae	*Populus*	*Populus deltoides subsp. monilifera*		n/a	n/a	n/a	-7.88	-28.46	21.18	21.18
Diefendorf et al. 2010	hovan & Ehleringer 1991	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Ericameria*	*Ericameria nauseosa var. nauseosa*		n/a	n/a	353.79	-8.00	not given	18.54	18.54
Diefendorf et al. 2010	hovan & Ehleringer 1991	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	*Acer*	*Acer negundo*		n/a	n/a	353.79	-8.00	not given	19.15	19.15
Diefendorf et al. 2010	hovan & Ehleringer 1991	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Salicaceae	*Salix*	*Salix exigua*		n/a	n/a	n/a	-8.00	not given	19.73	19.73
Diefendorf et al. 2010	hovan & Ehleringer 1991	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Ericameria*	*Ericameria nauseosa var. nauseosa*		n/a	n/a	353.79	-8.00	not given	20.01	20.01
Diefendorf et al. 2010	Dungait et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rosaceae	*Malus*	*Malus sylvestris*		n/a	n/a	n/a	-7.99	-27.30	19.85	19.85
Diefendorf et al. 2010	Dungait et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	*Acer*	*Acer campestre*		n/a	n/a	n/a	-7.99	-27.50	20.06	20.06
Diefendorf et al. 2010	Dungait et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Salicaceae	*Salix*	*Salix x fragilis*		n/a	n/a	n/a	-7.99	-28.70	21.32	21.32
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus massoniana*		n/a	n/a	n/a	-7.50	-26.40	19.41	19.41
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Myrtaceae	*Eucalyptus*	*Eucalyptus robusta*		n/a	n/a	n/a	-7.50	-27.40	20.46	20.46
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	*Platycladus*	*Platycladus orientalis*		n/a	n/a	n/a	-7.50	-27.77	20.85	20.85
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Burseraceae	*Canarium*	*Canarium album*		n/a	n/a	n/a	-7.50	-28.31	21.42	21.42
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Proteaceae	*Helicia*	*Helicia reticulata*		n/a	n/a	n/a	-7.50	-28.40	21.51	21.51
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lauraceae	*Lindera*	*Lindera communis*		n/a	n/a	n/a	-7.50	-29.10	22.25	22.25
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Euphorbiaceae	*Croton*	*Croton tiglium*		n/a	n/a	n/a	-7.50	-29.50	22.67	22.67
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	*Sarcosperma*	*Sarcosperma laurinum*		n/a	n/a	n/a	-7.50	-29.58	22.75	22.75
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Melastomataceae	*Memecylon*	*Memecylon ligustrifolium*		n/a	n/a	n/a	-7.50	-29.64	22.82	22.82
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Malvaceae	*Sterculia*	*Sterculia lanceolata*		n/a	n/a	n/a	-7.50	-29.74	22.92	22.92
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Curculionoidea	*Castanopsis*	*Castanopsis chinensis*		n/a	n/a	n/a	-7.50	-29.80	22.98	22.98
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Myrtaceae	*Syzgium*	*Syzygium rehderianum*		n/a	n/a	n/a	-7.50	-29.95	23.14	23.14
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Clusiaceae	*Garcinia*	*Garcinia oblongifolia*		n/a	n/a	n/a	-7.50	-30.02	23.22	23.22
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rosaceae	*Pygeum*	*Prunus arborea var. montana*		n/a	n/a	n/a	-7.50	-30.23	23.44	23.44
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	*Archidendron*	*Archidendron clypearia*		n/a	n/a	n/a	-7.50	-30.33	23.54	23.54
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Phyllanthaceae	*Aporosa*	*Aporosa yunnanensis*		n/a	n/a	n/a	-7.50	-30.82	24.06	24.06
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Magnoliaceae	*Magnolia*	*Magnolia odora*		n/a	n/a	n/a	-7.50	-31.18	24.44	24.44

Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Euphorbiaceae	Triadica	Triadica cochinchinensis		n/a	n/a	n/a	-7.50	-31.30	24.57	24.57
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lauraceae	Lindera	Lindera chunii		n/a	n/a	n/a	-7.50	-31.42	24.70	24.70
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Theaceae	Schima	Schima superba		n/a	n/a	n/a	-7.50	-31.55	24.83	24.83
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Araliaceae	Schefflera	Schefflera heptaphylla		n/a	n/a	n/a	-7.50	-31.95	25.26	25.26
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lauraceae	Machilus	Machilus velutina		n/a	n/a	n/a	-7.50	-32.24	25.56	25.56
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lauraceae	Cryptocarya	Cryptocarya chinensis		n/a	n/a	n/a	-7.50	-33.62	27.03	27.03
Diefendorf et al. 2010	Ehleringer et al. 1987	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lauraceae	Cryptocarya	Cryptocarya concinna		n/a	n/a	n/a	-7.50	-34.86	28.35	28.35
Diefendorf et al. 2010	Ehleringer et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	Hymenoclea	Ambrosia monogyra		n/a	n/a	n/a	-8.00	not given	18.50	18.50
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus halepensis		n/a	n/a	n/a	-8.06	-24.04	16.37	16.37
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus pinea		n/a	n/a	n/a	-8.06	-25.22	17.60	17.60
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus pinaster		n/a	n/a	n/a	-8.06	-25.29	17.68	17.68
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Taxaceae	Taxus	Taxus baccata		n/a	n/a	n/a	-8.06	-25.37	17.76	17.76
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus pinea		n/a	n/a	n/a	-8.06	-25.56	17.96	17.96
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus pinea		n/a	n/a	n/a	-8.06	-25.66	18.06	18.06
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Quercus	Quercus coccifera		n/a	n/a	n/a	-8.06	-25.86	18.27	18.27
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Oleaceae	Fraxinus	Fraxinus angustifolia		n/a	n/a	n/a	-8.06	-25.89	18.30	18.30
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Aquifoliaceae	Ilex	Ilex aquifolium		n/a	n/a	n/a	-8.06	-26.22	18.65	18.65
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Quercus	Quercus pyrenaica		n/a	n/a	n/a	-8.06	-26.38	18.82	18.82
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Quercus	Quercus suber		n/a	n/a	n/a	-8.06	-26.45	18.89	18.89
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus pinaster		n/a	n/a	n/a	-8.06	-26.61	19.06	19.06
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Quercus	Quercus rotundifolia		n/a	n/a	n/a	-8.06	-26.63	19.08	19.08
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	Acer	Acer monspessulanum		n/a	n/a	n/a	-8.06	-26.68	19.13	19.13
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	Acer	Acer monspessulanum		n/a	n/a	n/a	-8.06	-26.72	19.17	19.17
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Quercus	Quercus rotundifolia		n/a	n/a	n/a	-8.06	-26.79	19.25	19.25
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Quercus	Quercus pyrenaica		n/a	n/a	n/a	-8.06	-26.97	19.43	19.43
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Quercus	Quercus pyrenaica		n/a	n/a	n/a	-8.06	-27.12	19.59	19.59
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Quercus	Quercus suber		n/a	n/a	n/a	-8.06	-27.22	19.70	19.70
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Quercus	Quercus rotundifolia		n/a	n/a	n/a	-8.06	-27.40	19.88	19.88
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus sylvestris		n/a	n/a	n/a	-8.06	-27.45	19.94	19.94
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Quercus	Quercus pyrenaica		n/a	n/a	n/a	-8.06	-27.47	19.96	19.96
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rosaceae	Pyrus	Pyrus bourgaeana		n/a	n/a	n/a	-8.06	-27.58	20.07	20.07
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Quercus	Quercus rotundifolia		n/a	n/a	n/a	-8.06	-27.62	20.12	20.12
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rosaceae	Pyrus	Pyrus bourgaeana		n/a	n/a	n/a	-8.06	-27.72	20.22	20.22
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rosaceae	Prunus	Prunus spinosa		n/a	n/a	n/a	-8.06	-27.74	20.24	20.24
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Quercus	Quercus rotundifolia		n/a	n/a	n/a	-8.06	-27.81	20.31	20.31
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rosaceae	Crataegus	Crataegus monogyna		n/a	n/a	n/a	-8.06	-28.14	20.66	20.66
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Betulaceae	Betula	Betula pubescens		n/a	n/a	n/a	-8.06	-28.86	21.42	21.42
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rosaceae	Crataegus	Crataegus monogyna		n/a	n/a	n/a	-8.06	-28.94	21.50	21.50
Diefendorf et al. 2010	Escudero et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rhamnaceae	Frangula	Frangula alnus		n/a	n/a	n/a	-8.06	-29.04	21.61	21.61
Diefendorf et al. 2010	Franco et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	Pterodon	Pterodon emarginatus		n/a	n/a	n/a	-7.88	not given	18.45	18.45
Diefendorf et al. 2010	Franco et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Ochnaceae	Ouratea	Ouratea hexasperma		n/a	n/a	n/a	-7.88	not given	19.02	19.02
Diefendorf et al. 2010	Franco et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Vochysiaceae	Qualea	Qualea grandiflora		n/a	n/a	n/a	-7.88	not given	19.29	19.29
Diefendorf et al. 2010	Franco et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Araliaceae	Schefflera	Schefflera macrocarpa		n/a	n/a	n/a	-7.88	not given	19.46	19.46
Diefendorf et al. 2010	Franco et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	Dalbergia	Dalbergia miscolobium		n/a	n/a	n/a	-7.88	not given	20.39	20.39
Diefendorf et al. 2010	Franco et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	Sclerolobium	Sclerolobium paniculatum		n/a	n/a	n/a	-7.88	not given	21.08	21.08
Diefendorf et al. 2010	Franco et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Melastomataceae	Miconia	Miconia ferruginata		n/a	n/a	n/a	-7.88	not given	21.10	21.10
Diefendorf et al. 2010	Franco et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Proteaceae	Roupala	Roupala montana		n/a	n/a	n/a	-7.88	not given	21.90	21.90
Diefendorf et al. 2010	Franco et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Vochysiaceae	Vochysia	Vochysia elliptica		n/a	n/a	n/a	-7.88	not given	22.03	22.03
Diefendorf et al. 2010	Garten & Taylor 1992	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus sp.		n/a	n/a	n/a	-7.54	-26.96	19.96	19.96
Diefendorf et al. 2010	Garten & Taylor 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	Acer	Acer rubrum		n/a	n/a	n/a	-7.54	-28.80	21.89	21.89
Diefendorf et al. 2010	Garten & Taylor 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Quercus	Quercus sp.		n/a	n/a	n/a	-7.54	-28.80	21.89	21.89
Diefendorf et al. 2010	Garten & Taylor 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Magnoliaceae	Liriodendron	Liriodendron tulipifera		n/a	n/a	n/a	-7.54	-29.60	22.73	22.73
Diefendorf et al. 2010	Garten & Taylor 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Cornaceae	Nyssa	Nyssa sylvatica		n/a	n/a	n/a	-7.54	-30.12	23.28	23.28
Diefendorf et al. 2010	Gerdol et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Ericaceae	Vaccinium	Vaccinium vitis-idaea		n/a	n/a	n/a	-7.91	-28.53	21.23	21.23
Diefendorf et al. 2010	Gerdol et al. 2000	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Ericaceae	Vaccinium	Vaccinium myrtillus		n/a	n/a	n/a	-7.91	-30.12	22.90	22.90
Diefendorf et al. 2010	He et al. 2008	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Dipterocarpaceae	Parashorea	Parashorea chinensis		n/a	n/a	n/a	-8.13	-27.75	20.18	20.18
Diefendorf et al. 2010	Hemming et al. 2005	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus halepensis		2001	2001	371.69	unk	unk	15.05	15.05
Diefendorf et al. 2010	Hemming et al. 2005	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea abies		2001	2001	371.69	unk	unk	19.15	19.15
Diefendorf et al. 2010	Hemming et al. 2005	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus sylvestris		2001	2001	371.69	unk	unk	19.47	19.47
Diefendorf et al. 2010	Hemming et al. 2005	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Abies	Abies alba		2001	2001	371.69	unk	unk	19.69	19.69
Diefendorf et al. 2010	Hemming et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Quercus	Quercus ilex + Quercus suber		n/a	n/a	n/a	unk	unk	19.75	19.75
Diefendorf et al. 2010	Hemming et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Fagus	Fagus sylvatica		2001	2001	371.69	unk	unk	20.58	20.58
Diefendorf et al. 2010	Hemming et al. 2005	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea abies		2001	2001	371.69	unk	unk	20.69	20.69
Diefendorf et al. 2010	Hemming et al. 2005	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus sylvestris		2001	2001	371.69	unk	unk	20.98	20.98
Diefendorf et al. 2010	Hemming et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Fagus	Fagus sylvatica		2001	2001	371.69	unk	unk	21.11	21.11
Diefendorf et al. 2010	Hemming et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Quercus	Quercus robur + Fraxinus spp.		n/a	n/a	n/a	unk	unk	21.75	21.75
Diefendorf et al. 2010	Hemming et al. 2005	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea sitchensis		2001	2001	371.69	unk	unk	21.78	21.78
Diefendorf et al. 2010	Hemming et al. 2005	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus sylvestris		2001	2001	371.69	unk	unk	22.04	22.04
Diefendorf et al. 2010	Hemming et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Fagus	Fagus sylvatica		2001	2001	371.69	unk	unk	23.38	23.38
Diefendorf et al. 2010	Hemming et al. 2005	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea sitchensis		2001	2001	371.69	unk	unk	23.95	23.95
Diefendorf et al. 2010	Hemming et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Fagus	Fagus sylvatica		2001	2001	371.69	unk	unk	24.05	24.05
Diefendorf et al. 2010	Holtum & Winter 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Anacardiaceae	Anacardium	Anacardium excelsum		n/a	n/a	n/a	-7.82	-26.03	18.70	18.70
Diefendorf et al. 2010	Holtum & Winter 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Urticaceae	Cecropia	Cecropia longipes		n/a	n/a	n/a	-7.82	-26.60	19.29	19.29
Diefendorf et al. 2010	Holtum & Winter 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Moraceae	Ficus	Ficus maxima		n/a	n/a	n/a	-7.82	-26.70	19.40	19.40
Diefendorf et al. 2010	Holtum & Winter 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Bombacaceae	Pseudobomba	Pseudobombax septenatum		n/a	n/a	n/a	-7.82	-26.70	19.40	19.40
Diefendorf et al. 2010	Holtum & Winter 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Arecaceae	Acrocomia	Acrocomia aculeata		n/a	n/a	n/a	-7.82	-27.00	19.71	19.71
Diefendorf et al. 2010	Holtum & Winter 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Moraceae	Ficus	Ficus insipida		n/a	n/a	n/a	-7.82	-27.05	19.76	19.76
Diefendorf et al. 2010	Holtum & Winter 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Anacardiaceae	Spondias	Spondias mombin		n/a	n/a	n/a	-7.82	-27.40	20.13	20.13
Diefendorf et al. 2010	Holtum & Winter 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Malvaceae	Luehea	Luehea seemannii		n/a	n/a	n/a	-7.82	-27.60	20.34	20.34
Diefendorf et al. 2010	Holtum & Winter 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Urticaceae	Cecropia	Cecropia peltata		n/a	n/a	n/a	-7.82	-27.70	20.45	20.45
Diefendorf et al. 2010	Holtum & Winter 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Moraceae	Castilla	Castilla elastica		n/a	n/a	n/a	-7.82	-28.10	20.87	20.87
Diefendorf et al. 2010	Holtum & Winter 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	Enterolobium	Enterolobium cyclocarpum		n/a	n/a	n/a	-7.82	-28.30	21.08	21.08
Diefendorf et al. 2010	Holtum & Winter 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Araliaceae	Didymopanax	Schefflera morototoni		n/a	n/a	n/a	-7.82	-28.50	21.29	21.29
Diefendorf et al. 2010	Holtum & Winter 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	Albizia	Albizia adinocephala		n/a	n/a	n/a	-7.82	-28.60	21.39	21.39
Diefendorf et al. 2010	Holtum & Winter 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rubiaceae	Pittoniotis	Pittoniotis trichantha	not sure	n/a	n/a	n/a	-7.82	-28.70	21.50	21.50
Diefendorf et al. 2010	Holtum & Winter 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	Chrysophyllun	Chrysophyllum cainito		n/a	n/a	n/a	-7.82	-29.70	22.55	22.55
Diefendorf et al. 2010	Hultine & Marshall 2000	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pseudotsuga	Pseudotsuga menziesii		n/a	n/a	n/a	-7.88	-25.70	18.29	18.29
Diefendorf et al. 2010	Hultine & Marshall 2000	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea engelmannii		n/a	n/a	n/a	-7.88	-26.10	18.71	18.71
Diefendorf et al. 2010	Hultine & Marshall 2000	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Abies	Abies lasiocarpa		n/a	n/a	n/a	-7.88	-27.30	19.97	19.97
Diefendorf et al. 2010	Hultine & Marshall 2000	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus contorta		n/a	n/a	n/a	-7.88	-27.40	20.07	20.07
Diefendorf et al. 2010	Inagaki et al. 2004	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus densiflora		n/a	n/a	n/a	-8.06	-27.90	20.41	20.41
Diefendorf et al. 2010	Inagaki et al. 2004	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm		mixed	mixed species (Castaneacrenata, Cornus controversa, Prunus jam		n/a	n/a	n/a	-8.06	-29.00	21.57	21.57
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea abies		n/a	n/a	n/a	-7.90	-24.48	17.00	17.00
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea obovata		n/a	n/a	n/a	-7.90	-24.92	17.45	17.45
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea obovata		n/a	n/a	n/a	-7.90	-25.39	17.95	17.95
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea mariana		n/a	n/a	n/a	-7.90	-25.53	18.09	18.09
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus albicaulis		n/a	n/a	n/a	-7.90	-25.63	18.20	18.20
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pseudotsuga	Pseudotsuga menziesii		n/a	n/a	n/a	-7.90	-25.64	18.21	18.21
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea abies		n/a	n/a	n/a	-7.90	-25.73	18.30	18.30
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea abies		n/a	n/a	n/a	-7.90	-25.81	18.38	18.38
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea abies		n/a	n/a	n/a	-7.90	-26.14	18.73	18.73
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix decidua		n/a	n/a	n/a	-7.90	-26.19	18.78	18.78
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix occidentalis		n/a	n/a	n/a	-7.90	-26.36	18.95	18.95
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix decidua		n/a	n/a	n/a	-7.90	-26.44	19.04	19.04
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea abies		n/a	n/a	n/a	-7.90	-26.47	19.07	19.07
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea mariana		n/a	n/a	n/a	-7.90	-26.70	19.32	19.32
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix lyallii		n/a	n/a	n/a	-7.90	-26.85	19.47	19.47
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pseudotsuga	Pseudotsuga menziesii		n/a	n/a	n/a	-7.90	-26.85	19.47	19.47
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus sylvestris		n/a	n/a	n/a	-7.90	-26.86	19.48	19.48
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea mariana		n/a	n/a	n/a	-7.90	-27.01	19.64	19.64
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix occidentalis		n/a	n/a	n/a	-7.90	-27.06	19.69	19.69
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix decidua		n/a	n/a	n/a	-7.90	-27.07	19.70	19.70
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea abies		n/a	n/a	n/a	-7.90	-27.11	19.75	19.75
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea mariana		n/a	n/a	n/a	-7.90	-27.29	19.93	19.93
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix occidentalis		n/a	n/a	n/a	-7.90	-27.33	19.98	19.98
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix decidua		n/a	n/a	n/a	-7.90	-27.48	20.13	20.13
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea abies		n/a	n/a	n/a	-7.90	-27.52	20.18	20.18
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix gmelinii		n/a	n/a	n/a	-7.90	-27.55	20.21	20.21
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea sp.		n/a	n/a	n/a	-7.90	-27.56	20.22	20.22
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea sitchensis		n/a	n/a	n/a	-7.90	-27.62	20.28	20.28
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix sibirica		n/a	n/a	n/a	-7.90	-27.81	20.48	20.48
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix olgensis		n/a	n/a	n/a	-7.90	-27.82	20.49	20.49
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix decidua		n/a	n/a	n/a	-7.90	-27.84	20.51	20.51
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix decidua		n/a	n/a	n/a	-7.90	-28.00	20.68	20.68
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix laricina		n/a	n/a	n/a	-7.90	-28.02	20.70	20.70
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix decidua		n/a	n/a	n/a	-7.90	-28.15	20.84	20.84
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus contorta		n/a	n/a	n/a	-7.90	-28.18	20.87	20.87
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix laricina		n/a	n/a	n/a	-7.90	-28.47	21.17	21.17
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix laricina		n/a	n/a	n/a	-7.90	-28.58	21.29	21.29
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix decidua		n/a	n/a	n/a	-7.90	-28.61	21.32	21.32
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix laricina		n/a	n/a	n/a	-7.90	-28.77	21.49	21.49
Diefendorf et al. 2010	Kloeppel et al. 1998	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix sibirica		n/a	n/a	n/a	-7.90	-29.47	22.22	22.22
Diefendorf et al. 2010	Kohorn et al. 1994	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Simmondsiaceae	Simmondsia	Simmondsia chinensis		n/a	n/a	n/a	-7.82	-24.80	17.41	17.41
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rutaceae	Zanthoxylum	Zanthoxylum setulosum		n/a	n/a	n/a	-7.89	-27.70	20.37	20.37
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Celastraceae	Semialarium	Semialarium mexicanum		n/a	n/a	n/a	-7.89	-28.20	20.90	20.90
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	Sideroxylon	Sideroxylon capiri		n/a	n/a	n/a	-7.89	-28.50	21.21	21.21
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Boraginaceae	Cordia	Cordia alliodora		n/a	n/a	n/a	-7.89	-28.60	21.32	21.32
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	Manilkara	Manilkara chicle		n/a	n/a	n/a	-7.89	-28.60	21.32	21.32
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	Hymenaea	Hymenaea courbaril		n/a	n/a	n/a	-7.89	-29.00	21.74	21.74
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Capparaceae	Capparis	Capparis indica		n/a	n/a	n/a	-7.89	-29.30	22.06	22.06
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rubiaceae	Genipa	Genipa americana		n/a	n/a	n/a	-7.89	-29.50	22.27	22.27
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Meliaceae	Guarea	Guarea glabra		n/a	n/a	n/a	-7.89	-29.50	22.27	22.27
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Malpighiaceae	Bunchosia	Bunchosia biocellata		n/a	n/a	n/a	-7.89	-30.00	22.79	22.79
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Flacourtiaceae	Casearia	Casearia sylvestris		n/a	n/a	n/a	-7.89	-30.00	22.79	22.79
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Anacardiaceae	Astronium	Astronium graveolens		n/a	n/a	n/a	-7.89	-30.30	23.11	23.11
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	Cupania	Cupania guatemalensis		n/a	n/a	n/a	-7.89	-30.30	23.11	23.11
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Ebenaceae	Diospyros	Diospyros acapulcensis subsp. nicaraguensis		n/a	n/a	n/a	-7.89	-30.40	23.22	23.22
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Moraceae	Brosimum	Brosimum alicastrum		n/a	n/a	n/a	-7.89	-30.50	23.32	23.32
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rubiaceae	Guettarda	Guettarda macrosperma		n/a	n/a	n/a	-7.89	-30.50	23.32	23.32
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rubiaceae	Calycophyllun	Calycophyllum candidissimum		n/a	n/a	n/a	-7.89	-30.70	23.53	23.53
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lauraceae	Ocotea	Ocotea veraguensis		n/a	n/a	n/a	-7.89	-30.70	23.53	23.53
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	Ateleia	Ateleia herbert-smithii		n/a	n/a	n/a	-7.89	-31.10	23.96	23.96
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	Chrysophyllun	Chrysophyllum brenesii		n/a	n/a	n/a	-7.89	-31.10	23.96	23.96
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Piperaceae	Piper	Piper amalago		n/a	n/a	n/a	-7.89	-31.20	24.06	24.06
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Bignoniaceae	Tabebuia	Tabebuia ochracea		n/a	n/a	n/a	-7.89	-31.40	24.27	24.27
Diefendorf et al. 2010	Leffler & Enquist 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Moraceae	Trophis	Trophis racemosa		n/a	n/a	n/a	-7.89	-31.50	24.38	24.38
Diefendorf et al. 2010	Li et al. 2005	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus massoniana		n/a	n/a	n/a	-8.07	-29.15	21.71	21.71
Diefendorf et al. 2010	Li et al. 2005	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	Cunninghamia	Cunninghamia lanceolata		n/a	n/a	n/a	-8.07	-29.16	21.72	21.72
Diefendorf et al. 2010	Li et al. 2005	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Theaceae	Schima	Schima superba		n/a	n/a	n/a	-8.07	-29.65	22.24	22.24
Diefendorf et al. 2010	Li et al. 2005	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus elliottii		n/a	n/a	n/a	-8.07	-29.90	22.50	22.50
Diefendorf et al. 2010	Lockheart et al. 1997	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Fagus	Fagus sylvatica		n/a	n/a	n/a	-7.82	-26.40	19.08	19.08
Diefendorf et al. 2010	Lockheart et al. 1997	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Quercus	Quercus robur		n/a	n/a	n/a	-7.82	-28.70	21.50	21.50
Diefendorf et al. 2010	Marshall & Zhang 1994	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	Thuja	Thuja plicata		1991	1991	358.24	-8.00	unk	16.67	16.67
Diefendorf et al. 2010	Marshall & Zhang 1994	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus albicaulis		1991	1991	358.24	-8.00	unk	18.04	18.04
Diefendorf et al. 2010	Marshall & Zhang 1994	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Picea	Picea engelmannii		1991	1991	358.24	-8.00	unk	18.15	18.15
Diefendorf et al. 2010	Marshall & Zhang 1994	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pseudotsuga	Pseudotsuga menziesii		1991	1991	358.24	-8.00	unk	18.42	18.42
Diefendorf et al. 2010	Marshall & Zhang 1994	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Abies	Abies lasiocarpa		1991	1991	358.24	-8.00	unk	18.52	18.52
Diefendorf et al. 2010	Marshall & Zhang 1994	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus monticola		1991	1991	358.24	-8.00	unk	18.58	18.58
Diefendorf et al. 2010	Marshall & Zhang 1994	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus ponderosa		1991	1991	358.24	-8.00	unk	18.65	18.65
Diefendorf et al. 2010	Marshall & Zhang 1994	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Pinus	Pinus contorta		1991	1991	358.24	-8.00	unk	18.94	18.94
Diefendorf et al. 2010	Marshall & Zhang 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Salicaceae	Populus	Populus tremuloides		1991	1991	358.24	-8.00	unk	19.27	19.27
Diefendorf et al. 2010	Marshall & Zhang 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Salicaceae	Salix	Salix scouleriana		1991	1991	358.24	-8.00	unk	19.41	19.41
Diefendorf et al. 2010	Marshall & Zhang 1994	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Tsuga	Tsuga heterophylla		1991	1991	358.24	-8.00	unk	19.44	19.44
Diefendorf et al. 2010	Marshall & Zhang 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Salicaceae	Populus	Populus trichocarpa		1991	1991	358.24	-8.00	unk	19.45	19.45
Diefendorf et al. 2010	Marshall & Zhang 1994	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Abies	Abies grandis		1991	1991	358.24	-8.00	unk	19.75	19.75
Diefendorf et al. 2010	Marshall & Zhang 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	Acer	Acer glabrum		1991	1991	358.24	-8.00	unk	19.95	19.95
Diefendorf et al. 2010	Marshall & Zhang 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rosaceae	Sorbus	Sorbus sp.		1991	1991	358.24	-8.00	unk	20.30	20.30
Diefendorf et al. 2010	Marshall & Zhang 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rosaceae	Amelancher	Amelanchier alnifolia		1991	1991	358.24	-8.00	unk	20.60	20.60
Diefendorf et al. 2010	Marshall & Zhang 1994	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Betulaceae	Betula	Betula sp.		1991	1991	358.24	-8.00	unk	20.78	20.78
Diefendorf et al. 2010	Marshall & Zhang 1994	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	Larix	Larix occidentalis		1991	1991	358.24	-8.00	unk	20.95	20.95
Diefendorf et al. 2010	Arthur & Moorhead 1996	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	Taxodium	Taxodium distichum		n/a	n/a	n/a	-7.88	-28.20	20.91	20.91
Diefendorf et al. 2010	Arthur & Moorhead 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Aquifoliaceae	Ilex	Ilex opaca		n/a	n/a	n/a	-7.88	-29.70	22.49	22.49
Diefendorf et al. 2010	Arthur & Moorhead 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Aquifoliaceae	Ilex	Ilex opaca		n/a	n/a	n/a	-7.88	-30.00	22.80	22.80
Diefendorf et al. 2010	Arthur & Moorhead 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	Acer	Acer rubrum		n/a	n/a	n/a	-7.88	-30.20	23.02	23.02
Diefendorf et al. 2010	Arthur & Moorhead 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Quercus	Quercus laurifolia		n/a	n/a	n/a	-7.88	-30.20	23.02	23.02
Diefendorf et al. 2010	Arthur & Moorhead 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	Quercus	Quercus nigra		n/a	n/a	n/a	-7.88	-30.20	23.02	23.02
Diefendorf et al. 2010	Arthur & Moorhead 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Betulaceae	Carpinus	Carpinus caroliniana		n/a	n/a	n/a	-7.88	-30.50	23.33	23.33
Diefendorf et al. 2010	Arthur & Moorhead 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Altingiaceae	Liquidambar	Liquidambar styraciflua		n/a	n/a	n/a	-7.88	-31.00	23.86	23.86
Diefendorf et al. 2010	Arthur & Moorhead 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Betulaceae	Carpinus	Carpinus caroliniana		n/a	n/a	n/a	-7.88	-31.10	23.97	23.97
Diefendorf et al. 2010	Arthur & Moorhead 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	Acer	Acer rubrum		n/a	n/a	n/a	-7.88	-31.30	24.18	24.18
Diefendorf et al. 2010	Arthur & Moorhead 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapindaceae	Acer	Acer rubrum		n/a	n/a	n/a	-7.88	-31.30	24.18	24.18
Diefendorf et al. 2010	Arthur & Moorhead 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Cornaceae	Nyssa	Nyssa sylvatica		n/a	n/a	n/a	-7.88	-32.80	25.77	25.77
Diefendorf et al. 2010	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Capparaceae	Forchhammer	Forchhammeria pallida		n/a	n/a	n/a	-7.85	-24.10	16.65	16.70
Diefendorf et al. 2010	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Verbenaceae	Citharexylum	Citharexylum sp.		n/a	n/a	n/a	-7.85	-24.80	17.38	17.43
Diefendorf et al. 2010	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Theophrastaceae	Jacquinia	Bonellia macrocarpa subsp. pungens		n/a	n/a	n/a	-7.85	-25.70	18.32	18.37
Diefendorf et al. 2010	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	Caesalpinia	Caesalpinia sclerocarpa		n/a	n/a	n/a	-7.85	-26.50	19.16	19.21
Diefendorf et al. 2010	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Moraceae	Chlorophora	Maclura tinctoria		n/a	n/a	n/a	-7.85	-26.70	19.37	19.42
Diefendorf et al. 2010	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Burseraceae	Bursera	Bursera instabilis		n/a	n/a	n/a	-7.85	-26.80	19.47	19.52
Diefendorf et al. 2010	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Polygonaceae	Coccoloba	Coccoloba liebmannii		n/a	n/a	n/a	-7.85	-26.80	19.47	19.52
Diefendorf et al. 2010	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	Acacia	Acacia angustissima		n/a	n/a	n/a	-7.85	-26.90	19.58	19.63
Diefendorf et al. 2010	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	Caesalpinia	Caesalpinia coriaria		n/a	n/a	n/a	-7.85	-26.90	19.58	19.63
Diefendorf et al. 2010	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Erthroxylaceae	Erythroxylum	Erythroxylum havanense		n/a	n/a	n/a	-7.85	-27.00	19.68	19.73
Diefendorf et al. 2010	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fabaceae	Apoplanesia	Apoplanesia paniculata		n/a	n/a	n/a	-7.85	-27.30	20.00	20.05

Diefendorf et al. 2010	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Rubiaceae	*Hamelia*	*Hamelia rostrata*		n/a	n/a	n/a	-7.85	-27.40	20.10	20.15
Diefendorf et al. 2010	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Capparaceae	*Capparis*	*Capparis indica*		n/a	n/a	n/a	-7.85	-27.50	20.21	20.26
Diefendorf et al. 2010	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Rhamnaceae	*Colubrina*	*Colubrina triflora*		n/a	n/a	n/a	-7.85	-27.60	20.31	20.36
Diefendorf et al. 2010	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Apocynaceae	*Thevetia*	*Cascabela ovata*	genus changed	n/a	n/a	n/a	-7.85	-27.60	20.31	20.36
Diefendorf et al. 2010	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Flacourtiaceae	*Casearia*	*Casearia corymbosa*		n/a	n/a	n/a	-7.85	-28.10	20.84	20.89
Diefendorf et al. 2010	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Euphorbiaceae	*Croton*	*Croton pseudoniveus*		n/a	n/a	n/a	-7.85	-28.10	20.84	20.89
Diefendorf et al. 2010	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Boraginaceae	*Cordia*	*Cordia alliodora*		n/a	n/a	n/a	-7.85	-28.50	21.26	21.31
Diefendorf et al. 2010	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Solanaceae	*Capsicum*	*Capsicum annuum*		n/a	n/a	n/a	-7.85	-28.70	21.47	21.47
Diefendorf et al. 2010	Mooney et al. 1989	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Apocynaceae	*Stemmadenia*	*Stemmadenia sp*		n/a	n/a	n/a	-7.85	-28.80	21.57	21.62
Diefendorf et al. 2010	Nagy & Proctor 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Dipterocarpaceae	*Shorea*	*Shorea pinanga*	name unresolved	n/a	n/a	n/a	-7.85	-29.54	22.35	22.35
Diefendorf et al. 2010	Nagy & Proctor 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Dipterocarpaceae	*Shorea*	*Shorea scabrida*	name unresolved	n/a	n/a	n/a	-7.85	-29.89	22.72	22.72
Diefendorf et al. 2010	Nagy & Proctor 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Myrtaceae	*Tristaniopsis*	*Tristaniopsis obovata*		n/a	n/a	n/a	-7.85	-30.19	23.04	23.04
Diefendorf et al. 2010	Nagy & Proctor 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Dipterocarpaceae	*Cotylelobium*	*Cotylelobium melanoxylon*		n/a	n/a	n/a	-7.85	-30.25	23.10	23.10
Diefendorf et al. 2010	Nagy & Proctor 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Anacardiaceae	*Swintonia*	*Swintonia glauca*	unresolved	n/a	n/a	n/a	-7.85	-30.28	23.13	23.13
Diefendorf et al. 2010	Nagy & Proctor 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Dipterocarpaceae	*Dipterocarpus*	*Dipterocarpus cf. eurynchus*		n/a	n/a	n/a	-7.85	-30.39	23.25	23.25
Diefendorf et al. 2010	Nagy & Proctor 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Anacardiaceae	*Swintonia*	*Swintonia glauca*	unresolved	n/a	n/a	n/a	-7.85	-30.41	23.27	23.27
Diefendorf et al. 2010	Nagy & Proctor 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Dipterocarpaceae	*Cotylelobium*	*Cotylelobium melanoxylon*		n/a	n/a	n/a	-7.85	-30.84	23.72	23.72
Diefendorf et al. 2010	Nagy & Proctor 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Dipterocarpaceae	*Vatica*	*Vatica brunigii*	name unresolved	n/a	n/a	n/a	-7.85	-31.03	23.92	23.92
Diefendorf et al. 2010	Nagy & Proctor 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Myrtaceae	*Eugenia*	*Syzygium ecostulatum*		n/a	n/a	n/a	-7.85	-31.06	23.95	23.95
Diefendorf et al. 2010	Nagy & Proctor 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Dipterocarpaceae	*Shorea*	*Shorea amplexicaulis*	name unresolved	n/a	n/a	n/a	-7.85	-31.19	24.09	24.09
Diefendorf et al. 2010	Nagy & Proctor 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Clusiaceae	*Cratoxylum*	*Cratoxylum glaucum*		n/a	n/a	n/a	-7.85	-31.29	24.20	24.20
Diefendorf et al. 2010	Nagy & Proctor 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Dipterocarpaceae	*Cotylelobium*	*Cotylelobium burckii*		n/a	n/a	n/a	-7.85	-31.33	24.24	24.24
Diefendorf et al. 2010	Nagy & Proctor 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Dipterocarpaceae	*Shorea*	*Shorea leprosula*	name unresolved	n/a	n/a	n/a	-7.85	-31.60	24.52	24.52
Diefendorf et al. 2010	Nagy & Proctor 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Dipterocarpaceae	*Shorea*	*Shorea cf. rugosa*		n/a	n/a	n/a	-7.85	-32.34	25.31	25.31
Diefendorf et al. 2010	Sandquist & Cordell 2007	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rhamnaceae	*Colubrina*	*Colubrina oppositifolia*		n/a	n/a	n/a	-8.05	-25.14	17.53	17.53
Diefendorf et al. 2010	Sandquist & Cordell 2007	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rubiaceae	*Psydrax*	*Psydrax odorata*		n/a	n/a	n/a	-8.05	-25.83	18.25	18.25
Diefendorf et al. 2010	Sandquist & Cordell 2007	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Santalaceae	*Santalum*	*Santalum paniculatum*		n/a	n/a	n/a	-8.05	-26.07	18.50	18.50
Diefendorf et al. 2010	Sandquist & Cordell 2007	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Sapotaceae	*Planchonella*	*Planchonella sandwicensis*		n/a	n/a	n/a	-8.05	-27.10	19.58	19.58
Diefendorf et al. 2010	Sandquist & Cordell 2007	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Ebenaceae	*Diospyros*	*Diospyros sandwicensis*		n/a	n/a	n/a	-8.05	-27.14	19.62	19.62
Diefendorf et al. 2010	Sandquist & Cordell 2007	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Myrtaceae	*Metrosideros*	*Metrosideros polymorpha*		n/a	n/a	n/a	-8.05	-28.10	20.63	20.63
Diefendorf et al. 2010	Uemura et al. 2006	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Betulaceae	*Betula*	*Betula grossa*		n/a	n/a	n/a	-8.05	-27.23	19.72	19.72
Diefendorf et al. 2010	Uemura et al. 2006	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Fagus*	*Fagus japonica*		n/a	n/a	n/a	-8.05	-27.29	19.78	19.78
Diefendorf et al. 2010	Uemura et al. 2006	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Fagus*	*Fagus crenata*		n/a	n/a	n/a	-8.05	-27.78	20.29	20.29
Diefendorf et al. 2010	Valentini et al. 1994	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus sylvestris*		n/a	n/a	n/a	-7.79	-25.90	18.59	18.59
Diefendorf et al. 2010	Valentini et al. 1994	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Picea*	*Picea abies*		n/a	n/a	n/a	-7.79	-27.10	19.85	19.85
Diefendorf et al. 2010	Valentini et al. 1994	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Picea*	*Picea abies*		n/a	n/a	n/a	-7.79	-27.80	20.58	20.58
Diefendorf et al. 2010	Valentini et al. 1994	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Larix*	*Larix decidua*		n/a	n/a	n/a	-7.79	-28.30	21.11	21.11
Diefendorf et al. 2010	Valentini et al. 1994	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus cembra*		n/a	n/a	n/a	-7.79	-28.30	21.11	21.11
Diefendorf et al. 2010	Valentini et al. 1994	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Larix*	*Larix decidua*		n/a	n/a	n/a	-7.79	-29.00	21.84	21.84
Diefendorf et al. 2010	Valentini et al. 1992	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	*Juniperus*	*Juniperus oxycedrus*		n/a	n/a	n/a	-7.71	-22.90	15.55	15.55
Diefendorf et al. 2010	Valentini et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Anacardiaceae	*Pistacia*	*Pistacia lentiscus*		n/a	n/a	n/a	-7.71	-26.24	19.03	19.03
Diefendorf et al. 2010	Valentini et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Quercus*	*Quercus ilex*		n/a	n/a	n/a	-7.71	-26.44	19.24	19.24
Diefendorf et al. 2010	Valentini et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Oleaceae	*Phyllyrea*	*Phillyrea angustifolia*		n/a	n/a	n/a	-7.71	-26.49	19.29	19.29
Diefendorf et al. 2010	Valentini et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Quercus*	*Quercus pubescens*		n/a	n/a	n/a	-7.71	-27.19	20.02	20.02
Diefendorf et al. 2010	Valentini et al. 1992	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Quercus*	*Quercus cerris*		n/a	n/a	n/a	-7.71	-27.50	20.35	20.35
Diefendorf et al. 2010	Van de Water et al. 2002	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus edulis*		n/a	n/a	n/a	-7.85	-21.00	13.43	13.43
Diefendorf et al. 2010	Van de Water et al. 2002	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus edulis*		n/a	n/a	n/a	-7.85	-21.80	14.26	14.26
Diefendorf et al. 2010	Van de Water et al. 2002	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	*Juniperus*	*Juniperus coahuilensis*		n/a	n/a	n/a	-7.85	-22.80	15.30	15.30
Diefendorf et al. 2010	Van de Water et al. 2002	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	*Juniperus*	*Juniperus osteosperma*		n/a	n/a	n/a	-7.85	-23.30	15.82	15.82
Diefendorf et al. 2010	Van de Water et al. 2002	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	*Juniperus*	*Juniperus monosperma*		n/a	n/a	n/a	-7.85	-23.90	16.44	16.44
Diefendorf et al. 2010	Van de Water et al. 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rosaceae	*Cercocarpus*	*Cercocarpus montanus*		n/a	n/a	n/a	-7.85	-24.90	17.49	17.49
Diefendorf et al. 2010	Van de Water et al. 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rosaceae	*Amelanchier*	*Amelanchier utahensis*		n/a	n/a	n/a	-7.85	-25.00	17.59	17.59
Diefendorf et al. 2010	Van de Water et al. 2002	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	*Juniperus*	*Juniperus deppeana*		n/a	n/a	n/a	-7.85	-25.00	17.59	17.59
Diefendorf et al. 2010	Van de Water et al. 2002	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Rosaceae	*Cowania*	*Cowania mexicana*		n/a	n/a	n/a	-7.85	-25.10	17.69	17.69
Diefendorf et al. 2010	Van de Water et al. 2002	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rosaceae	*Cercocarpus*	*Cercocarpus montanus*		n/a	n/a	n/a	-7.85	-25.30	17.90	17.90
Diefendorf et al. 2010	Williams & Ehleringer 1996	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus edulis*		n/a	n/a	n/a	-8.00	-23.28	15.64	15.64
Diefendorf et al. 2010	Williams & Ehleringer 1996	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	*Juniperus*	*Juniperus osteosperma*		n/a	n/a	n/a	-8.00	-23.50	15.87	15.87
Diefendorf et al. 2010	Williams & Ehleringer 1996	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus edulis*		n/a	n/a	n/a	-8.00	-23.54	15.91	15.91
Diefendorf et al. 2010	Williams & Ehleringer 1996	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus edulis*		n/a	n/a	n/a	-8.00	-23.70	16.08	16.08
Diefendorf et al. 2010	Williams & Ehleringer 1996	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	*Juniperus*	*Juniperus osteosperma*		n/a	n/a	n/a	-8.00	-23.75	16.13	16.13
Diefendorf et al. 2010	Williams & Ehleringer 1996	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus edulis*		n/a	n/a	n/a	-8.00	-23.84	16.23	16.23
Diefendorf et al. 2010	Williams & Ehleringer 1996	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	*Juniperus*	*Juniperus osteosperma*		n/a	n/a	n/a	-8.00	-23.85	16.24	16.24
Diefendorf et al. 2010	Williams & Ehleringer 1996	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	*Juniperus*	*Juniperus osteosperma*		n/a	n/a	n/a	-8.00	-24.06	16.46	16.46
Diefendorf et al. 2010	Williams & Ehleringer 1996	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus edulis*		n/a	n/a	n/a	-8.00	-24.28	16.69	16.69
Diefendorf et al. 2010	Williams & Ehleringer 1996	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	*Juniperus*	*Juniperus osteosperma*		n/a	n/a	n/a	-8.00	-25.20	17.64	17.64
Diefendorf et al. 2010	Williams & Ehleringer 1996	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	*Juniperus*	*Juniperus osteosperma*		n/a	n/a	n/a	-8.00	-25.24	17.69	17.69
Diefendorf et al. 2010	Williams & Ehleringer 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Quercus*	*Quercus gambelii*		n/a	n/a	n/a	-8.00	-26.88	19.40	19.40
Diefendorf et al. 2010	Williams & Ehleringer 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Quercus*	*Quercus gambelii*		n/a	n/a	n/a	-8.00	-26.92	19.44	19.44
Diefendorf et al. 2010	Williams & Ehleringer 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Quercus*	*Quercus gambelii*		n/a	n/a	n/a	-8.00	-26.96	19.49	19.49
Diefendorf et al. 2010	Williams & Ehleringer 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Quercus*	*Quercus gambelii*		n/a	n/a	n/a	-8.00	-27.20	19.74	19.74
Diefendorf et al. 2010	Williams & Ehleringer 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Quercus*	*Quercus gambelii*		n/a	n/a	n/a	-8.00	-27.26	19.80	19.80
Diefendorf et al. 2010	Williams & Ehleringer 1996	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Quercus*	*Quercus gambelii*		n/a	n/a	n/a	-8.00	-27.45	20.00	20.00
Diefendorf et al. 2010	Williams & Ehleringer 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Quercus*	*Quercus turbinella*		1994	1994	360.94	unk	unk	18.00	18.00
Diefendorf et al. 2010	Williams & Ehleringer 2000	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Quercus*	*Quercus gambelii*		1994	1994	360.94	unk	unk	18.20	18.20
Diefendorf et al. 2010	n/a	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Ericaceae	*Arbutus*	*Arbutus menziesii*		n/a	n/a	n/a	-7.93	-27.05	19.65	19.65
Diefendorf et al. 2010	n/a	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Lauraceae	*Umbellularia*	*Umbellularia californica*		n/a	n/a	n/a	-7.93	-27.15	19.76	19.76
Diefendorf et al. 2010	n/a	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Quercus*	*Quercus agrifolia*		n/a	n/a	n/a	-7.93	-27.46	20.08	20.08
Diefendorf et al. 2010	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Ericaceae	*Vaccinium*	*Vaccinium ovatum*		n/a	n/a	n/a	-7.93	-28.22	20.88	20.88
Diefendorf et al. 2010	n/a	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Betulaceae	*Corylus*	*Corylus cornuta subsp. californica*		n/a	n/a	n/a	-7.93	-29.84	22.58	22.58
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Gymnosperm	Herbaceous	C3	Woody Gymnosperm	Pinaceae	*Pinus*	*Pinus massoniana*		n/a	1986		-7.71	-26.40	19.20	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	fern	Herbaceous	C3	Herbaceous fern	Polypodiaceae	*Lemmaphyllur*	*Lemmaphyllum microphyllum*		n/a	1986	n/a	-7.71	-26.50	19.30	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Euphorbiaceae	*Mallotus*	*Mallotus apelta*		n/a	1986	n/a	-7.71	-26.74	19.55	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Piperaceae	*Peperomia*	*Peperomia pellucida*		n/a	1986	n/a	-7.71	-26.90	19.72	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Molluginaceae	*Mollugo*	*Mollugo pentaphylla*		n/a	1986	n/a	-7.71	-26.90	19.72	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Rosaceae	*Rhaphiolepis*	*Rhaphiolepis indica*		n/a	1986	n/a	-7.71	-27.14	19.97	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Zingiberaceae	*Costus*	*Costus tonkinensis*		n/a	1986	n/a	-7.71	-27.40	20.24	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Myrtaceae	*Eucalyptus*	*Eucalyptus robusta*		n/a	1986	n/a	-7.71	-27.40	20.24	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Araceae	*Alocasia*	*Alocasia acuminata*		n/a	1986	n/a	-7.71	-27.44	20.29	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Oplismenus*	*Oplismenus compositus*		n/a	1986	n/a	-7.71	-27.58	20.43	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Gymnosperm	Woody	C3	Woody Gymnosperm	Cupressaceae	*Platycladus*	*Platycladus orientalis*		n/a	1986	n/a	-7.71	-27.77	20.63	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	fern	Herbaceous	C3	Herbaceous fern	Gleicheniaceae	*Dicranopteris*	*Dicranopteris linearis*		n/a	1986	n/a	-7.71	-27.99	20.86	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Zingiberaceae	*Alpinia*	*Alpinia pumila*		n/a	1986	n/a	-7.71	-28.20	21.08	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Plantaginaceae	*Plantago*	*Plantago major*		n/a	1986	n/a	-7.71	-28.20	21.08	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Burseraceae	*Canarium*	*Canarium album*		n/a	1986	n/a	-7.71	-28.31	21.20	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	fern	Herbaceous	C3	Herbaceous fern	Lindsaeaceae	*Odontosoria*	*Odontosoria chusana*		n/a	1986	n/a	-7.71	-28.34	21.23	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Thysanolaena*	*Thysanolaena latifolia*		n/a	1986	n/a	-7.71	-28.35	21.24	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Proteaceae	*Helicia*	*Helicia reticulata*		n/a	1986	n/a	-7.71	-28.40	21.29	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Eriocaulaceae	*Eriocaulon*	*Eriocaulon sexangulare*		n/a	1986	n/a	-7.71	-28.63	21.54	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Rubiaceae	*Oldenlandia*	*Oldenlandia diffusa*		n/a	1986	n/a	-7.71	-28.64	21.55	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Isachne*	*Isachne globosa*		n/a	1986	n/a	-7.71	-28.66	21.57	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Euphorbiaceae	*Euphorbia*	*Euphorbia antiquorum*		n/a	1986	n/a	-7.71	-28.80	21.72	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Pentaphylacaceae	*Eurya*	*Eurya chinensis*		n/a	1986	n/a	-7.71	-29.03	21.96	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Acanthaceae	*Justicia*	*Justicia procumbens*		n/a	1986	n/a	-7.71	-29.09	22.02	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Lauraceae	*Lindera*	*Lindera communis*		n/a	1986	n/a	-7.71	-29.10	22.03	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	fern	Herbaceous	C3	Herbaceous fern	Adiantaceae	*Adiantum*	*Adiantum capillus-veneris*		n/a	1986	n/a	-7.71	-29.20	22.14	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Amaranthaceae	*Alternanthera*	*Alternanthera philoxeroides*		n/a	1986	n/a	-7.71	-29.30	22.24	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Lamiaceae	*Perilla*	*Perilla frutescens*		n/a	1986	n/a	-7.71	-29.35	22.29	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Myrtaceae	*Baeckea*	*Baeckea frutescens*		n/a	1986	n/a	-7.71	-29.36	22.30	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asphodelaceae	*Hemerocallis*	*Hemerocallis fulva*		n/a	1986	n/a	-7.71	-29.49	22.44	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Euphorbiaceae	*Croton*	*Croton tiglium*		n/a	1986	n/a	-7.71	-29.50	22.45	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Arecaceae	*Daemonorops*	*Daemonorops jenkinsiana*		n/a	1986	n/a	-7.71	-29.58	22.54	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Sarcospermatacea	*Sarcosperma*	*Sarcosperma laurinum*		n/a	1986	n/a	-7.71	-29.58	22.54	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Annonaceae	*Fissistigma*	*Fissistigma glaucescens*		n/a	1986	n/a	-7.71	-29.59	22.55	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Zingiberaceae	*Cheilocostus*	*Cheilocostus speciosus*		n/a	1986	n/a	-7.71	-29.60	22.56	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Melastomaceae	*Memecylon*	*Memecylon ligustrifolium*		n/a	1986	n/a	-7.71	-29.64	22.60	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Euphorbiaceae	*Alchornea*	*Alchornea trewioides*		n/a	1986	n/a	-7.71	-29.65	22.61	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asphodelaceae	*Dianella*	*Dianella ensifolia*		n/a	1986	n/a	-7.71	-29.70	22.66	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	fern	Herbaceous	C3	Herbaceous fern	Dicksoniaceae	*Cibotium*	*Cibotium barometz*		n/a	1986	n/a	-7.71	-29.71	22.67	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Sterculiaceae	*Sterculia*	*Sterculia lanceolata*		n/a	1986	n/a	-7.71	-29.74	22.71	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Polygonaceae	*Persicaria*	*Persicaria hydropiper*		n/a	1986	n/a	-7.71	-29.77	22.74	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Fagaceae	*Castanopsis*	*Castanopsis chinensis*		n/a	1986	n/a	-7.71	-29.80	22.77	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Loranthaceae	*Elytranthe*	*Elytranthe cochinchinensis (unresolved;)*		n/a	1986	n/a	-7.71	-29.80	22.77	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Orchidaceae	*Arundina*	*Arundina graminifolia*		n/a	1986	n/a	-7.71	-29.86	22.83	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	fern	Herbaceous	C3	Herbaceous fern	Thelypteridaceae	*Cyclosorus*	*Cyclosorus multilineatus*		n/a	1986	n/a	-7.71	-29.88	22.85	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Leersia*	*Leersia hexandra*		n/a	1986	n/a	-7.71	-29.90	22.87	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Myrtaceae	*Syzygium*	*Syzygium rehderianum*		n/a	1986	n/a	-7.71	-29.95	22.93	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	woody	c3	Woody Angiosperm	Clusiaceae	*Garcinia*	*Garcinia oblongifolia*		n/a	1986	n/a	-7.71	-30.02	23.00	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Oxalidaceae	*Oxalis*	*Oxalis corniculata*		n/a	1986	n/a	-7.71	-30.15	23.14	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Rosaceae	*Pygeum*	*Pygeum topengii*		n/a	1986	n/a	-7.71	-30.23	23.22	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Scrophulariaceae	*Adenosma*	*Adenosma caeruleum*		n/a	1986	n/a	-7.71	-30.32	23.32	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Mimosaceae	*Archidendron*	*Archidendron clypearia*		n/a	1986	n/a	-7.71	-30.33	23.33	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Myrtaceae	*Rhodomyrtus*	*Rhodomyrtus tomentosa*		n/a	1986	n/a	-7.71	-30.38	23.38	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	fern	Herbaceous	C3	Herbaceous fern	Cyatheaceae	*Cyathea*	*Cyathea podophylla*		n/a	1986	n/a	-7.71	-30.57	23.58	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Euphorbiaceae	*Phyllanthus*	*Phyllanthus urinaria*		n/a	1986	n/a	-7.71	-30.61	23.62	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Polygalaceae	*Salomonia*	*Salomonia cantoniensis*		n/a	1986	n/a	-7.71	-30.65	23.67	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	fern		C3	Herbaceous fern	Angiopteridaceae	*Angiopteris*	*Angiopteris fokiensis*		n/a	1986	n/a	-7.71	-30.74	23.76	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Oxalidaceae	*Oxalis*	*Oxalis debilis var. corymbosa*		n/a	1986	n/a	-7.71	-30.76	23.78	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Loranthaceae	*Helixanthera*	*Helixanthera parasitica*		n/a	1986	n/a	-7.71	-30.80	23.82	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Lobeliaceae	*Lobelia*	*Lobelia chinensis*		n/a	1986	n/a	-7.71	-30.80	23.82	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Loranthaceae	*Taxillus*	*Taxillus chinensis*		n/a	1986	n/a	-7.71	-30.80	23.82	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Euphorbiaceae	*Aporosa*	*Aporosa yunnanensis*		n/a	1986	n/a	-7.71	-30.82	23.84	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Ageratum*	*Ageratum conyzoides*		n/a	1986	n/a	-7.71	-30.85	23.88	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Primulaceae	*Lysimachia*	*Lysimachia fortunei*		n/a	1986	n/a	-7.71	-30.92	23.95	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Fern	Herbaceous	C3	Herbaceous fern	Osmundaceae	*Osmunda*	*Osmunda vachellii*		n/a	1986	n/a	-7.71	-31.04	24.08	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Magnoliaceae	*Magnolia*	*Magnolia odora*		n/a	1986	n/a	-7.71	-31.18	24.23	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Pandanaceae	*Pandanus*	*Pandanus austrosinensis*		n/a	1986	n/a	-7.71	-31.28	24.33	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Rutaceae	*Evodia*	*Evodia lepta (unresolved)*		n/a	1986	n/a	-7.71	-31.29	24.34	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Woody Angiosperm	Euphorbiaceae	*Triadica*	*Triadica cochinchinensis*		n/a	1986	n/a	-7.71	-31.30	24.35	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Myrsinaceae	*Ardisia*	*Ardisia quinquegona*		n/a	1986	n/a	-7.71	-31.35	24.41	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Lauraceae	*Lindera*	*Lindera chunii*		n/a	1986	n/a	-7.71	-31.42	24.48	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Theaceae	*Schima*	*Schima superba*		n/a	1986	n/a	-7.71	-31.55	24.62	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asparagaceae	*Ophiopogon*	*Ophiopogon japonicus*		n/a	1986	n/a	-7.71	-31.70	24.78	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Senecio*	*Senecio scandens*		n/a	1986	n/a	-7.71	-31.92	25.01	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Araliaceae	*Schefflera*	*Schefflera octophylla*		n/a	1986	n/a	-7.71	-31.95	25.04	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Zingiberaceae	*Zingiber*	*Zingiber zerumbet*		n/a	1986	n/a	-7.71	-32.00	25.09	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Lauraceae	*Machilus*	*Machilus velutina*		n/a	1986	n/a	-7.71	-32.34	25.45	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	fern		C3	Herbaceous fern	Adiantaceae	*Adiantum*	*Adiantum flabellulatum*		n/a	1986	n/a	-7.71	-32.76	25.90	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Indocalamus*	*Indocalamus longiauritus*		n/a	1986	n/a	-7.71	-32.90	26.05	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Begoniaceae	*Begonia*	*Begonia fimbristipula*		n/a	1986	n/a	-7.71	-33.10	26.26	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Zingiberaceae	*Alpinia*	*Alpinia chinensis*		n/a	1986	n/a	-7.71	-33.20	26.37	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	fern	herbaceous	C3	Herbaceous fern	Tectariaceae	*Hemigramma*	*Hemigramma decurrens*		n/a	1986	n/a	-7.71	-33.40	26.58	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Lauraceae	*Cryptocarya*	*Cryptocarya chinensis*		n/a	1986	n/a	-7.71	-33.62	26.81	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Rubiaceae	*Psychotria*	*Psychotria asiatica*		n/a	1986	n/a	-7.71	-33.82	27.02	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Euphorbiaceae	*Croton*	*Croton lachnocarpus*		n/a	1986	n/a	-7.71	-34.40	27.64	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Asteraceae	*Senecio*	*Senecio hoi*		n/a	1986	n/a	-7.71	-34.50	27.75	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Zingiberaceae	*Alpinia*	*Alpinia zerumbet*		n/a	1986	n/a	-7.71	-34.60	27.85	
Ehleringer et al. 1987	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Lauraceae	*Cryptocarya*	*Cryptocarya concinna*		n/a	1986	n/a	-7.71	-34.86	28.13	
Körner et al. 1988	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Carex*	*Carex curvula*		n/a	n/a	n/a	n/a	-25.49	n/a	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Sphagnaceae	*Sphagnum*	*Sphagnum trinitense*		1990	1990	351.40	-7.78	-21.14	13.65	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Sphagnaceae	*Sphagnum*	*Sphagnum trinitense*		1990	1990	351.40	-7.78	-21.87	14.41	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Sphagnaceae	*Sphagnum*	*Sphagnum trinitense*		1990	1990	351.40	-7.78	-22.10	14.64	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Sphagnaceae	*Sphagnum*	*Sphagnum trinitense*		1990	1990	351.40	-7.78	-23.43	16.03	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Sphagnaceae	*Sphagnum*	*Sphagnum trinitense*		1990	1990	351.40	-7.78	-23.94	16.56	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Trichophorum*	*Trichophorum cespitosum*		1991	1991	353.08	-7.78	-26.18	18.89	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Sphagnaceae	*Sphagnum*	*Sphagnum compactum*		1991	1991	353.08	-7.78	-26.59	19.32	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Dicranaceae	*Leucobryum*	*Leucobryum glaucum*		1991	1991	353.08	-7.78	-26.71	19.45	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Sphagnaceae	*Sphagnum*	*Sphagnum papillosum*		1991	1991	353.08	-7.78	-26.74	19.48	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Schoenus*	*Schoenus nigricans*		1991	1991	353.08	-7.78	-26.75	19.49	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Molinia*	*Molinia caerulea*		1991	1991	353.08	-7.78	-26.87	19.62	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Sphagnaceae	*Sphagnum*	*Sphagnum tenellum*		1991	1991	353.08	-7.78	-27.24	20.00	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Poaceae	*Molinia*	*Molinia caerulea*		1991	1991	353.08	-7.78	-27.27	20.04	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Sphagnaceae	*Sphagnum*	*Sphagnum compactum*		1991	1991	353.08	-7.78	-27.69	20.48	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Ericaceae	*Erica*	*Erica tetralix*		1991	1991	353.08	-7.78	-27.81	20.60	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Sphagnaceae	*Sphagnum*	*Sphagnum subnitens*		1991	1991	353.08	-7.78	-27.84	20.63	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Sphagnaceae	*Sphagnum*	*Sphagnum magellanicum*		1991	1991	353.08	-7.78	-27.88	20.68	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Ericaceae	*Erica*	*Erica tetralix*		1991	1991	353.08	-7.78	-28.09	20.90	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Sphagnaceae	*Sphagnum*	*Sphagnum capillifolium subsp. Rubellum*		1991	1991	353.08	-7.78	-28.59	21.42	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Sphagnaceae	*Sphagnum*	*Sphagnum tenellum*		1991	1991	353.08	-7.78	-29.45	22.33	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Sphagnaceae	*Sphagnum*	*Sphagnum squarrosum*		1991	1991	353.08	-7.78	-29.50	22.38	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Sphagnaceae	*Sphagnum*	*Sphagnum flexuosum*		1991	1991	353.08	-7.78	-30.81	23.76	
Proctor et al. 1992	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Sphagnaceae	*Sphagnum*	*Sphagnum compactum*		1991	1991	353.08	-7.78	-34.70	27.89	
Royles et al. 2014	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Dicranaceae	*Chorisodontiu*	*Chorisodontium aciphyllum*		2008	2008	382.31	-8.00	-25.19	17.63	
Royles et al. 2014	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Pottiaceae	*Tortula*	*Syntrichia ruralis*		2008	2008	382.31	-8.00	-27.15	19.68	
Royles et al. 2014	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Marchantiaceae	*Marchantia*	*Marchantia polymorpha*		2008	2008	382.31	-8.00	-27.28	19.82	
Royles et al. 2014	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Conocephalaceae	*Conocephalur*	*Conocephalum conicum*		2008	2008	382.31	-8.00	-31.50	24.26	
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Pottiaceae	*Leptodontium*	*Leptodontium flexifolium*		1977	1977	331.00	-7.49	-21.26	14.07	
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Andreaeaceae	*Andreaea*	*Andreaea rupestris*		1977	1977	331.00	-7.49	-22.34	15.19	
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Jungermanniacea	*Saccobasis*	*Saccobasis polita*		1977	1977	331.00	-7.49	-22.69	15.20	

Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Mniaceae	*Mnium*	*Rhizomnium pseudopunctatum*		1977	1977	331.00	-7.49	-22.40	15.25
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Andreaeaceae	*Andreaea*	*Andreaea rupestris*		1977	1977	331.00	-7.49	-22.54	15.40
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Grimmiaceae	*Racomitrium*	*Racomitrium lanuginosum*		1977	1977	331.00	-7.49	-23.03	15.91
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Grimmiaceae	*Racomitrium*	*Racomitrium lanuginosum*		1977	1977	331.00	-7.49	-23.23	16.11
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Grimmiaceae	*Racomitrium*	*Racomitrium lanuginosum*		1977	1977	331.00	-7.49	-23.57	16.47
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Pottiaceae	*Tortula*	*Syntrichia bartramii*		1977	1977	331.00	-7.49	-23.59	16.49
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Amblystegiaceae	*Campylium*	*Campylium stellatum*		1977	1977	331.00	-7.49	-23.61	16.51
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Grimmiaceae	*Racomitrium*	*Bucklandiella heterosticha*		1977	1977	331.00	-7.49	-24.02	16.94
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Gymnomitriaceae	*Gymnomitrion*	*Gymnomitrion obtusum*		1977	1977	331.00	-7.49	-24.04	16.96
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Pottiaceae	*Barbula*	*Barbula australasiae*		1977	1977	331.00	-7.49	-24.44	17.37
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Grimmiaceae	*Racomitrium*	*Racomitrium heterostichum subsp. ramulosum*		1977	1977	331.00	-7.49	-24.88	17.83
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Amblystegiaceae	*Calliergon*	*Calliergon cordifolium*		1977	1977	331.00	-7.49	-25.47	18.45
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Pottiaceae	*Leptodontium*	*Leptodontium viticulosoides*		1977	1977	331.00	-7.49	-25.67	18.66
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Aulacomniaceae	*Aulacomnium*	*Aulacomnium palustre*		1977	1977	331.00	-7.49	-26.00	19.00
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Pottiaceae	*Desmatodon*	*Tortula atrovirens*		1977	1977	331.00	-7.49	-26.02	19.03
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Pottiaceae	*Tortula*	*Syntrichia ruralis*		1977	1977	331.00	-7.49	-26.40	19.42
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Dicranaceae	*Dicranella*	*Dicranella cerviculata*	genus misspelled	1977	1977	331.00	-7.49	-26.43	19.45
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Amblystegiaceae	*Cratoneurum*	*Cratoneuron commutatum*	genus misspelled	1977	1977	331.00	-7.49	-26.45	19.48
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Dicranaceae	*Paraleucobryu*	*Paraleucobryum longifolium*		1977	1977	331.00	-7.49	-26.83	19.87
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Geocalycaceae	*Harpanthus*	*Harpanthus flotovianus*		1977	1977	331.00	-7.49	-23.10	20.53
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Neckeraceae	*Homalia*	*Homalia trichomanoides*		1977	1977	331.00	-7.49	-27.46	20.53
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Grimmiaceae	*Racomitrium*	*Niphotrichum canescens*		1977	1977	331.00	-7.49	-27.62	20.70
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Pottiaceae	*Pleurochaete*	*Pleurochaete luteola*		1977	1977	331.00	-7.49	-27.68	20.76
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Sphagnaceae	*Sphagnum*	*Sphagnum palustre*		1977	1977	331.00	-7.49	-28.38	20.89
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Bryaceae	*Bryum*	*Bryum pseudotriquetrum*		1977	1977	331.00	-7.49	-28.62	21.75
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Aulacomniaceae	*Aulacomnium*	*Aulacomnium palustre*		1977	1977	331.00	-7.49	-28.73	21.87
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Amblystegiaceae	*Acrocladium*	*Acrocladium cuspidatum*		1977	1977	331.00	-7.49	-28.78	21.92
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Pottiaceae	*Hymenostyliu*	*Hymenostylium recurvirostrum*		1977	1977	331.00	-7.49	-29.03	22.18
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Climaciaceae	*Climacium*	*Climacium dendroides*		1977	1977	331.00	-7.49	-29.82	22.33
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Pottiaceae	*Weissia*	*Weissia controversa*		1977	1977	331.00	-7.49	-29.56	22.74
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Pottiaceae	*Drepanocladu*	*Limprichtia cossonii*		1977	1977	331.00	-7.49	-30.30	23.52
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Calliergonaceae	*Scorpidium*	*Scorpidium scorpioides*		1977	1977	331.00	-7.49	-34.77	28.26
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Fontinalaceae	*Fontinalis*	*Fontinalis antipyretica*		1977	1977	331.00	-7.49	-36.04	29.62
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Scapaniaceae	*Scapania*	*Scapania undulata*		1977	1977	331.00	-7.49	-37.26	30.92
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Fontinalaceae	*Fontinalis*	*Fontinalis antipyretica*		1977	1977	331.00	-7.49	-37.28	30.94
Rundel et al. 1979	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Fontinalaceae	*Fontinalis*	*Fontinalis antipyretica*		1977	1977	331.00	-7.49	-37.49	31.17
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	100.00	n/a	n/a	13.85
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	100.00	n/a	n/a	16.15
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	150.00	n/a	n/a	16.30
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	200.00	n/a	n/a	18.09
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	150.00	n/a	n/a	18.72
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	250.00	n/a	n/a	19.44
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	200.00	n/a	n/a	20.49
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	300.00	n/a	n/a	20.50
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	350.00	n/a	n/a	21.35
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	370.00	n/a	n/a	21.65
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	250.00	n/a	n/a	21.77
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	450.00	n/a	n/a	22.65
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	455.00	n/a	n/a	22.70
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	300.00	n/a	n/a	22.75
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	500.00	n/a	n/a	23.15
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	350.00	n/a	n/a	23.51
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	550.00	n/a	n/a	23.58
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	370.00	n/a	n/a	23.78
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	600.00	n/a	n/a	23.95
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	400.00	n/a	n/a	24.13
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	650.00	n/a	n/a	24.28
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	700.00	n/a	n/a	24.57
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	450.00	n/a	n/a	24.64
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	733.00	n/a	n/a	24.75
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	750.00	n/a	n/a	24.83
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	497.00	n/a	n/a	25.04
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	800.00	n/a	n/a	25.06
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	500.00	n/a	n/a	25.07
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	850.00	n/a	n/a	25.27
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	550.00	n/a	n/a	25.43
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	900.00	n/a	n/a	25.46
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	576.00	n/a	n/a	25.60
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	950.00	n/a	n/a	25.63
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	600.00	n/a	n/a	25.74
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	995.00	n/a	n/a	25.77
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	1000.00	n/a	n/a	25.79
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	1050.00	n/a	n/a	25.93
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	650.00	n/a	n/a	26.01
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	1100.00	n/a	n/a	26.07
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	1150.00	n/a	n/a	26.19
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	700.00	n/a	n/a	26.25
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	1200.00	n/a	n/a	26.30
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	1250.00	n/a	n/a	26.41
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	750.00	n/a	n/a	26.46
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	1302.00	n/a	n/a	26.51
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	780.00	n/a	n/a	26.58
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	800.00	n/a	n/a	26.65
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	850.00	n/a	n/a	26.82
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	900.00	n/a	n/a	26.97
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	950.00	n/a	n/a	27.11
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	1000.00	n/a	n/a	27.23
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	1843.00	n/a	n/a	27.26
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	1050.00	n/a	n/a	27.35
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	1100.00	n/a	n/a	27.45
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	1150.00	n/a	n/a	27.55
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Arabidopsis*	*Arabidopsis thaliana*		n/a	n/a	2255.00	n/a	n/a	27.61
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	1200.00	n/a	n/a	27.64
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	1250.00	n/a	n/a	27.72
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	1300.00	n/a	n/a	27.80
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	1350.00	n/a	n/a	27.87
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	1400.00	n/a	n/a	27.94
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	1450.00	n/a	n/a	28.00
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	1494.00	n/a	n/a	28.05
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	1500.00	n/a	n/a	28.06
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	1550.00	n/a	n/a	28.11
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	1600.00	n/a	n/a	28.16
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	1650.00	n/a	n/a	28.21
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	2623.00	n/a	n/a	28.81
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	3429.00	n/a	n/a	29.06
Schubert & Jahren 2012	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Brassicaceae	*Raphanus*	*Raphanus raphanistrum subsp. sativus*		n/a	n/a	4200.00	n/a	n/a	29.21
Simpson et al. 2005	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Khaosokia*	*Khaosokia caricoides*		n/a	n/a	n/a	n/a	-29.14	n/a
Sternberg et al. 1984	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Eleocharis*	*Eleocharis acicularis*		n/a	n/a	n/a	n/a	-25.60	n/a
Tu et al. 2004	n/a	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Quercus*	*Quercus petraea*		2000	2000	370.00	-8.20	-29.80	22.26
Tu et al. 2004	n/a	n/a	n/a	n/a	n/a	Angiosperm	Woody	C3	Woody Angiosperm	Fagaceae	*Quercus*	*Quercus petraea*		2000	2000	370.00	-8.20	-30.30	22.79
Ueno & Samejima 1988	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Eleocharis*	*Eleocharis vivipara*		n/a	n/a	n/a	n/a	-25.90	n/a
Winter & Troughton 1978	n/a	n/a	n/a	n/a	n/a	Angiosperm	Herbaceous	C3	Herbaceous Angiosperm	Cyperaceae	*Carex*	*Carex pachystylis*		n/a	n/a	n/a	n/a	-26.60	n/a
Zibulski et al. 2019	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Amblystegiaceae	*Drepanocladu*	*Drepanocladus revolvens*		2011	2011	387.47	-8.23	-22.50	14.60
Zibulski et al. 2019	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Meesiaceae	*Meesia*	*Meesia triquetra*		2011	2011	387.47	-8.23	-22.50	14.60
Zibulski et al. 2019	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Campyliaceae	*Warnstorfia*	*Warnstorfia exannulata*		2011	2011	387.47	-8.23	-22.60	14.70
Zibulski et al. 2019	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Calliergonaceae	*Calliergon*	*Calliergon giganteum*		2011	2011	387.47	-8.23	-22.80	14.91
Zibulski et al. 2019	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Calliergonaceae	*Scorpidium*	*Scorpidium scorpioides*		2011	2011	387.47	-8.23	-22.80	14.91
Zibulski et al. 2019	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Amblystegiaceae	*Hamatocaulis*	*Hamatocaulis lapponicus*		2011	2011	387.47	-8.23	-23.20	15.33
Zibulski et al. 2019	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Aulacomniaceae	*Aulacomnium*	*Aulacomnium palustre*		2011	2011	387.47	-8.23	-24.20	16.37
Zibulski et al. 2019	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Aulacomniaceae	*Aulacomnium*	*Aulacomnium turgidum*		2011	2011	387.47	-8.23	-24.30	16.47
Zibulski et al. 2019	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Brachytheciaceae	*Tomentypnum*	*Tomentypnum nitens*		2011	2011	387.47	-8.23	-24.50	16.68
Zibulski et al. 2019	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Hylocomiaceae	*Hylocomium*	*Hylocomium splendens*		2011	2011	387.47	-8.23	-25.60	17.83
Zibulski et al. 2019	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Amblystegiaceae	*Hamatocaulis*	*Hamatocaulis lapponicus*		2011	2011	387.47	-8.23	-26.60	18.87
Zibulski et al. 2019	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Aulacomniaceae	*Aulacomnium*	*Aulacomnium palustre*		2011	2011	387.47	-8.23	-30.10	22.55
Zibulski et al. 2019	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Aulacomniaceae	*Aulacomnium*	*Aulacomnium turgidum*		2011	2011	387.47	-8.23	-30.40	22.87
Zibulski et al. 2019	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Brachytheciaceae	*Tomentypnum*	*Tomentypnum nitens*		2011	2011	387.47	-8.23	-30.90	23.39
Zibulski et al. 2019	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Hylocomiaceae	*Hylocomium*	*Hylocomium splendens*		2011	2011	387.47	-8.23	-32.10	24.66
Zibulski et al. 2019	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Calliergonaceae	*Scorpidium*	*Scorpidium scorpioides*		2011	2011	387.47	-8.23	-33.00	25.62
Zibulski et al. 2019	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Campyliaceae	*Warnstorfia*	*Warnstorfia exannulata*		2011	2011	387.47	-8.23	-34.50	27.21
Zibulski et al. 2019	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Calliergonaceae	*Calliergon*	*Calliergon giganteum*		2011	2011	387.47	-8.23	-34.70	27.42
Zibulski et al. 2019	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Amblystegiaceae	*Drepanocladu*	*Drepanocladus revolvens*		2011	2011	387.47	-8.23	-34.90	27.63
Zibulski et al. 2019	n/a	n/a	n/a	n/a	n/a	Bryophyte	Bryophyte	C3	Bryophyte	Meesiaceae	*Meesia*	*Meesia triquetra*		2011	2011	387.47	-8.23	-37.00	29.88

Legend

A Etheridge DM, Steele LP, Langenfelds RL, Francey RJ, Barnola JM, Mogan VI, Historical CO2 records from the Law Dome DE08, DE08-2, and DSS ice cores. *Trends: a compendium of data on global change*, 351-364 (1998).

B Keeling CD, Piper SC, Bacastow RB, Wahlen M, Whorf TP, Heimann M, Meijer HA, Atmospheric CO2 and 13CO2 exchange with the terrestrial biosphere and oceans from 1978 to 2000: Observations and carbon cycle implications. In A history of atmospheric CO2 and its effects on plants, animals, and ecosystems (pp. 83-113). Springer, New York, NY (2005).

C Keeling CD, Piper SC, Bacastow RB, Wahlen M, Whorf TP, Heimann M, Meijer HA, Terrestrial Biosphere and Oceans from 1978 to 2000: Observations and Carbon Cycle Implications.

D Eggleston S, Schmitt J, Bereiter B, Schneider R, Fischer H, Evolution of the stable carbon isotope composition of atmospheric CO2 over the last glacial cycle. *Paleoceanography*, *31*(3), 434-452 (2016).

E Rubino M, Etheridge DM, Trudinger CM, Allison CE, Battle MO, Langenfelds RL, Jenk TM, A revised 1000 year atmospheric δ13C CO2 record from Law Dome and South Pole, Antarctica. *Journal of Geophysical Research: Atmospheres*, *118*(15), 8482-8499 (2013).

F Diefendorf AF, Mueller KE, Wing SL, Koch, PL. Freeman KH, Global patterns in leaf 13C discrimination and implications for studies of past and future climate. Proceedings of the National Academy of Sciences, 107(13), 5738-5743 (2010).

G US data from PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, created 4 Feb 2004.

n/a Araus JL, Reynolds MP, Acevedo E, Leaf posture, grain yield, growth, leaf structure, and carbon isotope discrimination in wheat. Crop Science, 33(6), 1273-1279 (1993).

n/a Arens NC, Jahren AH, Carbon isotope excursion in atmospheric CO2 at the Cretaceous-Tertiary boundary: evidence from terrestrial sediments. Palaios, 15(4), 314-322 (2000).

n/a Bai E, Boutton T, Liu F, Wu X, Archer S, Variation in woody plant $\delta^{13}C$ along a topoedaphic gradient in a subtropical savanna parkland. Oecologia 156:479-489 (2008).

n/a Beerling DJ, Woodward FI, Stomatal responses of variegated leaves to CO2 enrichment. Annals of Botany, 75(5), 507-511 (1995).

n/a Beerling DJ, 13C discrimination by fossil leaves during the late-glacial climate oscillation 12-10 ka BP: measurements and physiological controls. Oecologia, 108(1), 29-37 (1996).

n/a Bonal D, Sabatier D, Montpied P, Tremeaux D, Guehl JM, Interspecific variability of $\delta^{13}C$ among trees in rainforests of French Guiana: functional groups and canopy integration. Oecologia 124:454-468 (2000).

n/a Brooks JR, Flanagan LB, Buchmann N, Ehleringer JR, Carbon isotope composition of boreal plants: functional grouping of life forms. Oecologia 110:301-311 (1997).

n/a Broadmeadow MSJ, Griffiths H, Maxwell C, Borland AM, The carbon isotope ratio of plant organic material reflects temporal and spatial variations in CO 2 within tropical forest formations in Trinidad. Oecologia, 89(3), 435-441 (1992).

n/a Bruhl JJ, Wilson KL, Towards a comprehensive survey of C3 and C4 photosynthetic pathways in Cyperaceae. Aliso: A Journal of Systematic and Evolutionary Botany, 23(1), 99-148 (2007).

n/a Buchmann N, Guehl JM, Barigah TS, Ehleringer JR, Interseasonal comparison of CO_2 concentrations, isotopic composition, and carbon dynamics in an Amazonian rainforest (French Guiana). Oecologia 110:120-131 (1997).

n/a Chevillat VS, Siegwolf RTW, Pepin S, Körner C, Tissue-specific variation of $\delta^{13}C$ in mature canopy trees in a temperate forest in central Europe. Basic App Ecol 6:519-534 (2005).

n/a Collister JW, Rieley G, Stern B, Eglinton G, Fry B, Compound-specific $\delta^{13}C$ analyses of leaf lipids from plants with differing carbon dioxide metabolisms. Org Geochem 21:619-627 (1994).

n/a Condon AG, Richards RA, Farquhar GD, Relationships between carbon isotope discrimination, water use efficiency and transpiration efficiency for dryland wheat. Australian Journal of Agricultural Research, 44(8), 1693-1711 (1993).

n/a Dawson TE, Ehleringer JR, Isotopic enrichment of water in the "woody" tissues of plants: implications for plant water source, water uptake, and other studies which use the stable isotopic composition of cellulose. Geochimica et Cosmochimica Acta, 57(14), 3487-3492 (1993).

n/a De Lillis M, Matteucci G, Valentini R, Carbon assimilation, nitrogen, and photochemical efficiency of different Himalayan tree species along an altitudinal gradient. Photosynthetica 42:597-605 (2004).

n/a DeLucia EH, Schlesinger WH, Resource-use efficiency and drought tolerance in adjacent Great Basin and Sierran plants. Ecology 72:51-58 (1991).

n/a Dodd MB, Lauenroth WK, Welker JM, Differential water resource use by herbaceous and woody plant life-forms in a shortgrass steppe community. Oecologia 117:504-512 (1998).

n/a Donovan LA, Ehleringer JR, Ecophysiological differences among juvenile and reproductive plants of several woody species. Oecologia 86:594-597 (1991) .

n/a Dungait JAJ, Docherty G, Straker V, Evershed RP, Interspecific variation in bulk tissue, fatty acid and monosaccharide $\delta^{13}C$ values of leaves from a mesotrophic grassland plant community. Phytochemistry 69:2041-2051 (2008).

n/a Dupouey JL, Leavitt S, Choisnel E, Jourdain S, Modelling carbon isotope fractionation in tree rings based on effective evapotranspiration and soil water status. *Plant, Cell & Environment*, *16*(8), 939-947 (1993).

n/a Ehleringer JR, Cerling TE, Atmospheric CO2 and the ratio of intercellular to ambient CO2 concentrations in plants. Tree physiology, 15(2), 105-111 (1995).

n/a Ehleringer JR, Lin ZF, Field CB, Sun GC, Kuo CY, Leaf carbon isotope ratios of plants from a subtropical monsoon forest. Oecologia 72:109-114 (1987).

n/a Ehleringer JR, Phillips SL, Schuster WS, Sandquist DR, Differential utilization of summer rains by desert plants. Oecologia, 88(3), 430-434 (1991).

n/a Ehleringer JR, Phillips SL, Comstock JP, Seasonal variation in the carbon isotopic composition of desert plants. Func Ecol 6:396-404 (1992).

n/a Ehleringer JR, Hall AE, Farquhar GD (Eds.). Stable isotopes and plant carbon-water relations (Vol. 109129). San Diego: Academic Press (1993).

n/a Escudero A, Mediavilla S, Heilmeier H, Leaf longevity and drought: avoidance of the costs and risks of early leaf abscission as inferred from the leaf carbon isotopic composition. Func Plant Bio 35:705-713 (2008).

n/a Franco AC, Duarte HM, Geßler A, de Mattos EA, Nahm M, Rennenberg H, Lüttge U, In situ measurements of carbon and nitrogen distribution and composition, photochemical efficiency and stable isotope ratios in Araucaria angustifolia. Trees, 19(4), 422-430 (2005).

n/a Friend AD, Woodward FI, Switsur VR, Field measurements of photosynthesis, stomatal conductance, leaf nitrogen and δ 13 C along altitudinal gradients in Scotland. Functional Ecology, 117-122 (1989).

n/a Garten CT, Taylor GE, Foliar $\delta^{13}C$ within a temperate deciduous forest: spatial, temporal, and species sources of variation. Oecologia 90:1-7 (1992).

n/a Gerdol R, Iacumin P, Marchesini R, Bragazza L, Water- and nutrient-use efficiency of a deciduous species, Vaccinium myrtillus, and an evergreen species, V. vitis-idaea, in a subalpine dwarf shrub heath in the southern Alps, Italy. Oikos 88:19-32 (2000).

n/a Gutierrez MV, Meinzer FC, Carbon isotope discrimination and photosynthetic gas exchange in coffee hedgerows during canopy development. Functional Plant Biology, 21(2), 207-219 (1994).

n/a Guy RD, Reid DM, Photosynthesis and the influence of CO2 enrichment on δ13C values in a C3 halophyte. Plant, Cell & Environment, 9(1), 65-72 (1986).

n/a Hall AE, Richards RA, Condon AG, Wright GC, Farquhar GD, Carbon isotope discrimination and plant breeding. Plant breeding reviews, 12(81), 113 (1994).

n/a Hansen D, Steig E, Comparison of water use efficiency and internal leaf carbon dioxide concentration in juvenile leaves and phyllodes of Acacia koa (leguminosae) from Hawaii, estimated by two methods. American Journal of Botany, 80(10), 1121-1125 (1993).

n/a He C-X, Li J-Y, Zhou P, Guo M, Zheng Q-S,Changes of leaf morphological, anatomical structure and carbon isotope ratio with the height of the Wangtian Tree (Parashorea chinensis) in Xishuangbanna, China. Journal of Integrative Plant Biology 50:168-173 (2008).

n/a Hemming D, Yakir D, Ambus P, Aurela M, Besson C, Black K, Gross, P. Pan European δ13C values of air and organic matter from forest ecosystems. Global Change Biology, 11(7), 1065-1093 (2005).

n/a Holtum JAM, Winter K, Carbon isotope composition of canopy leaves in a tropical forest in Panama throughout a seasonal cycle. Trees Struc Func 19:545-551 (2005).

n/a Huc R, Ferhi A, Guehl JM, Pioneer and late stage tropical rainforest tree species (French Guiana) growing under common conditions differ in leaf gas exchange regulation, carbon isotope discrimination and leaf water potential. *Oecologia*, *99*(3-4), 297-305 (1994).

n/a Hultine KR, Marshall JD, Altitude trends in conifer leaf morphology and stable carbon isotope composition. Oecologia 123:32-40 (2000).

n/a Inagaki Y, Miura S, Kohzu A, Effects of forest type and stand age on litterfall quality and soil N dynamics in Shikoku district, southern Japan. For Ecol Manag 202:107-117 (2004).

n/a Ismail AM, Hall AE, Inheritance of carbon isotope discrimination and water use efficiency in cowpea. Crop Science, 33(3), 498-503 (1993).

n/a Ismail AM, Hall AE, Bray EA, Drought and pot size effects on transpiration efficiency and carbon isotope discrimination of cowpea accessions and hybrids. Functional Plant Biology, 21(1), 23-35 (1994).

n/a Johnson RC, Tieszen LL, Carbon isotope discrimination, water relations, and gas exchange in temperate grass species and accessions. In Stable isotopes and plant carbon-water relations (pp. 281-296). Academic Press (1993).

n/a Kloeppel BD, Gower ST, Treichel IW, Kharuk S, Foliar carbon isotope discrimination in Larix species and sympatric evergreen conifers: a global comparison. Oecologia 114:153-159 (1998).

n/a Körner C, Farquhar GD, Roksandic Z, A global survey of carbon isotope discrimination in plants from high altitude. Oecologia, 74(4), 623-632 (1988).

n/a Kohorn LU, Goldstein G, Rundel PW, Morphological and isotopic indicators of growth environment - variability in delta-C-13 in Simmondsia chinensis, a dioecious desert shrub. J Exp Bot 45:1817-1822 (1994).

n/a Leffler AJ, Enquist BJ, Carbon isotope composition of tree leaves from Guanacaste, Costa Rica: comparison across tropical forests and tree life history. J Trop Ecol 18:151-159 (2002).

n/a Li Z-H, Leavitt SW, Mora CI, Liu R-M, Influence of earlywood-latewood size and isotope differences on long-term tree-ring $\delta^{13}C$ trends. Chem Geol 216:191-201 (2005).

n/a Lockheart MJ, Van Bergen PF, Evershed RP, Variations in the stable carbon isotope compositions of individual lipids from the leaves of modern angiosperms: implications for the study of higher land plant-derived sedimentary organic matter. Org Geochem 26:137-153 (1997).

n/a Marshall JD, Zhang J, Carbon isotope discrimination and water-use efficiency in native plants of the north-central Rockies. Ecology 75:1887-1895 (1994).

n/a Martin B, Thorstenson YR, Stable carbon isotope composition (δ13C), water use efficiency, and biomass productivity of Lycopersicon esculentum, Lycopersicon pennellii, and the F1 hybrid. Plant Physiology, 88(1), 213-217 (1988).

n/a Martin B, Bytnerowicz A, Thorstenson YR, Effects of air pollutants on the composition of stable carbon isotopes, δ13C, of leaves and wood, and on leaf injury. Plant Physiology, 88(1), 218-223 (1988).

n/a Mayland HF, Johnson DA, Asay KH, Read JJ, Ash, carbon isotope discrimination, and silicon as estimators of transpiration efficiency in crested wheatgrass. Functional Plant Biology, 20(3), 361-369 (1993).

n/a McArthur JV, Moorhead KK, Characterization of riparian species and stream detritus using multiple stable isotopes. Oecologia 107:232-238 (1996).

n/a Mervenne C, *Isotope ecology of temperate conifers* (Masters' Thesis) (2015) .

n/a Mole S, Joern A, Feeding behavior of graminivorous grasshoppers in response to host-plant extracts, alkaloids, and tannins. *Journal of chemical ecology*, *20*(12), 3097-3109 (1994).

n/a Mooney HA, Bullock SH, Ehleringer JR, Carbon isotope ratios of plants of a tropical dry forest in Mexico. Func Ecol 3:137-142 (1989).

n/a Morgan JA, LeCain DR, McCaig TN, Quick JS, Gas exchange, carbon isotope discrimination, and productivity in winter wheat. Crop Science, 33(1), 178-186 (1993).

n/a Rao RN, Williams JH, Wadia KDR, Hubick KT, Farquhar GD, Crop growth, water use efficiency and carbon isotope discrimination in groundnut (Arachis hypogaea L.) genotypes under end of season drought conditions. Annals of applied Biology, 122(2), 357-367 (1993).

n/a Nagy L, Proctor J, Leaf $\delta^{13}C$ signatures in heath and lowland evergreen rain forest species from Borneo. J Trop Ecol 16:757-761 (2000).

n/a Osorio J, Pereira JS, Genotypic differences in water use efficiency and 13C discrimination in Eucalyptus globulus. Tree Physiology, 14(7-8-9), 871-882 (1994).

n/a Panek JA, Correlations between stable carbon-isotope abundance and hydraulic conductivity in Douglas-fir across a climate gradient in Oregon, USA. Tree Physiology, 16(9), 747-755 (1996).

n/a Peñuelas J, Azcón Bieto J, Changes in leaf Δ13C of herbarium plant species during the last 3 centuries of CO2 increase. Plant, Cell & Environment, 15(4), 485-489 (1992).

n/a Polley HW, Johnson HB, Mayeux HS, Nitrogen and water requirements of C3 plants grown at glacial to present carbon dioxide concentrations. *Functional Ecology*, 86-96 (1995).

n/a Proctor MCF, Raven JA, Rice SK (1992) Stable carbon isotope discrimination measurements in Sphagnum and other bryophytes: physiological and ecological implications. Journal of Bryology, 17(2), 193-202.

n/a Royles J, Horwath AB, Griffiths H, Interpreting bryophyte stable carbon isotope composition: Plants as temporal and spatial climate recorders. *Geochemistry, Geophysics, Geosystems*, *15*(4), 1462-1475 (2014).

n/a Rundel PW, Stichler W, Zander RH, Ziegler H, Carbon and hydrogen isotope ratios of bryophytes from arid and humid regions. Oecologia, 44(1), 91-94 (1979).

n/a Sandquist DR, Cordell S, Functional diversity of carbon-gain, water-use, and leaf-allocation traits in trees of a threatened lowland dry forest in Hawaii. Amer J Bot 94:1459-1469 (2007).

n/a Schubert BA, Jahren AH, The effect of atmospheric CO2 concentration on carbon isotope fractionation in C3 land plants. Geochimica et Cosmochimica Acta, 96, 29-43 (2012).

n/a Sheldon ND, Smith SY, Stein RA, Ng M, Carbon isotope ecology of gymnosperms and implications for paleoclimatic and paleoecological studies. Global and Planetary Change, 103060 (2019).

n/a Simpson DA, Muasya AM, Chayamarit K, Parnell JA, Suddee S, Wilde BD, Pooma R, Khaosokia caricoides, a new genus and species of Cyperaceae from Thailand. *Botanical Journal of the Linnean Society*, *149*(3), 357-364 (2005).

n/a Smedley MP, Dawson TE, Comstock JP, Donovan LA, Sherrill E, Cook CS, Ehleringer JR, Seasonal carbon isotope discrimination in a grassland community. Oecologia, 85(3), 314-320 (1991).

n/a Sternberg LO, Deniro MJ, Johnson HB, Isotope ratios of cellulose from plants having different photosynthetic pathways. Plant Physiology, 74(3), 557-561 (1984).

n/a Terwilliger VJ, Changes in the δ13C values of trees during a tropical rainy season: some effects in addition to diffusion and carboxylation by Rubisco?. American Journal of Botany, 84(12), 1693-1700 (1997).

n/a Toft NL, Anderson JE, Nowak RS, Water use efficiency and carbon isotope composition of plants in a cold desert environment. *Oecologia*, *80*(1), 11-18 (1989).

n/a Tu TTN, Kürschner WM, Schouten S, Van Bergen PF, Leaf carbon isotope composition of fossil and extant oaks grown under differing atmospheric CO2 levels. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *212*(3-4), 199-213 (2004).

n/a Uemura A, Harayama H, Koike N, Ishida A, Coordination of crown structure, leaf plasticity and carbon gain within the crowns of three winter-deciduous mature trees. Tree Phys 26:633-641 (2006).

n/a Ueno O, Samejima M, Muto S, Miyachi S, Photosynthetic characteristics of an amphibious plant, Eleocharis vivipara: expression of C4 and C3 modes in contrasting environments. Proceedings of the National Academy of Sciences, 85(18), 6733-6737 (1988).

n/a Valentini R, Anfodillo T, Ehleringer JR, Water sources and carbon-isotope composition (delta-C-13) of selected tree species of the Italian Alps. Canadian J For Res 24:1575-1579 (1994).

n/a Valentini R, Mugnozza GES, Ehleringer JR, Hydrogen and carbon isotope ratios of selected species of a Mediterranean Macchia ecosystem. Func Ecol 6:627-631 (1992).

n/a Van de Water P, Leavitt S, Betancourt J, Leaf $\delta^{13}C$ variability with elevation, slope aspect, and precipitation in the southwest United States. Oecologia 132:332-343 (2002).

n/a Van de Water PK, Leavitt SW, Betancourt JL, Trends in stomatal density and 13C/12C ratios of Pinus flexilis needles during last glacial-interglacial cycle. Science, 264(5156), 239-243 (1994).

n/a Welker JM, Wookey PA, Parsons AN, Press MC, Callaghan TV, Lee JA, Leaf carbon isotope discrimination and vegetative responses of Dryas octopetala to temperature and water manipulations in a High Arctic polar semi-desert, Svalbard. *Oecologia*, *95*(4), 463-469 (1993).

n/a White JW, Castillo JA, Ehleringer JR, Garcia JAC, Singh SP, Relations of carbon isotope discrimination and other physiological traits to yield in common bean (Phaseolus vulgaris) under rainfed conditions. The Journal of Agricultural Science, 122(2), 275-284 (1994).

n/a Williams DG, Ehleringer JR, Carbon isotope discrimination in three semi-arid woodland species along a monsoon gradient. Oecologia 106:455-460 (1996).

n/a Williams DG, Ehleringer JR, Carbon isotope discrimination and water relations of oak hybrid populations in southwestern Utah. West Nor Amer Nat 60:121-129 (2000).

n/a Winter K, Troughton JH, Carbon assimilation pathways in Mesembryanthemum nodiflorum L. under natural conditions. Zeitschrift für Pflanzenphysiologie, 88(2), 153-162 (1978).

n/a Wright GC, Rao RC, Farquhar GD, Water-use efficiency and carbon isotope discrimination in peanut under water deficit conditions. *Crop Science*, *34*(1), 92-97 (1994).

n/a Zhang J, Marshall JD, Jaquish BD, Genetic differentiation in carbon isotope discrimination and gas exchange in Pseudotsuga menziesii. *Oecologia*, *93*(1), 80-87 (1993).

n/a Zhang J, Fins L, Marshall JD, Stable carbon isotope discrimination, photosynthetic gas exchange, and growth differences among western larch families. *Tree Physiology*, *14*(5), 531-539 (1994).

n/a Zibulski, R, Wesener F, Wilkes H, Plessen B, Pestryakova LA, Herzschuh, U, C/N ratio, stable isotope (δ 13 C, δ 15 N), and n-alkane patterns of brown mosses along hydrological gradients of low-centred polygons of the Siberian Arctic (2019).

Table B2 Range of climate variables included in the historical portion of this study, as collected from PRISM Climate Group (2004), White et al. (2015), and Eggleston (2016).

Climate, Atmospheric or Temporal Variable	Minimum	Maximum	Mean
Time (Year)	1804	2019	1971
$[CO_2]$ (ppm)	283	411	351
$\delta^{13}C_{CO2}$ (‰)	-8.7	-6.4	-7.6
Latitude (°N)	9.9	68.2	42.5
Longitude (°E)	-152.3	139.9	-86.7
Mean Annual Precipitation (mm yr^{-1})	193	4368	999
Mean Annual Temperature (°C)	-5.6	25.0	8.0
Maximum Summer Temperature (°C)	13.3	35.9	26.2
Elevation (m)	4	2766	967
Annual Minimum Vapor Pressure Deficit (hPa)	0.18	6.32	1.23
Annual Maximum Vapor Pressure Deficit (hPa)	0.63	21.87	10.58

Table B3 Results from t-tests (assuming unequal variances) comparing the means and ranges of *Arabidopsis* (a) and *Raphanus* (b) and families highly sampled from the literature dataset. N/a denotes that the comparison to the model species is not applicable (in the cases that it would involve comparing the model species to itself).

Taxon	Mean	Standard Deviation	Sample Size	t-Stat	p(T<=t) two-tail value
Arabidopsis	22.66	10.65	22	n/a	n/a
Asteraceae	18.76	1.78	68	5.44	4.14×10^{-5}
Other Brassicace	20.37	0.93	5	2.80	0.02
Cupressaceae	19.28	3.49	584	4.83	7.72×10^{-5}
Cyperaceae	20.78	11.01	212	2.58	3.39×10^{-3}
Fabaceae	20.61	2.80	134	2.89	7.76×10^{-3}
Fagaceae	20.34	1.97	54	3.22	4.25×10^{-3}
Ginkgoaceae	19.93	2.21	221	3.89	7.88×10^{-4}
Pinaceae	20.24	3.45	356	3.45	2.28×10^{-3}
Poaceae	18.88	4.20	119	5.25	3.79×10^{-5}
Salicaceae	19.77	2.60	261	4.12	4.48×10^{-4}
Taxon	Mean	Standard Deviation	Sample Size	t-Stat	p(T<=t) two-tail value
Raphanus	24.47	8.16	23	n/a	n/a
Asteraceae	18.76	1.78	68	9.23	2.37×10^{-9}
Other Brassicace	20.37	0.93	5	5.33	1.37×10^{-4}
Cupressaceae	19.28	3.49	584	8.64	1.07×10^{-8}
Cyperaceae	20.78	11.01	212	5.80	1.23×10^{-5}
Fabaceae	20.61	2.80	134	6.30	1.25×10^{-6}
Fagaceae	20.34	1.97	54	6.61	5.34×10^{-7}
Ginkgoaceae	19.93	2.21	221	7.52	1.21×10^{-7}
Pinaceae	20.24	3.45	356	7.01	3.79×10^{-7}
Poaceae	18.88	4.20	119	8.95	2.60×10^{-9}
Salicaceae	19.77	2.60	261	7.79	6.69×10^{-8}

Table B4 Results showing the relationship between $\delta^{13}C_{CO2}$ and $\delta^{13}C_{plant}$ for each species studied over Industrialization. The first row shows the universal relationship proposed by Arens et al. (2000), and the second shows a generalized relationship that incorporates all 8 of the species we tested. Specimens sampled post-2017 were excluded to focus on the historical portion of this study.

Measurement	Slope	Intercept
Arens et al. (2000)	1.05	-18.72
Total Historical Dataset (pre-2017)	1.22	-17.10
Pinus strobus	1.58	-15.54
Platycladus orientalis	1.47	-15.72
Populus tremuloides	1.08	-18.77
Thuja koraiensis	0.36	-22.84
Thuja occidentalis	1.31	-15.66
Thuja plicata	0.95	-18.53
Thuja standishii	2.46	-6.77
Thuja sutchuenensis	6.42	27.19

Table B5 Sensitivity (S given as ‰ ppm^{-1}) for eight species with long historical record. S is compiled for the entire range of [CO_2] values spanning the collection, and as pre-1960 (acceleration; Keeling et al. 2001) and post-1960 ranges. Expected sensitivity is calculated using the best-fit function, S (‰ ppm^{-1}) = $0.21(28.26)^2 / [28.26+0.21(CO_2 + 25))^2$ from Schubert & Jahren's (2012) study using data from both *Arabidopsis thaliana* and *Raphanus sativus* growth chamber experiments. S-column cells highlighted in blue indicate actual sensitivities far more negative than expected. S-column cells in red indicate sensitivities far more positive than expected, and S-column cells in white indicate sensitivities matching what is expected. N/a is used when there are no samples collected of the species during the specified time period.

Genus	Species	Age (Range in [CO_2])	S (‰/ppm)	Standard Deviation (‰/ppm)
Pinus	*strobus*	Total (286-395)	-0.0117	3.019
		<1960 (286-320)	-0.0421	n=51
		>1960 (320-395)	0.0014	
Platycladus	*orientalis*	Total (290-408)	0.0077	1.642
		<1960 (290-320)	-0.0045	n=12
		>1960 (320-408)	0.0346	
Populus	*tremuloides*	Total (288-411)	0.0078	9.078
		<1960 (288-320)	-0.0441	n=79
		>1960 (320-411)	-0.0011	
Thuja	*koraiensis*	Total (311-408)	-0.0411	0.536
		<1960 (311-320)	-0.4977	n=6
		>1960 (320-408)	0.0495	
Thuja	*occidentalis*	Total (283-408)	0.0128	4.497
		<1960 (283-320)	0.0417	n=85
		>1960 (320-408)	-0.0012	
Thuja	*plicata*	Total (289-411)	0.0161	4.164
		<1960 (289-320)	-0.0085	n=163
		>1960 (320-411)	0.0338	
Thuja	*standishii*	Total (292-408)	0.0333	1.583
		<1960 (292-320)	0.0592	n=15
		>1960 (320-408)	0.0474	
Thuja	*sutchuenensis*	Total (366-408)	0.0851	0.203
		<1960 (n/a)	n/a	n=4
		>1960 (366-408)	0.0851	
Expected Sensitivity		<1960 (280-320)	0.0181	
		>1960 (320-408)	0.0139	

Table B6 Results showing the statistical relationship between carbon isotope discrimination and non-[CO_2] climate variables for each species studied over Industrialization for each species studied over Industrialization. Specimens collected in modern times were included. N/a denotes when climate variables were not accessible for the specified species.

a	R^2 value				
Species	Mean Annual Precipitation (mm yr^{-1})	Mean Annual Temperature (°C)	Maximum Summer Temperature (°C)	Elevation (m)	Latitude (°N)
Pinus strobus	4.00×10^{-3}	0.01	0.01	0.06	0.06
Platycladus orientalis	7.00×10^{-4}	0.01	0.74	0.10	3.47×10^{-6}
Populus tremuloides	0.05	0.01	3.00×10^{-3}	0.08	0.15
Thuja occidentalis	1.00×10^{-3}	0.01	4.00×10^{-3}	1.00×10^{-3}	0.01
Thuja koraiensis	0.15	0.76	0.32	0.10	0.37
Thuja plicata	0.06	0.02	0.07	0.04	0.05
Thuja standishii	0.55	0.34	n/a	0.03	0.25
Thuja sutchuenensis	0.03	0.06	n/a	0.44	0.01
Overall historical study	0.02	0.01	0.01	0.00	4.00×10^{-3}
b	**p-value**				
Species	Mean Annual Precipitation (mm yr^{-1})	Mean Annual Temperature (°C)	Maximum Summer Temperature (°C)	Elevation (m)	Latitude (°N)
Pinus strobus	0.62	0.33	0.43	0.04	0.03
Platycladus orientalis	0.93	0.77	0.00	0.27	0.99
Populus tremuloides	1.00×10^{-3}	0.20	0.50	7.88×10^{-6}	8.87×10^{-10}
Thuja occidentalis	0.72	0.30	0.47	0.66	0.23
Thuja koraiensis	0.52	0.05	0.43	0.53	0.08
Thuja plicata	2.00×10^{-3}	0.09	3.00×10^{-3}	8.00×10^{-3}	0.01
Thuja standishii	0.09	0.22	n/a	0.58	0.06
Thuja sutchuenensis	0.56	0.46	n/a	0.02	0.75
Overall historical study	4.00×10^{-3}	0.65	0.24	0.88	0.01

B. References

Araus, J. L., Reynolds, M. P., & Acevedo, E. (1993). Leaf posture, grain yield, growth, leaf structure, and carbon isotope discrimination in wheat. *Crop Science*, *33*(6), 1273-1279.

Arens N. C., Jahren A. H. (2000). Carbon isotope excursion in atmospheric CO_2 at the Cretaceous-Tertiary boundary: evidence from terrestrial sediments. *Palaios, 15*(4), 314-322.

Bai E., Boutton T., Liu F., Wu X., Archer S. (2008). Variation in woody plant $\delta^{13}C$ along a topoedaphic gradient in a subtropical savanna parkland. *Oecologia, 156*:479-489.

Beerling D. J., Woodward F. I. (1995). Stomatal responses of variegated leaves to CO_2 enrichment. *Annals of Botany, 75*(5), 507-511.

Beerling D. J. (1996). ^{13}C discrimination by fossil leaves during the late-glacial climate oscillation 12-10 ka BP: measurements and physiological controls. *Oecologia, 108*(1), 29-37.

Bonal D., Sabatier D., Montpied P., Tremeaux D., & Guehl J. M. (2000). Interspecific variability of $\delta^{13}C$ among trees in rainforests of French Guiana: functional groups and canopy integration. *Oecologia, 124*, 454-468.

Brooks J. R., Flanagan L. B., Buchmann N., & Ehleringer J. R. (1997). Carbon isotope composition of boreal plants: functional grouping of life forms. *Oecologia, 110*:301-311.

Broadmeadow M. S. J., Griffiths H., Maxwell C., & Borland A. M. (1992). The carbon isotope ratio of plant organic material reflects temporal and spatial variations in CO_2 within tropical forest formations in Trinidad. *Oecologia, 89*(3), 435-441.

Bruhl J. J., & Wilson K. L. (2007). Towards a comprehensive survey of C_3 and C_4 photosynthetic pathways in Cyperaceae. Aliso: A Journal of Systematic and Evolutionary Botany, 23(1), 99-148.

Buchmann N., Guehl J. M., Barigah T. S., & Ehleringer J. R. (1997). Interseasonal comparison of CO_2 concentrations, isotopic composition, and carbon dynamics in an Amazonian rainforest (French Guiana). *Oecologia, 110*, 120-131.

Chevillat V. S., Siegwolf R. T. W., Pepin S., & Körner C. (2005). Tissue-specific variation of $\delta^{13}C$ in mature canopy trees in a temperate forest in central Europe. *Basic and applied ecology,* 6, 519-534.

Collister J. W., Rieley G., Stern B., Eglinton G., & Fry B. (1994). Compound-specific $\delta^{13}C$ analyses of leaf lipids from plants with differing carbon dioxide metabolisms. *Organic Geochemistry, 21*, 619-627.

Condon A. G., Richards R. A., & Farquhar G. D. (1993). Relationships between carbon isotope discrimination, water use efficiency and transpiration efficiency for dryland wheat. *Australian Journal of Agricultural Research, 44*(8), 1693-1711.

Dawson T. E., Ehleringer J. R. (1993). Isotopic enrichment of water in the "woody" tissues of plants: implications for plant water source, water uptake, and other studies which use the stable isotopic composition of cellulose. Geochimica et Cosmochimica Acta, 57(14), 3487-3492.

De Lillis M., Matteucci G., & Valentini R. (2004). Carbon assimilation, nitrogen, and photochemical efficiency of different Himalayan tree species along an altitudinal gradient. *Photosynthetica, 42,* 597-605.

DeLucia E. H., & Schlesinger W. H. (1991). Resource-use efficiency and drought tolerance in adjacent Great Basin and Sierran plants. *Ecology, 72*, 51-58.

Diefendorf, A. F., Mueller, K. E., Wing, S. L., Koch, P. L., & Freeman, K. H. (2010). Global patterns in leaf ^{13}C discrimination and implications for studies of past and future climate. *Proceedings of the National Academy of Sciences*, *107*(13), 5738-5743.

Dodd M. B., Lauenroth W. K., & Welker J. M. (1998). Differential water resource use by herbaceous and woody plant life-forms in a shortgrass steppe community. *Oecologia, 117*, 504-512.

Donovan L. A., Ehleringer J. R., (1991). Ecophysiological differences among juvenile and reproductive plants of several woody species. *Oecologia, 86*, 594-597.

Dungait J. A. J., Docherty G., Straker V., & Evershed R. P. (2008). Interspecific variation in bulk tissue, fatty acid and monosaccharide $\delta^{13}C$ values of leaves from a mesotrophic grassland plant community. *Phytochemistry, 69*, 2041-2051.

Dupouey J. L., Leavitt S., Choisnel E., & Jourdain S., (1993). Modelling carbon isotope fractionation in tree rings based on effective evapotranspiration and soil water status. *Plant, Cell & Environment, 16*(8), 939-947.

Eggleston, S., Schmitt, J., Bereiter, B., Schneider, R., & Fischer, H. (2016). Evolution of the stable carbon isotope composition of atmospheric CO_2 over the last glacial cycle. *Paleoceanography*, *31*(3), 434-452.

Ehleringer J. R., & Cerling T. E. (1995). Atmospheric CO_2 and the ratio of intercellular to ambient CO_2 concentrations in plants. *Tree physiology, 15*(2), 105-111.

Ehleringer J. R., Lin Z. F., Field C. B., Sun G. C., Kuo C. Y. (1987). Leaf carbon isotope ratios of plants from a subtropical monsoon forest. *Oecologia, 72*, 109-114.

Ehleringer J. R., Phillips S. L., Schuster W. S., & Sandquist D. R. (1991). Differential utilization of summer rains by desert plants. *Oecologia, 88*(3), 430-434.

Ehleringer J. R., Phillips S. L., & Comstock J. P. (1992). Seasonal variation in the carbon isotopic composition of desert plants. *Functional Ecology, 6*, 396-404.

Ehleringer J. R., Hall A. E., Farquhar G. D. (Eds.). (1993). Stable isotopes and plant carbon-water relations (Vol. 109129). San Diego: Academic Press.

Escudero A., Mediavilla S., Heilmeier H. (2008). Leaf longevity and drought: avoidance of the costs and risks of early leaf abscission as inferred from the leaf carbon isotopic composition. *Functional Plant Biology,* 35, 705-713.

Etheridge, D. M., Steele, L. P., Langenfelds, R. L., Francey, R. J., Barnola, J. M., & Morgan, V. I. (1998). Historical CO_2 records from the Law Dome DE08, DE08-2, and DSS ice cores. *Trends: a compendium of data on global change*, 351-364.

Franco A. C., Duarte H. M., Geβler A., de Mattos E. A., Nahm M., Rennenberg H., Lüttge U. (2005). In situ measurements of carbon and nitrogen distribution and composition,

photochemical efficiency and stable isotope ratios in Araucaria angustifolia. *Trees,* 19(4), 422-430.

Friend A. D., Woodward F. I., & Switsur V. R. (1989). Field measurements of photosynthesis, stomatal conductance, leaf nitrogen and $\delta^{13}C$ along altitudinal gradients in Scotland. *Functional Ecology,* 117-122.

Garten C. T., & Taylor G. E. (1992). Foliar $\delta^{13}C$ within a temperate deciduous forest: spatial, temporal, and species sources of variation. *Oecologia, 90*, 1-7.

Gerdol R., Iacumin P., Marchesini R., & Bragazza L. (2000). Water- and nutrient-use efficiency of a deciduous species, *Vaccinium myrtillus*, and an evergreen species, *V. vitis-idaea*, in a subalpine dwarf shrub heath in the southern Alps, Italy. *Oikos 88*(1), 19-32.

Gutierrez M. V., & Meinzer F. C. (1994). Carbon isotope discrimination and photosynthetic gas exchange in coffee hedgerows during canopy development. *Functional Plant Biology, 21*(2), 207-219.

Guy R. D., & Reid D. M. (1986). Photosynthesis and the influence of CO_2-enrichment on $\delta^{13}C$ values in a C_3 halophyte. *Plant, Cell & Environment, 9*(1), 65-72.

Hall A. E., Richards R. A., Condon A. G., Wright G. C., & Farquhar G. D. (1994). Carbon isotope discrimination and plant breeding. *Plant breeding reviews, 12*(81), 113.

Hansen D., & Steig E. (1993). Comparison of water-use efficiency and internal leaf carbon dioxide concentration in juvenile leaves and phyllodes of *Acacia koa* (leguminosae) from Hawaii, estimated by two methods. *American Journal of Botany, 80*(10), 1121-1125.

He C.-X., Li J.-Y., Zhou P., Guo M., & Zheng Q.-S. (2008). Changes of leaf morphological, anatomical structure and carbon isotope ratio with the height of the Wangtian Tree (*Parashorea chinensis*) in Xishuangbanna, China. *Journal of Integrative Plant Biology 50*(2), 168-173.

Hemming D., Yakir D., Ambus P., Aurela M., Besson C., Black K., Gross, P. (2005). Pan-European $\delta^{13}C$ values of air and organic matter from forest ecosystems. *Global Change Biology, 11*(7), 1065-1093.

Holtum J. A. M., & Winter K. (2005). Carbon isotope composition of canopy leaves in a tropical forest in Panama throughout a seasonal cycle. *Trees, 19*(5), 545-551.

Huc R., Ferhi A., & Guehl J. M. (1994). Pioneer and late stage tropical rainforest tree species (French Guiana) growing under common conditions differ in leaf gas exchange regulation, carbon isotope discrimination and leaf water potential. *Oecologia, 99*(3-4), 297-305.

Hultine K. R., & Marshall J. D. (2000). Altitude trends in conifer leaf morphology and stable carbon isotope composition. *Oecologia, 123*(1), 32-40.

Inagaki Y., Miura S., & Kohzu A. (2004). Effects of forest type and stand age on litterfall quality and soil N dynamics in Shikoku district, southern Japan. *Forest Ecology and Management, 202*(1-3), 107-117.

Ismail A. M., & Hall, A. E. (1993). Inheritance of carbon isotope discrimination and water-use efficiency in cowpea. *Crop Science, 33*(3), 498-503.

Ismail A. M., Hall A. E., & Bray E. A. (1994). Drought and pot size effects on transpiration efficiency and carbon isotope discrimination of cowpea accessions and hybrids. *Functional Plant Biology, 21*(1), 23-35.

Johnson R. C., & Tieszen L. L. (1993). Carbon isotope discrimination, water relations, and gas exchange in temperate grass species and accessions. In *Stable isotopes and plant carbon-water relations* (pp. 281-296). Academic Press.

Keeling, C. D., Piper, S. C., Bacastow, R. B., Wahlen, M., Whorf, T. P., Heimann, M., & Meijer, H. A. (2005). Atmospheric CO_2 and $^{13}CO_2$ exchange with the terrestrial biosphere and oceans from 1978 to 2000: Observations and carbon cycle implications. In *A history of atmospheric CO_2 and its effects on plants, animals, and ecosystems* (pp. 83-113). Springer, New York, NY.

Keeling, C. D., Piper, S. C., Bacastow, R. B., Wahlen, M., Whorf, T. P., Heimann, M., & Meijer, H. A. (2005). Terrestrial biosphere and oceans from 1978 to 2000: observations and carbon cycle implications. *A History of Atmospheric CO_2 and Its Effects on Plants, Animals and Ecosystems*, *2*, 83-113.

Kloeppel B. D., Gower S. T., Treichel I. W., & Kharuk S. (1998). Foliar carbon isotope discrimination in *Larix* species and sympatric evergreen conifers: a global comparison. *Oecologia, 114*(2), 153-159.

Körner C., Farquhar G. D., Roksandic Z. (1988). A global survey of carbon isotope discrimination in plants from high altitude. *Oecologia, 74*(4), 623-632.

Kohorn L. U., Goldstein G., & Rundel P. W. (1994). Morphological and isotopic indicators of growth environment - variability in $\delta^{13}C$ in *Simmondsia chinensis*, a dioecious desert shrub. Journal of Experimental Botany, *45*(12), 1817-1822.

Leffler A. J., & Enquist B. J. (2002).Carbon isotope composition of tree leaves from Guanacaste, Costa Rica: comparison across tropical forests and tree life history. *Journal of Tropical Ecology, 18*(1), 151-159.

Li Z.-H., Leavitt S. W., Mora C. I., & Liu R.-M., (2005). Influence of earlywood-latewood size and isotope differences on long-term tree-ring $\delta^{13}C$ trends. Chemical Geology, *216*(3-4), 191-201.

Lockheart M. J., Van Bergen P. F., & Evershed R. P. (1997). Variations in the stable carbon isotope compositions of individual lipids from the leaves of modern angiosperms:

implications for the study of higher land plant-derived sedimentary organic matter. *Organic Geochemistry, 26*(1-2), 137-153.

Marshall J. D., & Zhang J. (1994). Carbon isotope discrimination and water-use efficiency in native plants of the north-central Rockies. *Ecology, 75*(7), 1887-1895.

Martin B., & Thorstenson Y. R. (1988). Stable carbon isotope composition ($\delta^{13}C$), water use efficiency, and biomass productivity of *Lycopersicon esculentum, Lycopersicon pennellii*, and the F1 hybrid. *Plant Physiology, 88*(1), 213-217.

Martin B., Bytnerowicz A., & Thorstenson Y. R. (1988). Effects of air pollutants on the composition of stable carbon isotopes, $\delta^{13}C$, of leaves and wood, and on leaf injury. *Plant Physiology, 88*(1), 218-223.

Mayland H. F., Johnson D. A., Asay K. H., & Read J. J. (1993). Ash, carbon isotope discrimination, and silicon as estimators of transpiration efficiency in crested wheatgrass. *Functional Plant Biology, 20*(3), 361-369.

McArthur J. V., & Moorhead K. K. (1996). Characterization of riparian species and stream detritus using multiple stable isotopes. *Oecologia 107*(2), 32-238.

Mervenne C. (2015). Isotope ecology of temperate conifers (Masters' Thesis, University of Michigan, Ann Arbor, MI, United States of America).

Mole S., Joern A. (1994). Feeding behavior of graminivorous grasshoppers in response to host-plant extracts, alkaloids, and tannins. *Journal of chemical ecology, 20*(12), 3097-3109.

Mooney H. A., Bullock S. H., & Ehleringer J. R. (1989). Carbon isotope ratios of plants of a tropical dry forest in Mexico. *Functional Ecology, 3,* 137-142.

Morgan J. A., LeCain D. R., McCaig T. N., & Quick J. S. (1993). Gas exchange, carbon isotope discrimination, and productivity in winter wheat. *Crop Science, 33*(1), 178-186.

PRISM Climate Group, Oregon State University. (2004). http://prism.oregonstate.edu, created 4 Feb 2004.

Rubino, M., Etheridge, D. M., Trudinger, C. M., Allison, C. E., Battle, M. O., Langenfelds, R. L., Steele, L. P., Curran, M., Bender, M., White, J. W. C. & Jenk, T. M. (2013). A revised 1000 year atmospheric $\delta^{13}C$-CO_2 record from Law Dome and South Pole, Antarctica. *Journal of Geophysical Research: Atmospheres*, *118*(15), 8482-8499.

Rao R. N., Williams J. H., Wadia K. D. R., Hubick K. T., & Farquhar G. D. (1993). Crop growth, water-use efficiency and carbon isotope discrimination in groundnut (*Arachis hypogaea L.*) genotypes under end-of season drought conditions. *Annals of applied Biology, 122*(2), 357-367.

Nagy L., & Proctor J. (2000). Leaf $\delta^{13}C$ signatures in heath and lowland evergreen rain forest species from Borneo. *Journal of Tropical Ecology, 16,* 757-761.

Osorio J., & Pereira J. S. (1994). Genotypic differences in water use efficiency and ^{13}C discrimination in *Eucalyptus globulus*. *Tree Physiology, 14*(7-8-9), 871-882.

Panek J. A. (1996). Correlations between stable carbon-isotope abundance and hydraulic conductivity in Douglas-fir across a climate gradient in Oregon, USA. *Tree Physiology, 16*(9), 747-755.

Peñuelas J., & Azcón-Bieto J. (1992). Changes in leaf $\Delta^{13}C$ of herbarium plant species during the last 3 centuries of CO_2 increase. *Plant, Cell & Environment, 15*(4), 485-489.

Polley H. W., Johnson H. B., & Mayeux H. S. (1995). Nitrogen and water requirements of C_3 plants grown at glacial to present carbon dioxide concentrations. *Functional Ecology,* 86-96.

Royles J., Horwath A. B., & Griffiths H. (2014). Interpreting bryophyte stable carbon isotope composition: Plants as temporal and spatial climate recorders. *Geochemistry, Geophysics, Geosystems, 15*(4), 1462-1475.

Rundel P. W., Stichler W., Zander R. H., & Ziegler H. (1979). Carbon and hydrogen isotope ratios of bryophytes from arid and humid regions. *Oecologia, 44*(1), 91-94.

Sandquist D. R., & Cordell S. (2007). Functional diversity of carbon-gain, water-use, and leaf-allocation traits in trees of a threatened lowland dry forest in Hawaii. *American Journal of Botany, 94*(9), 1459-1469.

Schubert B. A., & Jahren A. H. (2012). The effect of atmospheric CO_2 concentration on carbon isotope fractionation in C_3 land plants. *Geochimica et Cosmochimica Acta, 96,* 29-43.

Sheldon N. D., Smith SY, Stein R. A., & Ng M. (2020). Carbon isotope ecology of gymnosperms and implications for paleoclimatic and paleoecological studies. *Global and Planetary Change, 184,* 103060, 1-17.

Simpson D. A., Muasya A. M., Chayamarit K., Parnell J. A., Suddee S., Wilde B. D., & Pooma R. (2005). *Khaosokia caricoides*, a new genus and species of Cyperaceae from Thailand. *Botanical Journal of the Linnean Society, 149*(3), 357-364.

Smedley M. P., Dawson T. E., Comstock J. P., Donovan L. A., Sherrill E., Cook C. S., & Ehleringer J. R. (1991). Seasonal carbon isotope discrimination in a grassland community. *Oecologia, 85*(3), 314-320.

Sternberg L. O., Deniro M. J., & Johnson H. B. (1984). Isotope ratios of cellulose from plants having different photosynthetic pathways. *Plant Physiology, 74*(3), 557-561.

Terwilliger V. J. (1997). Changes in the $\delta^{13}C$ values of trees during a tropical rainy season: some effects in addition to diffusion and carboxylation by Rubisco? *American Journal of Botany, 84*(12), 1693-1700.

Toft N. L., Anderson J. E., & Nowak R. S. (1989). Water use efficiency and carbon isotope composition of plants in a cold desert environment. *Oecologia, 80*(1), 11-18.

Tu T. T. N., Kürschner W. M., Schouten S., & Van Bergen P. F. (2004). Leaf carbon isotope composition of fossil and extant oaks grown under differing atmospheric CO_2 levels. *Palaeogeography, Palaeoclimatology, Palaeoecology, 212*(3-4), 199-213.

Uemura A., Harayama H., Koike N., & Ishida A. (2006). Coordination of crown structure, leaf plasticity and carbon gain within the crowns of three winter-deciduous mature trees. *Tree Physiology, 26*(5), 633-641.

Ueno O., Samejima M., Muto S., & Miyachi S. (1988). Photosynthetic characteristics of an amphibious plant, Eleocharis vivipara: expression of C_4 and C_3 modes in contrasting environments. *Proceedings of the National Academy of Sciences, 85*(18), 6733-6737.

Valentini R., Anfodillo T., & Ehleringer J. R. (1994). Water sources and carbon-isotope composition ($\delta^{13}C$) of selected tree species of the Italian Alps. *Canadian Journal of Forest Research, 24*(8), 1575-1579.

Valentini R., Mugnozza G. E. S., & Ehleringer J. R. (1992). Hydrogen and carbon isotope ratios of selected species of a Mediterranean Macchia ecosystem. *Functional Ecology,* 627-631.

Van de Water P., Leavitt S., & Betancourt J. (2002). Leaf $\delta^{13}C$ variability with elevation, slope aspect, and precipitation in the southwest United States. *Oecologia*, *132*(3), 332-343.

Van de Water P. K., Leavitt S. W., & Betancourt J. L. (1994). Trends in stomatal density and $^{13}C/^{12}C$ ratios of *Pinus flexilis* needles during last glacial-interglacial cycle. *Science, 264*(5156), 239-243.

Welker J. M., Wookey P. A., Parsons A. N., Press M. C., Callaghan T. V., & Lee J. A. (1993). Leaf carbon isotope discrimination and vegetative responses of *Dryas octopetala* to temperature and water manipulations in a High Arctic polar semi-desert, Svalbard. *Oecologia, 95*(4), 463-469.

White J. W., Castillo J. A., Ehleringer J. R., Garcia J. A. C., & Singh S. P. (1994). Relations of carbon isotope discrimination and other physiological traits to yield in common bean (*Phaseolus vulgaris*) under rainfed conditions. *The Journal of Agricultural Science, 122*(2), 275-284.

White, J.W.C., Vaughn, B.H., Michel, S.E. (2015). University of Colorado, Institute of Arctic and 720 Alpine Research (INSTAAR), Stable Isotopic Composition of Atmospheric Carbon Dioxide (^{13}C and ^{18}O) from the NOAA ESRL Carbon Cycle Cooperative Global Air Sampling Network, 722 1990-2014, Version: 2015-10-26.

Williams D. G., & Ehleringer J. R. (1996). Carbon isotope discrimination in three semi-arid woodland species along a monsoon gradient. *Oecologia, 106(*4), 455-460.

Williams D. G., & Ehleringer J. R. (2000). Carbon isotope discrimination and water relations of oak hybrid populations in southwestern Utah. *Western North American Naturalist,* 121-129.

Winter K., Troughton J. H. (1978). Carbon assimilation pathways in *Mesembryanthemum nodiflorum* L. under natural conditions. *Zeitschrift für Pflanzenphysiologie, 88*(2), 153-162.

Wright G. C., Rao R. C., & Farquhar G. D. (1994). Water-use efficiency and carbon isotope discrimination in peanut under water deficit conditions. *Crop Science, 34*(1), 92-97 (1994).

Zhang J., Marshall J. D., & Jaquish B. D. (1993). Genetic differentiation in carbon isotope discrimination and gas exchange in *Pseudotsuga menziesii*. *Oecologia, 93*(1), 80-87.

Zhang J., Fins L., & Marshall J. D. (1994). Stable carbon isotope discrimination, photosynthetic gas exchange, and growth differences among western larch families. *Tree Physiology, 14*(5), 531-539.

Zibulski, R., Wesener F., Wilkes H., Plessen B., Pestryakova L. A., & Herzschuh, U. (2019). C/N ratio, stable isotope ($\delta^{13}C$, $\delta^{15}N$), and n-alkane patterns of brown mosses along hydrological gradients of low-centred polygons of the Siberian Arctic. *Biogeosciences, 14*(6), 1617-1630.

APPENDIX C

Supplemental Figures, Tables and References for Chapter IV

Table C1 Range of conditions for which soils are tested.

Variable	Unit	Minimum	Maximum
Time	Year	1900	2017
$\delta^{13}C_{atm}$	‰	-8.59	-6.50
pCO_2	ppm	295.3	411.75
Latitude	°N	-78.03	54.65
Longitude	°E	-155.73	175.36
Mean Annual Precipitation	mm yr^{-1}	100	3350
Mean Annual Temperature	°C	2.5	23.4
Elevation	m	1.0	2854.6
Growing Season Precipitation	mm / season	22.5	1777.2
Vapor Pressure Deficit (Minimum)	hPa	0.00	7.04
Vapor Pressure Deficit (Maximum)	hPa	7.45	32.11

Table C2 Multivariate relationships including coefficients of determination (R^2) and significance (p-value column). Error for coefficients is shown in parentheses in each equation. The comparative single variable relationship between MAP and carbon isotope values in soil is provided in the box below.

Equation	R^2	p - value
Δ_{SOM} = 5.24(±0.57)*log10MAP - 0.01(±0.01)*(√Elevation) + 4.70(±1.77)	0.62	<0.001
Δ_{SOM} = 0.002(±0.00)*(MAP) -0.01(±0.01)*(√Elevation) + 18.03(±0.43)	0.58	<0.001
Δ_{SOM} = 5.25(±0.56)*(log10MAP) - 0.00(±0.00)*(Elevation) + 4.54(±1.70)	0.62	<0.001
Δ_{SOM} = 0.002(±0.00)(MAP) - 0.00(±0.00)*(Elevation) + 17.80(±0.36)	0.58	<0.001
Δ_{SOM} = 4.83(±0.36)(log10MAP) + 0.00(±0.00)(Longitude) + 5.69(±1.08)	0.64	<0.001
Δ_{SOM} = 0.00(±0.00)*(MAP) + 0.00(±0.00)*(Longitude) + 17.76(±0.23)	0.59	<0.001
Δ_{SOM} = 0.01(±0.01)*([Latitude|) + 5.07(±0.35)*($\log_{10}$MAP) + 4.74(±1.17)	0.63	<0.001
Δ_{SOM} = 0.02(±0.01)*(|Latitude|) + 0.002(±0.00)*(MAP) + 16.76(±0.49)	0.59	<0.001
Δ_{SOM} = 4.69(±0.48)*(log10MAP) + 0.01(±0.06)*(VPD Min) + 6.00(±1.39)	0.37	<0.001
Δ_{SOM} = 0.00(±0.00)*(MAP) - 0.31(±0.06)*(VPD Min) + 18.45(±0.16)	0.33	<0.001
Δ_{SOM} = 2.14LN(MAP) + 5.37	0.64	<0.001
$\delta^{13}C_{SOM}$ = -2.04LN(MAP)-11.99	0.68	<0.001

Table C3 All soil, paleosol, and reference data for modern and ancient samples included in this study. For soil carbon isotope data taken from literature, there is an accompanying reference to the published journal article.

Study	Soil Order[A]	Collector	RS Sample ID	Munsell's Color	Parent Material	Family or broad taxonomic IDID	Genus	Species	Year	Date	pCO_2 [B]	Preindustrial $\delta^{13}C_{atm}$	$\delta^{13}C_{atm}$ [C]	Origin	Latitude (°N)	ABS(Latitude) (°)	Longitude (°E)	Mean Annual Precipitation (mm yr^{-1})	MAP source	Elevation (m)	Growing Season Precipitation (mm season^{-1})	MAT (°C, PRISM)	Maximum Growing Season Month Temperature (°C)	VPD Min (hPa)	VPD Max (hPa)	%N (acidified)	%C acidified	C:N (weight %) acidified	Acidified $\delta^{13}C_{SOM}$ (‰ VPDB)	actual Δ_{SOM} (see equation 2)	actual ΔSOM using fixed $\delta^{13}C_{atm}$ value of -6.5‰ (see equation 2)	$\delta^{13}C_{leaf}$ (‰)
This study	Alfisol	Rebekah St	697-O	2.5YR 2.5/1	n/a	Cupressaceae	*Thuja*	*Thuja occidentalis*	2017	9/24/2017	403.38	-6.5	-8.59	42 24.383', -83 56.516	42.406383	42.406383	-83.941933	793.65	PRISM Clim	281.94	551.05	8.8	22.6	0	23.98	0.37	5.43	14.675676	n/a	n/a	n/a	-26.71
This study	Alfisol	Rebekah St	698-O	2.5 YR 5/3	n/a	Cupressaceae	*Thuja*	*Thuja occidentalis*	2017	9/24/2017	403.38	-6.5	-8.59	42 24.388', 83 56.455'	42.406467	42.406467	83.940917	793.65	PRISM Clim	277.7	551.05	8.8	22.6	0	23.98	0.1	1.12	11.2	-24.55517	16.367062	18.509674	-27.21
This study	Alfisol	Rebekah St	699-O	5 YR 2.5/1	n/a	Cupressaceae	*Thuja*	*Thuja occidentalis*	2017	9/24/2017	403.38	-6.5	-8.59	42 24.402' -83 56.436'	42.4067	42.4067	-83.940600	793.65	PRISM Clim	287.4	551.05	8.8	22.6	0	23.98	n/a	n/a	n/a	n/a	n/a	n/a	-26.17
This study	Entisol	Rebekah St	742-O	5YR 5/2	n/a	Cupressaceae	*Thuja*	*Thuja plicata*	2018	5/15/2018	411.24	-6.5	-8.51	Cedar Grove Picnic Area	46.53888	46.53888	-114.675760	826	PRISM Clim	1105.8	399.57	7.2	17.3	0	31.74	0.17	3.78	22.235294	-27.34766	19.367308	21.433823	-28.18
This study	Spodosol	Rebecca D	17-05	n/a	n/a	unk	unk	unk	2017	May	unk	-6.5	-8.49	Mt. Rainier NP	47.15252	47.15252	-121.684050	unk	PRISM Clim	800	unk	7.5	11.9	unk	unk	n/a	n/a	n/a	-24.5674	16.482328	18.522448	n/a
This study	Spodosol	Rebecca D	17-08	n/a	n/a	unk	unk	unk	2017	May	unk	-6.5	-8.49	Mt. Rainier NP	47.15271	47.15271	-121.684280	unk	PRISM Clim	799	unk	8.1	12.2	unk	unk	n/a	n/a	n/a	-25.7565	17.722982	19.765592	n/a
This study	Spodosol	Rebecca D	17-04	n/a	n/a	unk	unk	unk	2017	May	unk	-6.5	-8.49	Mt. Rainier NP	47.15252	47.15252	-121.684050	unk	PRISM Clim	800	unk	7.5	11.9	unk	unk	n/a	n/a	n/a	-25.2013	17.143334	19.184781	n/a
This study	Spodosol	Rebecca D	17-03	n/a	n/a	unk	unk	unk	2017	May	unk	-6.5	-8.49	Mt. Rainier NP	47.15252	47.15252	-121.684050	1877.73	PRISM Clim	800	unk	7.5	11.9	unk	unk	n/a	n/a	n/a	-26.1172	18.099919	20.143286	n/a
This study	Spodosol	Rebecca D	17-01	n/a	n/a	unk	unk	unk	2017	May	unk	-6.5	-8.49	Mt. Rainier NP	47.15252	47.15252	-121.684050	1877.73	PRISM Clim	800	unk	7.5	11.9	unk	unk	n/a	n/a	n/a	-26.6947	18.703998	20.748577	n/a
This study	Andisol	Rebekah St	768-twoO	n/a	n/a	Cupressaceae	*Thuja*	*Thuja plicata*	2018	5/18/2018	411.24	-6.5	-8.51	Staircase Campground	47.51615	47.51615	-123.3277	alues >3000	PRISM Clim	296.6	970.22	10.4	18	0.12	23.47	0.55	28.14	51.163636	-26.50315	18.483003	20.547725	-32.41
This study	Andisol	Rebekah St	768-fiveO	n/a	n/a	Cupressaceae	*Thuja*	*Thuja plicata*	2018	5/18/2018	411.24	-6.5	-8.51	Staircase Campground	47.51615	47.51615	-123.3277	alues >3000	PRISM Clim	296.6	970.22	10.4	18	0.12	23.47	1.03	50	48.543689	-26.00373	17.960774	20.024437	-32.41
This study	Andisol	Rebekah St	768-O (10m	5YR 4/2	n/a	Cupressaceae	*Thuja*	*Thuja plicata*	2018	5/18/2018	411.24	-6.5	-8.51	Staircase Campground	47.51615	47.51615	-123.3277	alues >3000	PRISM Clim	296.6	970.22	10.4	18	0.12	23.47	0.39	12.06	30.923077	-26.70663	18.69594	20.761093	-32.41
This study	Andisol	Rebekah St	770-O	5YR 4/2	n/a	Cupressaceae	*Thuja*	*Thuja plicata*	2018	5/18/2018	411.24	-6.5	-8.51	Copper Mountain	47.51687	47.51687	-123.32836	3195.57	PRISM Clim	289.56	970.22	10.4	18	0.12	23.47	n/a	n/a	n/a	n/a	n/a	n/a	-30.11
This study	Alfisol	Rebekah St	779**	n/a	n/a	Cupressaceae	*Thuja*	*Thuja occidentalis*	2018	7/25/2018	406.38	-6.5	-8.52	Stinchfield Woods	42.28154	42.28154	-83.73957	793.65	PRISM Clim	276.5	614.17	9.8	22.6	0	23.98	n/a	n/a	n/a	n/a	n/a	n/a	-29.52
This study	Alfisol	Rebekah St	779-tenO	n/a	n/a	Cupressaceae	*Thuja*	*Thuja occidentalis*	2018	7/25/2018	406.38	-6.5	-8.52	Stinchfield Woods	42.28154	42.28154	-83.73957	793.65	PRISM Clim	276.5	614.17	9.8	22.6	0	23.98	2.98	48.38	16.234899	n/a	n/a	n/a	-29.52
This study	Alfisol	Rebekah St	804-twoO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	7/31/2018	406.90	-6.5	-8.52	Beaver Creek Road, Rio Grand	37.647636	37.647636	-106.651966	418.07	PRISM Clim	2531.8	163.35	5.4	16.6	0.05	28.84	0.22	2.82	12.818182	-24.2537	16.124785	18.194995	-26.69
This study	Alfisol	Rebekah St	804-fiveO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	7/31/2018	406.90	-6.5	-8.52	Beaver Creek Road, Rio Grand	37.647636	37.647636	-106.651966	418.07	PRISM Clim	2531.8	163.35	5.4	16.6	0.05	28.84	0.18	2.39	13.277778	-23.29187	15.124136	17.192308	-26.69
This study	Alfisol	Rebekah St	810-fiveO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	7/31/2018	406.90	-6.5	-8.52	Rio Grande National Forest	37.647918	37.647918	-106.651856	418.07	PRISM Clim	2531.9	163.35	5.4	16.6	0.05	28.84	0.25	4.25	17	-24.9518	16.852298	18.923991	-28.04
This study	Alfisol	Rebekah St	810-tenO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	7/31/2018	406.90	-6.5	-8.52	Rio Grande National Forest	37.647918	37.647918	-106.651856	418.07	PRISM Clim	2531.9	163.35	5.4	16.6	0.05	28.84	0.32	4.48	14	-24.61245	16.498516	18.569488	-28.04
This study	Inceptisol	Rebekah St	831-twoO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	8/3/2018	406.38	-6.5	-8.52	Cub Lake Trail, ROMO	40.355497	40.355497	-105.616112	759.91	PRISM Clim	2470	298.91	5.4	15.7	0.73	24.76	0.32	4.98	15.5625	-25.85643	17.796586	19.870202	-30.42
This study	Inceptisol	Rebekah St	831-fiveO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	8/3/2018	406.38	-6.5	-8.52	Cub Lake Trail, ROMO	40.355497	40.355497	-105.616112	759.91	PRISM Clim	2470	298.91	5.4	15.7	0.73	24.76	0.48	6.98	14.541667	-26.3897	18.354062	20.428814	-30.42
This study	Inceptisol	Rebekah St	831-tenO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	8/3/2018	406.38	-6.5	-8.52	Cub Lake Trail, ROMO	40.355497	40.355497	-105.616112	759.91	PRISM Clim	2470	298.91	5.4	15.7	0.73	24.76	0.38	5.19	13.657895	-25.97472	17.920192	19.99406	-30.42
This study	Inceptisol	Rebekah St	833-twoO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	8/3/2018	406.38	-6.5	-8.52	Fern Lake Trail	40.355149	40.355149	-105.632551	759.91	PRISM Clim	2504.2	298.91	5.4	15.7	0.73	24.76	0.27	4.5	16.666667	-26.02882	17.976737	20.05072	-30.39
This study	Inceptisol	Rebekah St	833-fiveO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	8/3/2018	406.38	-6.5	-8.52	Fern Lake Trail	40.355149	40.355149	-105.632551	759.91	PRISM Clim	2504.2	298.91	5.4	15.7	0.73	24.76	0.37	7.18	19.405405	-26.07625	18.026313	20.100398	-30.39
This study	Inceptisol	Rebekah St	839-twoO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	8/3/2018	406.38	-6.5	-8.52	Rocky Mountain National Park	40.39555	40.39555	-105.653029	1023.92	PRISM Clim	2854.6	364.53	2.5	12.6	0.44	19.11	0.45	8.59	19.088889	-25.80944	17.747498	19.821014	-29.27
This study	Inceptisol	Rebekah St	839-fiveO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	8/3/2018	406.38	-6.5	-8.52	Rocky Mountain National Park	40.39555	40.39555	-105.653029	1023.92	PRISM Clim	2854.6	364.53	2.5	12.6	0.44	19.11	0.49	9.11	18.591837	-25.56555	17.492765	19.565763	-29.27
This study	Inceptisol	Rebekah St	839-tenO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	8/3/2018	406.38	-6.5	-8.52	Rocky Mountain National Park	40.39555	40.39555	-105.653029	1023.92	PRISM Clim	2854.6	364.53	2.5	12.6	0.44	19.11	0.42	8.64	20.571429	-24.78666	16.680102	18.751443	-29.27
This study	Inceptisol	Rebekah St	842-twoO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	8/3/2018	406.38	-6.5	-8.52	Glacier Grove, Alberta Falls	40.309483	40.309483	-105.640485	1300.66	PRISM Clim	2793.2	408.72	2.8	13.1	0.46	19.38	0.24	3.63	15.125	-26.05132	18.000247	20.074279	-28.07
This study	Inceptisol	Rebekah St	842-fiveO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	8/3/2018	406.38	-6.5	-8.52	Glacier Grove, Alberta Falls	40.309483	40.309483	-105.640485	1300.66	PRISM Clim	2793.2	408.72	2.8	13.1	0.46	19.38			n/a	n/a	n/a	n/a	-28.07
This study	Inceptisol	Rebekah St	842-tenO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	8/3/2018	406.38	-6.5	-8.52	Glacier Grove, Alberta Falls	40.309483	40.309483	-105.640485	1300.66	PRISM Clim	2793.2	408.72	2.8	13.1	0.46	19.38	0.28	4.53	16.178571	-25.09045	16.996915	19.068902	-28.07
This study	Inceptisol	Rebekah St	847-fiveO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	8/4/2018	406.38	-6.5	-8.52	Vail Resorts Stables	39.643875	39.643875	-106.369176	636.7	PRISM Clim	2576.3	300.61	4.5	15.7	0.2	26.07			n/a	n/a	n/a	n/a	-27.20
This study	Inceptisol	Rebekah St	847-tenO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	8/4/2018	406.38	-6.5	-8.52	Vail Resorts Stables	39.643875	39.643875	-106.369176	636.7	PRISM Clim	2576.3	300.61	4.5	15.7	0.2	26.07	0.65	8.33	12.815385	-26.02514	17.972885	20.046861	-27.20
This study	Mollisol	Rebekah St	867-twoO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	8/6/2018	406.38	-6.5	-8.52	206 and 72, Fishlake NF	38.58189	38.58189	-111.479193	448.95	PRISM Clim	2729.7	158.29	6	16.8	0.57	29.08	0.33	5.05	15.30303	-24.82285	16.717832	18.789251	-26.24
This study	Mollisol	Rebekah St	867-fiveO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	8/6/2018	406.38	-6.5	-8.52	206 and 72, Fishlake NF	38.58189	38.58189	-111.479193	448.95	PRISM Clim	2729.7	158.29	6	16.8	0.57	29.08	0.23	3.04	13.217391	-23.58662	15.430577	17.499373	-26.24
This study	Mollisol	Rebekah St	867-tenO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	8/6/2018	406.38	-6.5	-8.52	206 and 72, Fishlake NF	38.58189	38.58189	-111.479193	448.95	PRISM Clim	2729.7	158.29	6	16.8	0.57	29.08	0.23	3.29	14.304348	-24.52477	16.407155	18.47794	-26.24
This study	Mollisol	Rebekah St	868-twoO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	8/6/2018	406.38	-6.5	-8.52	Pando, Fishlake National Fores	38.526664	38.526664	-111.748425	650.8	PRISM Clim	2718.1	264.55	4.6	15.8	0.49	26.32	0.21	2.78	13.238095	-23.20751	15.036472	17.104465	-25.55
This study	Mollisol	Rebekah St	868-fiveO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	8/6/2018	406.38	-6.5	-8.52	Pando, Fishlake National Fores	38.526664	38.526664	-111.748425	650.8	PRISM Clim	2718.1	264.55	4.6	15.8	0.49	26.32	n/a	3.26	n/a	-23.84744	15.701891	17.77124	-25.55
This study	Mollisol	Rebekah St	868-tenO	n/a	n/a	Salicaceae	*Populus*	*Populus tremuloide*	2018	8/6/2018	406.38	-6.5	-8.52	Pando, Fishlake National Fores	38.526664	38.526664	-111.748425	650.8	PRISM Clim	2718.1	264.55	4.6	15.8	0.49	26.32	n/a	n/a	n/a	n/a	n/a	n/a	-25.55
This study	Alfisol	Rebekah St	914-twoOB	n/a	n/a	Cupressaceae	*Thuja*	*Thuja occidentalis*	2018	10/13/2018	403.56	-6.5	-8.51	Stinchfield Woods	42.28154	42.28154	-83.73957	793.65	PRISM Clim	276.5	551.05	8.8	22.6	0	23.98	0.11	1.52	13.818182	-25.8183	17.767013	19.830283	-30.11
This study	Alfisol	Rebekah St	914-twoOT	n/a	n/a	Cupressaceae	*Thuja*	*Thuja occidentalis*	2018	10/13/2018	403.56	-6.5	-8.51	Stinchfield Woods	42.28154	42.28154	-83.73957	793.65	PRISM Clim	276.5	551.05	8.8	22.6	0	23.98	0.11	1.33	12.090909	-25.92822	17.881864	19.945367	-30.11
This study	Alfisol	Rebekah St	914-fiveOT	n/a	n/a	Cupressaceae	*Thuja*	*Thuja occidentalis*	2018	10/13/2018	403.56	-6.5	-8.51	Stinchfield Woods	42.28154	42.28154	-83.73957	793.65	PRISM Clim	276.5	551.05	8.8	22.6	0	23.98	0.09	1.01	11.222222	-25.6242	17.564271	19.62713	-30.11
This study	Alfisol	Rebekah St	914-fiveOB	n/a	n/a	Cupressaceae	*Thuja*	*Thuja occidentalis*	2018	10/13/2018	403.56	-6.5	-8.51	Stinchfield Woods	42.28154	42.28154	-83.73957	793.65	PRISM Clim	276.5	551.05	8.8	22.6	0	23.98	0.11	1.43	13	-24.82441	16.729717	18.790884	-30.11
This study	Alfisol	Rebekah St	914-tenOB	n/a	n/a	Cupressaceae	*Thuja*	*Thuja occidentalis*	2018	10/13/2018	403.56	-6.5	-8.51	Stinchfield Woods	42.28154	42.28154	-83.73957	793.65	PRISM Clim	276.5	551.05	8.8	22.6	0	23.98	0.27	3.77	13.962963	-25.7017	17.645207	19.70823	-30.11
This study	Alfisol	Rebekah St	914-tenOT	n/a	n/a	Cupressaceae	*Thuja*	*Thuja occidentalis*	2018	10/13/2018	403.56	-6.5	-8.51	Stinchfield Woods	42.28154	42.28154	-83.73957	793.65	PRISM Clim	276.5	551.05	8.8	22.6	0	23.98	0.2	2.63	13.15	-25.52485	17.460525	19.523174	-30.11
This study	Alfisol	Rebekah St	915-twoOB	n/a	n/a	Cupressaceae	*Thuja*	*Thuja occidentalis*	2018	10/13/2018	403.56	-6.5	-8.51	Stinchfield Woods	42.28154	42.28154	-83.73957	793.65	PRISM Clim	276.5	551.05	8.8	22.6	0	23.98	0.07	0.85	12.142857	-24.40316	16.290701	18.350979	-29.84
This study	Alfisol	Rebekah St	915-twoOT	n/a	n/a	Cupressaceae	*Thuja*	*Thuja occidentalis*	2018	10/13/2018	403.56	-6.5	-8.51	Stinchfield Woods	42.28154	42.28154	-83.73957	793.65	PRISM Clim	276.5	551.05	8.8	22.6	0	23.98	0.09	1.07	11.888889	-26.20343	18.16953	20.233616	-29.84
This study	Alfisol	Rebekah St	915-fiveOB	n/a	n/a	Cupressaceae	*Thuja*	*Thuja occidentalis*	2018	10/13/2018	403.56	-6.5	-8.51	Stinchfield Woods	42.28154	42.28154	-83.73957	793.65	PRISM Clim	276.5	551.05	8.8	22.6	0	23.98	0.07	0.8	11.428571	-24.7042	16.604393	18.665306	-29.84
This study	Alfisol	Rebekah St	915-fiveOT	n/a	n/a	Cupressaceae	*Thuja*	*Thuja occidentalis*	2018	10/13/2018	403.56	-6.5	-8.51	Stinchfield Woods	42.28154	42.28154	-83.73957	793.65	PRISM Clim	276.5	551.05	8.8	22.6	0	23.98	0.09	1.04	11.555556	-24.29983	16.183076	18.243135	-29.84
This study	Alfisol	Rebekah St	915-tenOT	n/a	n/a	Cupressaceae	*Thuja*	*Thuja occidentalis*	2018	10/13/2018	403.56	-6.5	-8.51	Stinchfield Woods	42.28154	42.28154	-83.73957	793.65	PRISM Clim	276.5	551.05	8.8	22.6	0	23.98	n/a	n/a	n/a	-25.35595	17.284206	19.346497	-29.84
This study	Alfisol	Rebekah St	920-twoOT	n/a	n/a	Cupressaceae	*Thuja*	*Thuja occidentalis*	2019	2/9/2019	411.75	-6.5	-8.51	Stinchfield Woods	42.406508	42.406508	-83.941841	793.65	PRISM Clim	276.5	551.05	8.8	22.6	0	23.98	n/a	n/a	n/a	n/a	n/a	n/a	n/a
This study	Alfisol	Rebekah St	920-fiveOT	n/a	n/a	Cupressaceae	*Thuja*	*Thuja occidentalis*	2019	2/9/2019	411.75	-6.5	-8.51	Stinchfield Woods	42.406508	42.406508	-83.941841	793.65	PRISM Clim	276.5	551.05	8.8	22.6	0	23.98	n/a	n/a	n/a	n/a	n/a	n/a	n/a
This study	Alfisol	Rebekah St	920-tenOT	n/a	n/a	Cupressaceae	*Thuja*	*Thuja occidentalis*	2019	2/9/2019	411.75	-6.5	-8.51	Stinchfield Woods	42.406508	42.406508	-83.941841	793.65	PRISM Clim	276.5	551.05	8.8	22.6	0	23.98	n/a	n/a	n/a	-27.71277	19.7501	21.817391	n/a
This study	Alfisol	Rebekah St	921-00	n/a	n/a	Cupressaceae	*Thuja*	*Thuja occidentalis*	2019	2/9/2019	411.75	-6.5	-8.51	Stinchfield Woods	42.406765	42.406765	-83.941899	793.65	PRISM Clim	276.5	551.05	8.8	22.6	0	23.98	n/a	n/a	n/a	-25.83898	17.788617	19.851931	n/a
McPherson et al. 1993 O	Alfisol	n/a	n/a	n/a	n/a	Fagaceae	*Quercus*	*Quercus sp.*	1990	n/a	351.4	-6.5	-7.76	Southern AZ; 31 ~ 36' N, 110 ~ 30" W, in	31.559892	31.559892	-110.526484	309.63	PRISM Clim	1461		14.4		3.13	22.81	n/a	n/a	n/a	-21	13.524004	14.811032	n/a
Wynn et al. 2006 Geoder	Alfisol	n/a	n/a	n/a	n/a	Fagaceae	*Quercus*	*Quercus stellata*	2004	n/a	374.49	-6.5	-8.11	Goodwin Creek Control Site va	34.255725	34.255725	-89.89658	1829.04	PRISM Clim	92	865.94	16.6	23.4	unk	unk	n/a	n/a	n/a	-27.2	19.623766	21.278783	n/a
Wynn et al. 2006 Geoder	Alfisol	n/a	n/a	n/a	n/a	Fagaceae	*Quercus*	*Quercus stellata*	2004	n/a	374.49	-6.5	-8.11	Goodwin Creek Control Site sl	34.255725	34.255725	-89.89658	1829.04	PRISM Clim	92	865.94	16.6	23.4	unk	unk	n/a	n/a	n/a	-27.4	19.833436	21.488793	n/a
Wynn et al. 2006 Geoder	Alfisol	n/a	n/a	n/a	n/a	Fagaceae	*Quercus*	*Quercus stellata*	2004	n/a	374.49	-6.5	-8.11	Goodwin Creek Control Site up	34.255725	34.255725	-89.89658	1829.04	PRISM Clim	92	865.94	16.6	23.4	unk	unk	n/a	n/a	n/a	-28	20.462963	22.119342	n/a
Wynn et al. 2006 Geoder	Alfisol	n/a	n/a	n/a	n/a	Fagaceae	*Quercus*	*Quercus stellata*	2004	n/a	387.47	-6.5	-8.23	Goodwin Creek Control Site rid	34.255725	34.255725	-89.89658	1829.04	PRISM Clim	92	865.94	16.6	23.4	unk	unk	n/a	n/a	n/a	-27.8	20.129603	21.909072	n/a
Sheldon et al. 2020	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2011	n/a	387.47	-6.5	-8.23	Cornville	35.227	35.227	-111.629	374	PRISM Clim	2169	269.68	8	16.5	1.53	16.58	n/a	n/a	n/a	-23.88	16.032865	17.805188	-27.01
Sheldon et al. 2020	Vertisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2011	n/a	387.47	-6.5	-8.23	Momoli	35.331	35.331	-112.805	311	PRISM Clim	1644	1777.2	11.5	20.9	2.39	23.08	n/a	n/a	n/a	-24.59	16.772434	18.546047	-22.02
Sheldon et al. 2020	Entisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2011	n/a	387.47	-6.5	-8.23	Collbran	34.752	34.752	-111.112	352.18	PRISM Clim	1900	190.52	9.4	17.5	2.06	17.84	n/a	n/a	n/a	-23.23	15.356737	17.127881	-27.47
Sheldon et al. 2020	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2011	n/a	387.47	-6.5	-8.23	Cross	35.482	35.482	-112.175	339	PRISM Clim	1872	214.2	10.3	18.5	2.49	19.57	n/a	n/a	n/a	-20.39	12.413103	14.179112	n/a
Sheldon et al. 2020	Aridisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2011	n/a	387.47	-6.5	-8.23	Disterheff	34.603	34.603	-111.854	313.35	PRISM Clim	957	171.12	16.5	25.7	4.56	32.11	n/a	n/a	n/a	-23.54	15.679086	17.450792	-27.91
Sheldon et al. 2020	Alfisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2011	n/a	387.47	-6.5	-8.23	Katy	30.385	30.385	-95.877	1120	PRISM Clim	106	238.02	21	27.7	1.64	26.79	n/a	n/a	n/a	-27.8	20.129603	21.909072	
Sheldon et al. 2020	Alfisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2011	n/a	387.47	-6.5	-8.23	Katy	30.385	30.385	-95.877	1120	PRISM Clim	106	238.02	21	27.7	1.64	26.79	n/a	n/a	n/a	-26.77	19.049968	20.827554	n/a
Sheldon et al. 2020	Ultisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2011	n/a	387.47	-6.5	-8.23	Bernaldo	32.489	32.489	-94.346	839.97	PRISM Clim	91	294.21	19.3	25.9	2.39	25.4	n/a	n/a	n/a	-27.7	20.024684	21.80397	n/a
Sheldon et al. 2020	Alfisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2011	n/a	387.47	-6.5	-8.23	Loring	33.768	33.768	-89.846	1257	PRISM Clim	92	933.79	17	23.4	0.69	17.27	n/a	n/a	n/a	-26.77	19.049968	20.827554	n/a
Sheldon et al. 2020	Alfisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2011	n/a	387.47	-6.5	-8.23	Memphis	36.074	36.074	-89.459	1245	PRISM Clim	122	1083.94	15.5	21.2	1.3	15.21	n/a	n/a	n/a	-27.29	19.59474	21.373277	n/a
Sheldon et al. 2020	Alfisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2011	n/a	387.47	-6.5	-8.23	Wellston	37.557	37.557	-86.939	1270	PRISM Clim	139	1099.3	14.5	20	1.13	14.27	n/a	n/a	n/a	-26.3	18.558077	20.334805	n/a
Sheldon et al. 2020	Alfisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2011	n/a	387.47	-6.5	-8.23	Wellston	37.557	37.557	-86.939	1270	PRISM Clim	139	1099.3	14.5	20	1.13	14.27	n/a	n/a	n/a	-25.73	17.962167	19.737855	n/a
Sheldon et al. 2020	Alfisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2011	n/a	387.47	-6.5	-8.23	Bonnell	39.507	39.507	-85.16	1067	PRISM Clim	245	911.79	12.1	17.8	0.76	12.93	n/a	n/a	n/a	-27.05	19.343234	21.121332	n/a
Sheldon et al. 2020	Histosol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2011	n/a	387.47	-6.5	-8.23	Wawasee	41.708	41.708	-85.011	940	PRISM Clim	299	758.85	9.3	14.4	0.56	9.81	n/a	n/a	n/a	-25.55	17.774129	19.549489	n/a
Ruf et al. 2006	Alfisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2009	n/a	383.84	-6.5	-8.21	long-term field experimental st	48.710565	48.710565	9.213301	713	Wulfmeyer	387	unk	unk	unk	unk	unk	n/a	n/a	n/a	-26	18.264887	20.020534	n/a
Dijkstra et al. 2006	Alfisol	n/a	n/a	n/a	n/a	Pinaceae	*Pinus*	*Pinus pondersoa*	2001	Aug-01	369.12	-6.5	-7.99	Flagstaff	35.174452	35.174452	-111.630277	660	PRISM Clim	2100	224.61	8.1	16.5	1.54	16.46	n/a	n/a	n/a	-21.9	14.22145	15.744811	n/a
Dijkstra et al. 2006	Alfisol	n/a	n/a	n/a	n/a	Pinaceae	*Pinus*	*Pinus pondersoa*	2001	Aug-01	369.12	-6.5	-7.99	Flagstaff	35.174452	35.174452	-111.630277	660	PRISM Clim	2100	224.61	8.1	16.5	1.54	16.46	n/a	n/a	n/a	-23	15.363357	16.888434	n/a
Dijkstra et al. 2006	Alfisol	n/a	n/a	n/a	n/a	Salicaceae	*Salix*	*Salix bebbiana an*	2003	May-03	372.79	-6.5	-8.08	Flagstaff	35.174452	35.174452	-111.630277	790	PRISM Clim	2600	272.47	8.1	16.5	1.54	16.46	n/a	n/a	n/a	-24.5	16.832394	18.452076	n/a
Balesdent et al. 1987	Alfisol	n/a	n/a	n/a	n/a	n/a	n/a	C3 grasses	1979	n/a	334.43	-6.5	-7.45	Auzeville, Institut National de la Recherche Agronomique, Western France	48.00724	48.00724	-4.108567	1037	Balesdent,	37	unk	11.5	unk	unk	unk	n/a	n/a	n/a	-26.2	19.254467	20.230027	n/a
Balesdent et al. 1987	Alfisol	n/a	n/a	n/a	n/a	n/a	n/a	C3 grasses	1979	n/a	334.43	-6.5	-7.45	Doazit, Institut National de la Recherche Agronomique, Western France	48.00724	48.00724	-4.108567	1037	Balesdent,	37	unk	11.5	unk	unk	unk	n/a	n/a	n/a	-26.7	19.778075	20.754135	n/a
Dumig et al. 2008	Alfisol	n/a	n/a	n/a	n/a	Araucariaceae	n/a	*Araucaria*	2006	n/a	378.42	-6.5	-8.16	Serra Geral, 35km east of Sao	-29.46667	29.46667	-50.21667	2252	Dumig et al.	924	unk	14.5	unk	unk	unk	n/a	n/a	n/a	-28.8	21.252059	22.961285	n/a
Dumig et al. 2008	Alfisol	n/a	n/a	n/a	n/a	Pinaceae	*Pinus*	*Pinus taeda & Pin*	2006	n/a	378.42	-6.5	-8.16	Serra Geral, 35km east of Sao	-29.46667	29.46667	-50.21667	2252	Dumig et al.	924	unk	14.5	unk	unk	unk	n/a	n/a	n/a	-28.6	21.041795	22.750669	n/a
Tabor et al. 2013	Alfisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1999	n/a	365.48	-6.5	-7.97	Bellevista: California	39.75	39.75	-120.18	347	Tabor et al.	1439	102.44	8.3	16.7	2.38	16.99	n/a	n/a	n/a	-24	16.42418	17.930328	n/a
Tabor et al. 2013	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1999	n/a	365.48	-6.5	-7.97	Anacapa: California	34.2	34.2	-119.2	377	Tabor et al.	152	137.72	15.4	20.1	2.15	11.96	n/a	n/a	n/a	-24.2	16.632507	18.138963	n/a
Wynn et al. 2005	Andisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1997	n/a	364.02	-6.5	-8.05	Iron Range National Park, Far	-12.65483	12.65483	143.4048	2159	Wynn et al.	23	unk	unk	unk	unk	unk	n/a	n/a	n/a	-27.8	20.31475	21.909072	n/a
Wynn et al. 2005	Andisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1997	n/a	364.02	-6.5	-8.05	Iron Range National Park, Far	-12.7407	12.7407	143.2475	2519	Wynn et al.	51	unk	unk	unk	unk	unk	n/a	n/a	n/a	-27.2	19.685444	21.278783	n/a
Wynn 2007	Oxisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2005	n/a	378.18	-6.5	-8.1	Kakamega Forest Reserve, Ke	0.264693	0.264693	34.883801	2040	Wynn P3 2	1600	unk	unk	27	unk	unk	n/a	n/a	n/a	-27.8	20.26332	21.909072	n/a
Wynn 2007	Oxisol	Grand-Clement, unpubli		n/a	n/a	n/a	n/a	n/a	2005	n/a	378.18	-6.5	-8.1	Zengoaga, Cameroon	4.633333	4.633333	12.633333	1551	Wynn P3 2	677	unk	23.4	unk	unk	unk	n/a	n/a	n/a	-27.9	20.368275	22.014196	n/a
Krull et al. 2005	Alfisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2002	n/a	372.33	-6.5	-8.03	Longreach, Queensland, Austr	-23.21667	23.21667	143.95	440	Krull et al. 2	211	unk	23.4	unk	unk	unk	n/a	n/a	n/a	-24.5	16.883649	18.452076	n/a
Mintz et al. 2011	Vertisol	n/a	n/a	n/a	Late Quarternary Post-Beaumont alluviu			n/a	2011	n/a	387.47	-6.5	-8.23	Churnabog Clay soil series, Te	29.076773	29.076773	-96.018066	520.83	Mintz et al.	12	unk	21.6	27.5	1.2	22.04	n/a	1.5	13.5	-23.7	15.845539	17.617536	n/a
Tabor et al. 2017	Alfisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	60s and 70s	n/a	319.30	-6.5	-7.01	Aco, California	33.969446	33.969446	-117.368619	583	PRISM Clim	273	160.55	21.2	26.7	0.9	17.72	n/a	n/a	n/a	-24.6	18.033627	18.55649	n/a
Tabor et al. 2017		n/a	n/a	n/a	n/a	n/a	n/a	n/a	60s and 70s	n/a	319.30	-6.5	-7.01	Ager, California				690	PRISM Clim	unk		unk	unk	unk	unk	n/a	n/a	n/a	-25.3	18.764748	19.287986	n/a
Tabor et al. 2017	Vertisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	60s and 70s	n/a	319.30	-6.5	-7.01	Alturas, California	41.478573	41.478573	-120.539369	432	PRISM Clim	1330	206.15	8.1	17.4	1.04	17.12	n/a	n/a	n/a	-24.7	18.138009	18.660925	n/a
Tabor et al. 2017	Aridisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	60s and 70s	n/a	319.30	-6.5	-7.01	Amedee, California	40.315945	40.315945	-120.187711	299	PRISM Clim	1236	111.76	9.5	17.8	2.12	18.43	n/a	n/a	n/a	-25.6	19.078407	19.601806	n/a
Tabor et al. 2017	Inceptisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	60s and 70s	n/a	319.30	-6.5	-7.01	Balcom, California	34.444823	34.444823	-118.994332	284	PRISM Clim	1275	266.77	9.5	17.8	2.12	18.43	n/a	n/a	n/a	-23.6	16.990987	17.513314	n/a
Tabor et al. 2017	Inceptisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	60s and 70s	n/a	319.30	-6.5	-7.01	Bellevista 1, California	39.976296	39.976296	-120.613411	423	PRISM Clim	2207	340.17	6.3	12.6	1.68	11.34	n/a	n/a	n/a	-24	17.407787	17.930328	n/a
Tabor et al. 2017	Inceptisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	60s and 70s	n/a	319.30	-6.5	-7.01	Bellevista 2	39.976296	39.976296	-120.613411	423	PRISM Clim	2207	340.17	6.3	12.6	1.68	11.34	n/a	n/a	n/a	-24.5	17.929267	18.452076	n/a
Tabor et al. 2017	Entisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	60s and 70s	n/a	319.30	-6.5	-7.01	Beveridge, California	36.703027	36.703027	-117.914733	402	PRISM Clim	1740	125.54	9.2	14.9	3.13	13.41	n/a	n/a	n/a	-24.1	17.51204	18.034635	n/a
Tabor et al. 2017	Entisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	60s and 70s	n/a	319.30	-6.5	-7.01	Bidwell, California	41.857469	41.857469	-120.153198	359.68	PRISM Clim	1387	182.05	8	15.6	1.65	15.39	n/a	n/a	n/a	-23.4	16.782716	17.304935	n/a
Tabor et al. 2017	Entisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	60s and 70s	n/a	319.30	-6.5	-7.01	Bousic, California	34.3649	34.3649	-116.909591	494.16	PRISM Clim	1283	95.47	14.4	22.2	4.33	23.7	n/a	n/a	n/a	-24.9	18.346836	18.86986	n/a
Tabor et al. 2017	Alfisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	60s and 70s	n/a	319.30	-6.5	-7.01	Buchenau	37.153004	37.153004	-119.615371	990.31	PRISM Clim	656	185.95	14.8	22.4	1.82	21.1	n/a	n/a	n/a	-26.6	20.125334	20.649271	n/a
Tabor et al. 2017	Aridisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	60s and 70s	n/a	319.30	-6.5	-7.01	Caudle	36.229697	36.229697	-116.251536	227.11	PRISM Clim	1080	120.49	15.7	23	7.04	26.73	n/a	n/a	n/a	-22.9	16.262409	16.784362	n/a
Tabor et al. 2017	Aridisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	60s and 70s	n/a	319.30	-6.5	-7.01	Lavic	37.973545	37.973545	-116.311359	285.4	PRISM Clim	1801	158.98	8.6	17.2	2.27	18.17	n/a	n/a	n/a	-25.1	18.555749	19.07888	n/a
Tabor et al. 2017	Entisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	60s and 70s	n/a	319.30	-6.5	-7.01	Marcuse	37.973545	37.973545	-121.638533	530	PRISM Clim	1	75.58	15	21.6	1.68	17.53	n/a	n/a	n/a	-26.2	19.706305	20.230027	n/a
Tabor et al. 2017	Vertisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	60s and 70s	n/a	319.30	-6.5	-7.01	Milham, California	36.004103	36.004103	-119.982605	385	PRISM Clim	144	70.23	17.7	23.9	5.64	24.13	n/a	n/a	n/a	-23.6	16.990987	17.513314	n/a
Tabor et al. 2017	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	60s and 70s	n/a	319.30	-6.5	-7.01	Montague	41.714873	41.714873	-122.529633	585.27	PRISM Clim	773	136.28	10.8	19	1.39	18.21	n/a	n/a	n/a	-24	17.407787	17.930328	n/a
Tabor et al. 2017	Entisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	60s and 70s	n/a	319.30	-6.5	-7.01	Muroc	34.915193	34.915193	-117.785074	310.27	PRISM Clim	695	81.87	15.5	23.6	4.59	26.28	n/a	n/a	n/a	-23.6	16.990987	17.513314	n/a
Minck et al. 2017	Spodosol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2008 (May)	n/a	319.30	-6.5	-8.28	White Mountain National Fores	43.93333	43.93333	-71.75	1358.34	PRISM Clim	474	916.6	4.2	9.8	0.65	7.67	n/a	n/a	n/a	-26.1	18.297566	20.12527	n/a
Rothstein et al. 2018	Spodosol	n/a	n/a	n/a	n/a	n/a	n/a	Sugar Maple	2012	n/a	389.46	-6.5	-8.33	Chippewa Township, UP	46.32	46.32	-85.04	1043.71	PRISM Clim	275	442.74	4.4	10	0.38	7.45	n/a	n/a	n/a	-26.2	18.350791	20.230027	n/a
Rothstein et al. 2018	Spodosol	n/a	n/a	n/a	n/a	n/a	n/a	Red Pine	2012	n/a	389.46	-6.5	-8.33	Chippewa Township, UP	46.33	46.33	-85.02	1043.71	PRISM Clim	275	442.74	4.4	10	0.38	7.45	n/a	n/a	n/a	-25.5	17.619292	19.497178	n/a
Bol et al. 1999	Spodosol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1993	n/a	354.9	-6.5	-7.75	Moor House Nature Reserve, N	54.65	54.65	-2.25	1900	Bol et al. 19	760	unk	4	unk	unk	unk	n/a	n/a	n/a	-26.8	19.574599	20.859022	n/a
Bol et al. 1999	Spodosol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1993	n/a	354.9	-6.5	-7.75	Moor House Nature Reserve, N	54.65	54.65	-2.25	1900	Bol et al. 19	760	unk	4	unk	unk	unk	n/a	n/a	n/a	-26.2	18.946396	20.230027	n/a
Bol et al. 1999	Gelisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1993	n/a	354.9	-6.5	-7.75	Moor House Nature Reserve, N	54.65	54.65	-2.25	2065	ECN Data C	760	unk	4	unk	unk	unk	n/a	n/a	n/a	-28	20.833333	22.119342	n/a
Cerling & Quade 1993	Aridisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1984	n/a	341.70	-6.5	-7.65	S Nevada SM6 Mojave Desert	unk	unk	unk	238.04	PRISM Clim	881	unk	unk	unk	unk	unk	n/a	n/a	n/a	-23.9	16.647884	17.826042	n/a
Cerling & Quade 1993	Aridisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1984	n/a	341.70	-6.5	-7.65	S Nevada SM5 Mojave Desert	unk	unk	unk	238.04	PRISM Clim	881	unk	unk	unk	unk	unk	n/a	n/a	n/a	-23.7	16.439619	17.617536	n/a
Cerling & Quade 1993	Aridisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1984	n/a	341.70	-6.5	-7.65	S Nevada SM-4	unk	unk	unk	238.04	PRISM Clim	881	unk	unk	unk	unk	unk	n/a	n/a	n/a	-23.4	16.127381	17.304935	n/a
Cerling & Quade 1993	Alfisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1984	n/a	341.70	-6.5	-7.65	Howard, New York	42.360621	42.360621	-77.513167	806.52	PRISM Clim	522	800.6	7.1	13.3	0.13	9.37	n/a	n/a	n/a	-25.6	18.421593	19.601806	n/a
Cerling & Quade 1993	Vertisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1984	n/a	341.70	-6.5	-7.65	Turkey Pasalar	39.958023	39.958023	28.296181	700	Cerling & Q	414.5	unk	unk	unk	unk	unk	n/a	n/a	n/a	-24.5	17.273193	18.452076	n/a
Cerling & Quade 1993	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1984	n/a	341.70	-6.5	-7.65	Greece Samos	37.759947	37.759947	26.979434	750	Cerling & Q	54	unk	unk	unk	unk	unk	n/a	n/a	n/a	-25.7	18.526121	19.706456	n/a
Cerling & Quade 1993	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1984	n/a	341.70	-6.5	-7.65	Greece Axios	40.594708	40.594708	22.686008	450	Cerling & Q	1	unk	unk	unk	unk	unk	n/a	n/a	n/a	-23.7	16.439619	17.617536	n/a
Cerling & Quade 1993	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1984	n/a	341.70	-6.5	-7.65	Saskatchewan Elstow	50.985023	50.985023	-106.055794	350	Cerling & Q	595	unk	unk	unk	unk	unk	n/a	n/a	n/a	-24.2	16.960443	18.138963	n/a
Cerling & Quade 1993	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1984	n/a	341.70	-6.5	-7.65	Saskatchewan Elstow	50.985023	50.985023	-106.055794	350	Cerling & Q	595	unk	unk	unk	unk	unk	n/a	n/a	n/a	-24.1	16.856235	18.034635	n/a
Torn et al. 2002	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1900	n/a	295.90	-6.5	**-6.78**	Russian Kamennaya Steppe,	51.281201	51.281201	40.470303	550	Cheverdin &	111	unk	6.4	unk	unk	unk	n/a	n/a	n/a	-25.8	19.523712	19.811127	n/a
Torn et al. 2002	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1997	n/a	363.11	-6.5	-7.94	Russian Kamennaya Steppe	51.281201	51.281201	40.470303	600	Cheverdin &	111	unk	6.4	unk	unk	unk	n/a	n/a	n/a	-25.8	18.332991	19.811127	n/a
Torn et al. 2002	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1997	n/a	363.11	-6.5	-7.94	Russian Kamennaya Steppe	51.281201	51.281201	40.470303	600	Cheverdin &	111	unk	6.4	unk	unk	unk	n/a	n/a	n/a	-26	18.542094	20.020534	n/a
Du et al. 2014	Ultisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2010	n/a	unk	-6.5	-8.43	Tongyuan	29.51667	29.51667	115.85	1429	Du et al. 20	219	unk	16.2	unk	unk	unk	n/a	n/a	n/a	-27.2	19.294819	21.278783	n/a
Du et al. 2014	Ultisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2010	n/a	unk	-6.5	-8.43	Saiyang	29.51667	29.51667	115.85	1549	Du et al. 20	405	unk	15.3	unk	unk	unk	n/a	n/a	n/a	-27.5	19.609254	21.59383	n/a
Du et al. 2014	Ultisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2010	n/a	unk	-6.5	-8.43	Beiyun	29.51667	29.51667	115.85	1794	Du et al. 20	780	unk	13.6	unk	unk	unk	n/a	n/a	n/a	-27	19.085303	21.068859	n/a
Volkoff & Cerri 1987	Oxisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1986	n/a	344.5	-6.5	-7.63	Parana state, GPR1	-24.712252	24.712252	-49.011517	1250	Volkoff & Ce	900	unk	unk	unk	unk	unk	n/a	n/a	n/a	-26	18.86037	20.020534	n/a
Billings & Richter 2006	Ultisol	n/a	n/a	n/a	n/a	n/a	n/a	oak, hickory, *Pinu*	1997	n/a	363.11	-6.5	-7.94	Calhoun Experimental Forest,	34.62188	34.62188	-81.679571	1169.01	Billings & R	162	629.26	15	22.3	0.15	16.64	n/a	n/a	n/a	-26.5	19.065229	20.544427	n/a
Osher et al. 2003	Andisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	366.53	-6.5	-8	Flank of Mauna Kea	20.072061	20.072061	-155.519146	2500	Osher et al.	700	unk	22	unk	unk	unk	n/a	n/a	n/a	-28	20.576132	22.119342	n/a
De Camargo et al. 1999	Oxisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	354.9	-6.5	-7.75	Victoria Ranch near Paragomi	-2.983333	2.983333	-47.51667	1750	De Camarg	124	unk	unk	unk	unk	unk	n/a	n/a	n/a	-27.4	20.203578	21.488793	n/a
De Camargo et al. 1999	Oxisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	354.9	-6.5	-7.75	Victoria Ranch near Paragomi	-2.983333	2.983333	-47.51667	1750	De Camarg	124	unk	unk	unk	unk	unk	n/a	n/a	n/a	-27.9	20.72832	22.014196	n/a
Townsend et al. 1997	Andisol	n/a	n/a	n/a	n/a	Myrtaceae	*Metrosidero*	*Metrosideros poly*	1990s	n/a	354.9	-6.5	-7.75	Flank of Mauna Kea	20.03579	20.03579	-155.436609	2000	Townsend e	900	unk	unk	unk	unk	unk	n/a	n/a	n/a	-26.7	19.469845	20.754135	n/a
Chabbi et al. 2009	Inceptisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2000s	n/a	366.53	-6.5	-8	SW France near Lusignan	46.42025	46.42025	0.1248194	900	Chabbi et al	142	unk	10.5	unk	unk	unk	n/a	n/a	n/a	-25.3	17.749051	19.287986	n/a
Stevenson et al. 2005	Mollisol	n/a	n/a	n/a	n/a	Asteraceae	*Artemisia*	shrub (*Artemisia*	60s and 70s	n/a	319.30	-6.5	-7.01	Palouse Washington, KP1	46.630569	46.630569	-118.645508	324.13	PRISM Clim	374	86.37	11.6	18.1	2.2	16.94	n/a	n/a	n/a	-24.2	17.616315	18.138963	n/a
Stevenson et al. 2005	Mollisol	n/a	n/a	n/a	n/a	Asteraceae	*Artemisia*	shrub (*Artemisia*	60s and 70s	n/a	319.30	-6.5	-7.01	Palouse Washington, CLY 1	46.512563	46.512563	-118.517372	342.76	PRISM Clim	405	96.05	11.8	18.1	2.28	16.77	n/a	n/a	n/a	-24.9	18.346836	18.86986	n/a
Stevenson et al. 2005	Mollisol	n/a	n/a	n/a	n/a	Asteraceae	*Artemisia*	shrub (*Artemisia*	60s and 70s	n/a	319.30	-6.5	-7.01	Palouse Washington UND1	46.725247	46.725247	-118.164375	390.16	PRISM Clim	400	110.92	11.4	18	2.12	17	n/a	n/a	n/a	-25.7	19.183003	19.706456	n/a
Stevenson et al. 2005	Mollisol	n/a	n/a	n/a	n/a	Asteraceae	*Artemisia*	shrub (*Artemisia*	60s and 70s	n/a	319.30	-6.5	-7.01	Palouse Washington WIN1	47.0823	47.0823	-117.9128	443.36	PRISM Clim	528	152.13	10.1	16.9	1.58	14.37	n/a	n/a	n/a	-25.5	18.973833	19.497178	n/a
Stevenson et al. 2005	Mollisol	n/a	n/a	n/a	n/a	Asteraceae	*Artemisia*	shrub (*Artemisia*	60s and 70s	n/a	319.30	-6.5	-7.01	Palouse Washington CHR1	46.555156	46.555156	-118.098774	486.87	PRISM Clim	421	121.41	11.6	18	1.96	16.18	n/a	n/a	n/a	-25.7	19.183003	19.706456	n/a
Stevenson et al. 2005	Mollisol	n/a	n/a	n/a	n/a	Asteraceae	*Artemisia*	shrub (*Artemisia*	60s and 70s	n/a	319.30	-6.5	-7.01	Palouse Washington SAP 2	46.139728	46.139728	-118.325149	517.42	PRISM Clim	315	182.58	12.7	18.6	2.76	16.73	n/a	n/a	n/a	-25.8	19.287621	19.811127	n/a
Stevenson et al. 2005	Mollisol	n/a	n/a	n/a	n/a	Asteraceae	*Artemisia*	shrub (*Artemisia*	60s and 70s	n/a	319.30	-6.5	-7.01	Palouse Washington CH1	46.4341	46.4341	-117.8874	586.78	PRISM Clim	535	189.97	10.3	16.7	1.53	14.61	n/a	n/a	n/a	-25.8	19.287621	19.811127	n/a
Stevenson et al. 2005	Mollisol	n/a	n/a	n/a	n/a	Asteraceae	*Artemisia*	shrub (*Artemisia*	60s and 70s	n/a	319.30	-6.5	-7.01	Palouse Washiongton VM 1	46.4341	46.4341	-117.8874	724.79	PRISM Clim	428	189.97	10.3	16.7	1.53	14.61	n/a	n/a	n/a	-26	19.49692	20.020534	n/a
Stevenson et al. 2005	Mollisol	n/a	n/a	n/a	n/a	Asteraceae	*Artemisia*	shrub (*Artemisia*	60s and 70s	n/a	319.30	-6.5	-7.01	Palouse Washiongton RBM2	46.0954	46.0954	-118.1562	800.06	PRISM Clim	553	258.24	10.9	16.9	2.07	14.98	n/a	n/a	n/a	-25.6	19.078407	19.601806	n/a
Stevenson et al. 2005	Mollisol	n/a	n/a	n/a	n/a	Asteraceae	*Artemisia*	shrub (*Artemisia*	60s and 70s	n/a	319.30	-6.5	-7.01	Palouse Washiongton RBM1	46.073293	46.073293	-118.098384	1050.41	PRISM Clim	699	402.54	8.7	15	1.33	13.4	n/a	n/a	n/a	-25.8	19.287621	19.811127	n/a
Goh et al. 1976	Entisol	n/a	n/a	n/a	n/a	Poaceae	*Ammophila*	*Ammophila arena*	Sep-70	n/a	319.30	-6.5	-7.01	Waitarere	-40.512234	40.512234	175.211851	1000	niwa.co.nz/	16	unk	unk	unk	unk	unk	n/a	n/a	n/a	-26.8	20.334977	20.859022	n/a
Goh et al. 1976	Inceptisol	n/a	n/a	n/a	n/a	Dennstaedtiacea	*Pteridium*	*Pteridium aquilinu*	Sep-70	n/a	319.30	-6.5	-7.01	Motuiti	-40.456444	40.456444	175.333454	1500	niwa.co.nz/	27	unk	unk	unk	unk	unk	n/a	n/a	n/a	-27.4	20.964425	21.488793	n/a
Goh et al. 1976	Alfisol	n/a	n/a	n/a	n/a	unk	unk	*Leptospermum er*	Sep-70	n/a	319.30	-6.5	-7.01	Foxton black	-40.456444	40.456444	175.333454	1500	niwa.co.nz/	27	unk	unk	unk	unk	unk	n/a	n/a	n/a	-26.9	20.439831	20.96393	n/a
Goh et al. 1976	Alfisol	n/a	n/a	n/a	n/a	unk	unk	*Leptospermum er*	Sep-70	n/a	319.30	-6.5	-7.01	Foxton brown	-40.456444	40.456444	175.333454	1500	niwa.co.nz/	27	unk	unk	unk	unk	unk	n/a	n/a	n/a	-27.5	21.069409	21.59383	n/a
Goh et al. 1976	Alfisol	n/a	n/a	n/a	n/a	coastal forest, u	n/a	n/a	Sep-70	n/a	319.30	-6.5	-7.01	Koputaroa	-40.592523	40.592523	175.363945	1000	niwa.co.nz/	43	unk	unk	unk	unk	unk	n/a	n/a	n/a	-26.2	19.706305	20.230027	n/a
von Fischer & Tieszen 19	Ultisol	n/a	n/a	n/a	n/a	Palm, unspecifie	n/a	n/a	unk	n/a	n/a	-6.5	n/a	Long Term Experimental Rese	18.3	18.3	-65.783	2000	von Fischer	800	unk	unk	unk	unk	unk	n/a	n/a	n/a	-26.4	n/a	20.439606	n/a
von Fischer & Tieszen, B	Ultisol	n/a	n/a	n/a	n/a	Burseraceae	*Dacryodes*	*Dacryodes excels*	unk	n/a	n/a	-6.5	n/a	Long Term Experimental Rese	18.3	18.3	-65.783	2000	von Fischer	800	unk	unk	unk	unk	unk	n/a	n/a	n/a	-27	n/a	21.068859	n/a
Conen et al. 2006	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	r 2005-2006	n/a	n/a	-6.5	-8.2	Halle	51.423583	51.423583	11.958788	508	PRISM Clim	unk	342	9.1	unk	unk	unk	n/a	n/a	n/a	-25.7	n/a	19.706456	n/a
Conen et al. 2006	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	r 2005-2006	n/a	n/a	-6.5	-8.2	Rotthalmunster, Germany	48.385182	48.385182	13.194304	931	PRISM Clim	unk	627	unk	unk	unk	unk	n/a	n/a	n/a	-26.7	n/a	20.754135	n/a
Griffith et al. 2017	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2015	n/a	399.4	-6.5	-8.54	Willow Creek, Alberta	49.46	49.46	-113.51	unk	unk	unk		unk	unk	unk	unk	n/a	n/a	n/a	-25.68	17.591756	19.685524	n/a
Griffith et al. 2017	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2015	n/a	399.4	-6.5	-8.54	Badger, MN	48.8	48.8	-95.98	736.74	PRISM Clim	unk	unk	unk	unk	unk	unk	n/a	n/a	n/a	-25.6	17.50821	19.601806	n/a
Griffith et al. 2017	Inceptisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2015	n/a	399.4	-6.5	-8.54	Sublett, Idaho	42.25	42.25	-113.15	348.64	PRISM Clim	1607	unk	unk	unk	unk	unk	n/a	n/a	n/a	-22.64	14.426619	16.513874	n/a
von Fischer et al. 2008	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	unk	n/a	n/a	-6.5	n/a	Milk River, Alberta	49.08	49.08	-112.1	342	PRISM Clim	unk	unk	unk	unk	unk	unk	n/a	n/a	n/a	-23.4	n/a	17.304935	n/a
von Fischer et al. 2008	Inceptisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	unk	n/a	n/a	-6.5	n/a	Tolstoi Prairie, Manitoba	49.08	49.08	-96.8	200	PRISM Clim	unk	unk	unk	unk	unk	unk	n/a	n/a	n/a	-21	n/a	14.811032	n/a
von Fischer et al. 2008	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	unk	n/a	n/a	-6.5	n/a	Living Prairie, Manitoba	49.88	49.88	-97.3	200	PRISM Clim	unk	unk	unk	unk	unk	unk	n/a	n/a	n/a	-21.4	n/a	15.225833	n/a
von Fischer et al. 2008	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	unk	n/a	n/a	-6.5	n/a	Head Smashed In, Alberta	49.5	49.5	-113.8	488	PRISM Clim	unk	unk	unk	unk	unk	unk	n/a	n/a	n/a	-24.1	n/a	18.034635	n/a
von Fischer et al. 2008	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	unk	n/a	n/a	-6.5	n/a	Grosse Isle Manitoba	50.07	50.07	-97.5		PRISM Clim	unk	unk	unk	unk	unk	unk	n/a	n/a	n/a	-20.6	n/a	14.396569	n/a
von Fischer et al. 2008	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	unk	n/a	n/a	-6.5	n/a	Oak Hammock, Manitoba	50.2	50.2	-97.2		PRISM Clim	unk	unk	unk	unk	unk	unk	n/a	n/a	n/a	-19.1	n/a	12.845346	n/a
von Fischer et al. 2008	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	unk	n/a	n/a	-6.5	n/a	Stavely, Alberta	50.22	50.22	-113.9	434	PRISM Clim	unk	unk	unk	unk	unk	unk	n/a	n/a	n/a	-25.2	n/a	19.183422	n/a
von Fischer et al. 2008	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	unk	n/a	n/a	-6.5	n/a	Matador, Saskatchewan	50.67	50.67	-109.3	380	PRISM Clim	unk	unk	unk	unk	unk	unk	n/a	n/a	n/a	-24.1	n/a	18.034635	n/a
von Fischer et al. 2008	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	unk	n/a	n/a	-6.5	n/a	Biddulph, Saskatchewan	50.68	50.68	-107.7	347.2	saskatoon.c	unk	unk	unk	unk	unk	unk	n/a	n/a	n/a	-22.9	n/a	16.784362	n/a
von Fischer et al. 2008	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	unk	n/a	n/a	-6.5	n/a	Kernan Prairie, Saskatchewan	51.9	51.9	-106.7	500	saskatoon.c	unk	unk	unk	unk	unk	unk	n/a	n/a	n/a	-25.1	n/a	19.07888	n/a
Zeller et al. 2007	Spodosol	n/a	n/a	n/a	n/a	Fagaceae	*Fagus*	*Fagus sp.*	2001	n/a	n/a	-6.5	-8.17	Breuil-Chenue, Nièvre, France	47.30278	47.30278	4.078889	1280	Zeller, Brec	640	unk	9	unk	unk	unk	n/a	n/a	n/a	-28.3	20.71627	22.434908	n/a
Zeller, Brechet, Maurice,	Spodosol	n/a	n/a	n/a	n/a	Pinaceae	*Pinus*	*Picea abies*	2001	n/a	n/a	-6.5	-8.17	Breuil-Chenue, Nièvre, France	47.30278	47.30278	4.078889	1280	Zeller, Brec	640	unk	9	unk	unk	unk	n/a	n/a	n/a	-27.1	19.457293	21.17381	n/a
Hopkins et al. 2009	Gelisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	unk	n/a	n/a	-6.5	n/a	Garwood hillslope soil	-78.03333	78.03333	164.116667	100	Doran, McK	unk	unk	unk	unk	unk	unk	n/a	n/a	n/a	-22	n/a	n/a	n/a
Hopkins et al. 2009	Gelisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	unk	n/a	n/a	-6.5	n/a	Garwood polygon soil	-78.03333	78.03333	164.116667	100	Doran, McK	unk	unk	unk	unk	unk	unk	n/a	n/a	n/a	-22.5	n/a	n/a	n/a
Ambrose & Sikes 1991	Inceptisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	unk	n/a	n/a	-6.5	n/a	Mt. Eburu	-0.633927	0.633927	36.26974	721	Ambrose &	2520	unk	unk	unk	unk	unk	n/a	n/a	n/a	-25	n/a	n/a	n/a
Yoneyama et al. 2001	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1996	n/a	n/a	-6.5	-8.08	Imaichi	36.733671	36.733671	139.699971	580	Yoneyama,	unk	unk	unk	unk	unk	unk	n/a	n/a	n/a	-25.5	17.875834	19.497178	n/a
Yoneyama et al. 2001	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1996	n/a	n/a	-6.5	-8.08	Tanegashima	30.606927	30.606927	130.977638	2237.6	saskatoon.c	unk	unk	unk	unk	unk	unk	n/a	n/a	n/a	-27.6	20.074044	21.698889	n/a
Lefroy et al. 1993	Mollisol	n/a	n/a	n/a	n/a	n/a	n/a	n/a	unk	n/a	n/a	-6.5	n/a	Warra Queensland	-26.930654	26.930654	150.946378	628	www.stateo	unk	unk	unk	unk	unk	unk	n/a	n/a	n/a	-24.6	n/a	n/a	n/a

labor et al. 2017																			
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-23.8	-25.8	Presence of carbonates								862.47898		13.51	7.09	400.418
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-24.2	-26.2	Presence of carbonates								1039.3464		13.51	7.09	400.418
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-25.8	-27.8	Presence of carbonates								2191.8336		13.51	7.09	400.418
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-26.8	-28.8	Presence of carbonates								3494.1142		13.51	7.09	400.418
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-21.6	-23.6	Presence of carbonates								309.16019		13.51	7.09	400.418
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-22.5	-24.5	Presence of carbonates								470.39223		13.51	7.09	400.418
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-25.5	-27.5	Presence of carbonates								1905.6745		13.51	7.09	400.418
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-24.7	-26.7	Presence of carbonates								1312.2757		13.51	7.09	400.418
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-25.8	-27.8	Presence of carbonates								2191.8336		13.51	7.09	400.418
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-24.2	-26.2	Presence of carbonates								1039.3464		13.51	7.09	400.418
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-26.2	-28.2	Presence of carbonates								2641.3101		13.51	7.09	400.418
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-26.6	-28.6	Presence of carbonates								3182.9601		13.51	7.09	400.418
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-24.8	-26.8	Presence of carbonates								1374.922		13.51	7.09	400.418
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-29.3	-31.3	Presence of carbonates								11211.428		13.51	7.09	400.418
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-24.1	-26.1	Presence of carbonates								991.99019		13.51	7.09	400.418
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-25.9	-27.9	Presence of carbonates								2296.4687		13.51	7.09	400.418
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-23.6	-25.6	Presence of carbonates								785.67442		13.51	7.09	400.418
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-24.5	-26.5	Presence of carbonates								1195.4163		13.51	7.09	400.418
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-24.4	-26.4	Presence of carbonates								1140.949		13.51	7.09	400.418
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-21.9	-23.9	Presence of carbonates								355.58417		13.51	7.09	400.418
labor et al. 2017	Upper Permian	Maradi, Niger	-6.0	-2.0	-22.7	-24.7	Presence of carbonates								516.37599		13.51	7.09	400.418
labor et al. 2017	Lower Triassic	Teloua, Niger	-6.0	-2.0	-20.9	-22.9	Presence of carbonates								223.05548		17.31	8.19	400.418
labor et al. 2017	Lower Triassic	Teloua, Niger	-6.0	-2.0	-20.8	-22.8	Presence of carbonates								212.89229		17.31	8.19	400.418
labor et al. 2017	Lower Triassic	Teloua, Niger	-6.0	-2.0	-22.1	-24.1	Presence of carbonates								390.34474		17.31	8.19	400.418
labor et al. 2017	Lower Triassic	Teloua, Niger	-6.0	-2.0	-20.7	-22.7	Presence of carbonates								203.19218		17.31	8.19	400.418
labor et al. 2017	Lower Triassic	Teloua, Niger	-6.0	-2.0	-21.7	-23.7	Presence of carbonates								323.91907		17.31	8.19	400.418
labor et al. 2017	Middle Triassic	Manda, Tanzania	-6.0	-2.0	-25.4	-27.4	Presence of carbonates								1818.8453		-8.51	32.71	400.418
labor et al. 2017	Middle Triassic	Manda, Tanzania	-6.0	-2.0	-24.8	-26.8	Presence of carbonates								1374.922		-8.51	32.71	400.418
labor et al. 2017	Middle Triassic	Manda, Tanzania	-6.0	-2.0	-27.5	-29.5	Presence of carbonates								4842.9253		-8.51	32.71	400.418
labor et al. 2017	Middle Triassic	Manda, Tanzania	-6.0	-2.0	-24.1	-26.1	Presence of carbonates								991.99019		-8.51	32.71	400.418
labor et al. 2017	Middle Triassic	Manda, Tanzania	-6.0	-2.0	-24.4	-26.4	Presence of carbonates								1140.949		-8.51	32.71	400.418
labor et al. 2017	Middle Triassic	Manda, Tanzania	-6.0	-2.0	-25.0	-27.0	Presence of carbonates								1509.3291		-8.51	32.71	400.418
labor et al. 2017	Middle Triassic	Manda, Tanzania	-6.0	-2.0	-24.7	-26.7	Presence of carbonates								1312.2757		-8.51	32.71	400.418
labor et al. 2017	Middle Triassic	Manda, Tanzania	-6.0	-2.0	-26.9	-28.9	Presence of carbonates								3660.9184		-8.51	32.71	400.418
labor et al. 2017	Middle Triassic	Manda, Tanzania	-6.0	-2.0	-24.5	-26.5	Presence of carbonates								1195.4163		-8.51	32.71	400.418
labor et al. 2017	Middle Triassic	Manda, Tanzania	-6.0	-2.0	-24.7	-26.7	Presence of carbonates								1312.2757		-8.51	32.71	400.418
labor et al. 2017	Middle Triassic	Manda, Tanzania	-6.0	-2.0	-24.6	-26.6	Presence of carbonates								1252.4839		-8.51	32.71	400.418
labor et al. 2017	Middle Triassic	Manda, Tanzania	-6.0	-2.0	-26.7	-28.7	Presence of carbonates								3334.9102		-8.51	32.71	400.418
labor et al. 2017	Middle Triassic	Manda, Tanzania	-6.0	-2.0	-25.4	-27.4	Presence of carbonates								1818.8453		-8.51	32.71	400.418
labor et al. 2017	Middle Triassic	Manda, Tanzania	-6.0	-2.0	-24.3	-26.3	Presence of carbonates								1088.9634		-8.51	32.71	400.418
labor et al. 2017	Middle Triassic	Manda, Tanzania	-6.0	-2.0	-24.8	-26.8	Presence of carbonates								1374.922		-8.51	32.71	400.418
labor et al. 2017	Middle Triassic	Manda, Tanzania	-6.0	-2.0	-23.5	-25.5	Presence of carbonates								749.87636		-8.51	32.71	400.418
labor et al. 2017	Middle Triassic	Manda, Tanzania	-6.0	-2.0	-24.3	-26.3	Presence of carbonates								1088.9634		-8.51	32.71	400.418
labor et al. 2017	Upper Permian	Madumabisa, Zambia	-6.0	-2.0	-21.5	-23.5	Presence of carbonates								295.07377				400.418
labor et al. 2017	Upper Permian	Madumabisa, Zambia	-6.0	-2.0	-20.7	-22.7	Presence of carbonates								203.19218				400.418
labor et al. 2017	Upper Permian	Madumabisa, Zambia	-6.0	-2.0	-21.7	-23.7	Presence of carbonates								323.91907				400.418
labor et al. 2017	Upper Permian	Madumabisa, Zambia	-6.0	-2.0	-21.1	-23.1	Presence of carbonates								244.86054				400.418
labor et al. 2017	Upper Permian	Madumabisa, Zambia	-6.0	-2.0	-24.0	-26.0	Presence of carbonates								946.79167				400.418
labor et al. 2017	Upper Permian	Madumabisa, Zambia	-6.0	-2.0	-21.3	-23.3	Presence of carbonates								268.79718				400.418
labor et al. 2017	Upper Permian	Madumabisa, Zambia	-6.0	-2.0	-21.0	-23.0	Presence of carbonates								233.70384				400.418
labor et al. 2017	Upper Permian	Madumabisa, Zambia	-6.0	-2.0	-21.0	-23.0	Presence of carbonates								233.70384				400.418
labor et al. 2017	Upper Permian	Madumabisa, Zambia	-6.0	-2.0	-21.0	-23.0	Presence of carbonates								233.70384				400.418
labor et al. 2017	Upper Permian	Madumabisa, Zambia	-6.0	-2.0	-20.8	-22.8	Presence of carbonates								212.89229				400.418
labor et al. 2017	Upper Permian	Madumabisa, Zambia	-6.0	-2.0	-21.1	-23.1	Presence of carbonates								244.86054				400.418
labor et al. 2017	Upper Permian	Madumabisa, Zambia	-6.0	-2.0	-21.2	-23.2	Presence of carbonates								256.54984				400.418
labor et al. 2017	Upper Permian	Madumabisa, Zambia	-6.0	-2.0	-23.9	-25.9	Presence of carbonates								903.65254				400.418
labor et al. 2017	Upper Permian	Madumabisa, Zambia	-6.0	-2.0	-22.6	-24.6	Presence of carbonates								492.8481				400.418
labor et al. 2017	Upper Permian	Madumabisa, Zambia	-6.0	-2.0	-22.4	-24.4	Presence of carbonates								448.95952				400.418
labor et al. 2017	Upper Permian	Madumabisa, Zambia	-6.0	-2.0	-20.5	-22.5	Presence of carbonates								185.09773				400.418
labor et al. 2017	Upper Permian	Madumabisa, Zambia	-6.0	-2.0	-19.5	-21.5	Presence of carbonates								116.11052				400.418
labor et al. 2017	Upper Permian	Madumabisa, Zambia	-6.0	-2.0	-23.7	-25.7	Presence of carbonates								823.18144				400.418
labor et al. 2017	Upper Permian	Ikakern, Morocco	-6.0	-2.0	-25.4	-27.4	Presence of carbonates								1818.8453		30.82	-8.99	400.418
labor et al. 2017	Upper Permian	Ikakern, Morocco	-6.0	-2.0	-24.7	-26.7	Presence of carbonates								1312.2757		30.82	-8.99	400.418
labor et al. 2017	Upper Permian	Ikakern, Morocco	-6.0	-2.0	-24.8	-26.8	Presence of carbonates								1374.922		30.82	-8.99	400.418
labor et al. 2017	Upper Permian	Ikakern, Morocco	-6.0	-2.0	-24.8	-26.8	Presence of carbonates								1374.922		30.82	-8.99	400.418
labor et al. 2017	Upper Permian	Ikakern, Morocco	-6.0	-2.0	-24.1	-26.1	Presence of carbonates								991.99019		30.82	-8.99	400.418
labor et al. 2017	Upper Permian	Ikakern, Morocco	-6.0	-2.0	-24.4	-26.4	Presence of carbonates								1140.949		30.82	-8.99	400.418
labor et al. 2017	Upper Permian	Ikakern, Morocco	-6.0	-2.0	-23.5	-25.5	Presence of carbonates								749.87636		30.82	-8.99	400.418
labor et al. 2017	Upper Permian	Ikakern, Morocco	-6.0	-2.0	-23.2	-25.2	Presence of carbonates								651.97479		30.82	-8.99	400.418
labor et al. 2017	Upper Permian	Ikakern, Morocco	-6.0	-2.0	-23.3	-25.3	Presence of carbonates								683.09917		30.82	-8.99	400.418
labor et al. 2017	Upper Permian	Ikakern, Morocco	-6.0	-2.0	-23.9	-25.9	Presence of carbonates								903.65254		30.82	-8.99	400.418
labor et al. 2017	Upper Permian	Balfour, South Africa	-6.0	-2.0	-26.1	-28.1	Presence of carbonates								2520.9628		-26.67	28.56	400.418
labor et al. 2017	Upper Permian	Balfour, South Africa	-6.0	-2.0	-25.8	-27.8	Presence of carbonates								2191.8336		-26.67	28.56	400.418
labor et al. 2017	Upper Permian	Balfour, South Africa	-6.0	-2.0	-25.9	-27.9	Presence of carbonates								2296.4687		-26.67	28.56	400.418
labor et al. 2017	Upper Permian	Balfour, South Africa	-6.0	-2.0	-26.6	-28.6	Presence of carbonates								3182.9601		-26.67	28.56	400.418
Pustovoytov & Terhorst 2004	Quartemary	Wurm, Schattenhausen	-6.5	-1.5	-25.4	-26.9		200	851	543.02083	1420.5454	509.20207	1649.1667	1079.1844			49.35	8.72	400.418	180
Pustovoytov & Terhorst 2004	Quartemary	Wurm, Schattenhausen	-6.5	-1.5	-23.3	-24.8					548.64936						49.35	8.72	400.418	
Pustovoytov & Terhorst 2004	Quartemary	Wurm, Schattenhausen	-6.5	-1.5	-24.2	-25.7					807.96842						49.35	8.72	400.418	
Pustovoytov & Terhorst 2004	Quartemary	Wurm, Schattenhausen	-6.5	-1.5	-24.6	-26.1					996.62706						49.35	8.72	400.418	
Pustovoytov & Terhorst 2004	Quartemary	Wurm, Schattenhausen	-6.5	-1.5	-23.2	-24.7					509.20207						49.35	8.72	400.418	
Pustovoytov & Terhorst 2004	Quartemary	Wurm, Schattenhausen	-6.5	-1.5	-24.2	-25.7					834.77888						49.35	8.72	400.418	
Pustovoytov & Terhorst 2004	Quartemary	Wurm, Schattenhausen	-6.5	-1.5	-24.7	-26.2					1053.9893						49.35	8.72	400.418	
Pustovoytov & Terhorst 2004	Quartemary	Wurm, Schattenhausen	-6.5	-1.5	-24.0	-25.5					763.99558						49.35	8.72	400.418	
Pustovoytov & Terhorst 2004	Quartemary	Riss, Schattenhausen	-6.5	-1.5	-24.5	-26.0					960.1306						49.35	8.72	400.418	
Pustovoytov & Terhorst 2004	Quartemary	Riss, Schattenhausen	-6.5	-1.5	-24.4	-25.9					916.38371						49.35	8.72	400.418	
Pustovoytov & Terhorst 2004	Quartemary	Riss, Schattenhausen	-6.5	-1.5	-24.0	-25.5					753.38151						49.35	8.72	400.418	
Pustovoytov & Terhorst 2004	Quartemary	Riss, Schattenhausen	-6.5	-1.5	-24.0	-25.5					736.01808						49.35	8.72	400.418	
Pustovoytov & Terhorst 2004	Quartemary	Riss, Schattenhausen	-6.5	-1.5	-24.8	-26.3					1078.854						49.35	8.72	400.418	
Pustovoytov & Terhorst 2004	Quartemary	Riss, Schattenhausen	-6.5	-1.5	-24.6	-26.1					1001.2856						49.35	8.72	400.418	
Pustovoytov & Terhorst 2004	Quartemary	Riss, Schattenhausen	-6.5	-1.5	-24.9	-26.4					1146.2822						49.35	8.72	400.418	

Pustovoytov & Terhorst 2004	Quarternary	Riss, Schattenhausen	-6.5	-1.5	-25.7	-27.2				1649.1667						49.35	8.72	400.418		
Hatte et al. 2001		Nussloch	-7.0	-1.0	-24.7	-25.7	Pollen	315	315	315	823.18144	823.18144	823.18144	823.18144	16000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.9	-1.1	-24.9	-26.0	Pollen	402	402	402	946.79167	946.79167	946.79167	946.79167	17000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.9	-1.1	-24.9	-26.0	Pollen	495	495	495	946.79167	946.79167	946.79167	946.79167	18000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-25.0	-26.5	Pollen	597	597	597	1195.4163	1195.4163	1195.4163	1195.4163	19000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.8	-26.3	Pollen	621	621	621	1088.9634	1088.9634	1088.9634	1088.9634	20000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.3	-25.8	Pollen	551	551	551	862.47898	862.47898	862.47898	862.47898	21000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.2	-25.7	Pollen	570	570	570	823.18144	823.18144	823.18144	823.18144	22000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.2	-25.7	Pollen	532	532	532	823.18144	823.18144	823.18144	823.18144	23000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.0	-25.5	Pollen	527	527	527	749.87636	749.87636	749.87636	749.87636	24000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.1	-25.6	Pollen	612	612	612	785.67442	785.67442	785.67442	785.67442	25000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.1	-25.6	Pollen	575	575	575	785.67442	785.67442	785.67442	785.67442	26000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.1	-25.6	Pollen	550	550	550	785.67442	785.67442	785.67442	785.67442	27000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.1	-25.6	Pollen	474	474	474	785.67442	785.67442	785.67442	785.67442	28000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.2	-25.7	Pollen	545	545	545	823.18144	823.18144	823.18144	823.18144	29000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.2	-25.7	Pollen	617	617	617	823.18144	823.18144	823.18144	823.18144	30000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.2	-25.7	Pollen	591	591	591	823.18144	823.18144	823.18144	823.18144	31000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.7	-26.2	Pollen	691	691	691	1039.3464	1039.3464	1039.3464	1039.3464	32000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.5	-26.0	Pollen	581	581	581	946.79167	946.79167	946.79167	946.79167	33000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.4	-25.9	Pollen	512	512	512	903.65254	903.65254	903.65254	903.65254	34000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.3	-25.8	Pollen	490	490	490	862.47898	862.47898	862.47898	862.47898	44000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.4	-25.9	Pollen	569	569	569	903.65254	903.65254	903.65254	903.65254	45000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.6	-26.1	Pollen	672	672	672	991.99019	991.99019	991.99019	991.99019	46000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.6	-26.1	Pollen	727	727	727	991.99019	991.99019	991.99019	991.99019	47000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.7	-26.2	Pollen	745	745	745	1039.3464	1039.3464	1039.3464	1039.3464	48000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.7	-26.2	Pollen	699	699	699	1039.3464	1039.3464	1039.3464	1039.3464	49000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.5	-26.0	Pollen	579	579	579	946.79167	946.79167	946.79167	946.79167	50000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.1	-25.6	Pollen	462	462	462	785.67442	785.67442	785.67442	785.67442	51000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-23.9	-25.4	Pollen	379	379	379	715.70938	715.70938	715.70938	715.70938	52000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-23.8	-25.3	Pollen	342	342	342	683.09917	683.09917	683.09917	683.09917	53000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.0	-25.5	Pollen	412	412	412	749.87636	749.87636	749.87636	749.87636	54000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.0	-25.5	Pollen	408	408	408	749.87636	749.87636	749.87636	749.87636	55000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-23.8	-25.3	Pollen	366	366	366	683.09917	683.09917	683.09917	683.09917	56000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-23.8	-25.3	Pollen	373	373	373	683.09917	683.09917	683.09917	683.09917	57000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-23.7	-25.2	Pollen	343	343	343	651.97479	651.97479	651.97479	651.97479	58000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-23.7	-25.2	Pollen	277	277	277	651.97479	651.97479	651.97479	651.97479	59000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-23.6	-25.1	Pollen	200	200	200	622.26855	622.26855	622.26855	622.26855	60000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-23.9	-25.4	Pollen	295	295	295	715.70938	715.70938	715.70938	715.70938	61000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.7	-26.2	Pollen	542	542	542	1039.3464	1039.3464	1039.3464	1039.3464	62000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.6	-26.1	Pollen	533	533	533	991.99019	991.99019	991.99019	991.99019	63000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.5	-26.0	Pollen	530	530	530	946.79167	946.79167	946.79167	946.79167	64000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.6	-26.1	Pollen	570	570	570	991.99019	991.99019	991.99019	991.99019	65000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.8	-26.3	Pollen	652	652	652	1088.9634	1088.9634	1088.9634	1088.9634	66000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.9	-26.4	Pollen	694	694	694	1140.949	1140.949	1140.949	1140.949	67000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-25.0	-26.5	Pollen	750	750	750	1195.4163	1195.4163	1195.4163	1195.4163	68000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.7	-26.2	Pollen	698	698	698	1039.3464	1039.3464	1039.3464	1039.3464	69000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-24.8	-26.3	Pollen	722	722	722	1088.9634	1088.9634	1088.9634	1088.9634	70000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-25.2	-26.7	Pollen	851	851	851	1312.2757	1312.2757	1312.2757	1312.2757	71000	49.35	8.72	400.418	180	
Hatte et al. 2001		Nussloch	-6.5	-1.5	-25.2	-26.7	Pollen	827	827	827	1312.2757	1312.2757	1312.2757	1312.2757	72000	49.35	8.72	400.418	180	

Letter	Citation
A	USDA Natural Resources Conservation Service (2017). ArcGIS Soil Survey. Retrieved from https://www.arcgis.com/home/item.html?id=2064d94c9b1374de8a21574c9e8a3164
B	Keeling, C. D., Piper, S. C., Bacastow, R. B., Wahlen, M., Whorf, T. P., Heimann, M., & Meijer, H. A. (2005). Atmospheric CO2 and 13CO2 exchange with the terrestrial biosphere and oceans from 1978 to 2000: observations and carbon cycle implications. 83-113, in: In A History of Atmospheric CO2 and its effects on Plants, Animals and Ecosystems, eds. Ehleringer, J. R., Cerling, T. E., Dearing, M. D., Springer Verlag, New York. Retrieved from ftp://aftp.cmdl.noaa.gov/data/trace_gases/co2/flask/surface/co2_spo_surface-flask_1_ccgg_month.txt ; from NOAA)
C	Keeling, C. D., Piper, S. C., Bacastow, R. B., Wahlen, M., Whorf, T. P., Heimann, M., & Meijer, H. A. (2005). Atmospheric CO2 and 13CO2 exchange with the terrestrial biosphere and oceans from 1978 to 2000: observations and carbon cycle implications. 83-113, in: In A History of Atmospheric CO2 and its effects on Plants, Animals and Ecosystems, eds. Ehleringer, J. R., Cerling, T. E., Dearing, M. D., Springer Verlag, New York. Retrieved from ftp://aftp.cmdl.noaa.gov/data/trace_gases/co2/c13/flask/surface/co2c13_spo_surface-flask_1_all_month.txt
D	Tipple, B. J., Meyers, S. R., & Pagani, M. (2010). Carbon isotope ratio of Cenozoic CO2: A comparative evaluation of available geochemical proxies. *Paleoceanography*, *25* (3).
Modern Soils	Ambrose, S. H., & Sikes, N. E. (1991). Soil carbon isotope evidence for Holocene habitat change in the Kenya Rift Valley. *Science*, *253*(5026), 1402-1405.
Modern Soils	Balesdent, J., Mariotti, A., & Guillet, B. (1987). Natural 13C abundance as a tracer for studies of soil organic matter dynamics. *Soil Biology and Biochemistry*, *19*(1), 25-30.
Modern Soils	Billings, S. A., & Richter, D. D. (2006). Changes in stable isotopic signatures of soil nitrogen and carbon during 40 years of forest development. *Oecologia*, *148* (2), 325-333.
Modern Soils	Boi, R. A., Hantemes, D. D., Huang, Y., & Howard, D. M. (1999). The influence of soil processes on carbon isotope distribution and turnover in the British uplands. *European Journal of Soil Science*, *50*(1), 41-51.
Modern Soils	Cerling, T. E., & Quade, J. "Stable carbon and oxygen isotopes in soil carbonates." P. K Swart K. C Lohmann J McKenzieand S Savinda. Climate change in continental isotopic records. Geophysical Monograph 78 (1993): 217-231.
Modern Soils	Chabbi, A., Kögel-Knabner, I., & Rumpel, C. (2009). Stabilised carbon in subsoil horizons is located in spatially distinct parts of the soil profile. *Soil Biology and Biochemistry*, *41* (2), 256-261.
Modern Soils	Conen, F., Leifeld, J., Seth, B., & Alewell, C. (2006). Warming mineralises young and old soil carbon equally.
Modern Soils	De Camargo, P. B., Trumbore, S. E., Martinelli, L. A., Davidson, E. A., Nepstad, D. C., & Victoria, R. L. (1999). Soil carbon dynamics in regrowing forest of eastern Amazonia. *Global Change Biology*, *5* (6), 693-702.
Modern Soils	Dijkstra, P., Ishizu, A., Doucett, R., Hart, S. C., Schwartz, E., Menyailo, O. V., & Hungate, B. A. (2006). 13C and 15N natural abundance of the soil microbial biomass. Soil Biology and Biochemistry, 38(11), 3257-3266.
Modern Soils	Du, B., Liu, C., Kang, H., Zhu, P., Yin, S., Shen, G., ... & Iwamoto, H. (2014). Climatic control on plant and soil δ 13 C along an altitudinal transect of Lushan Mountain in Subtropical China: Characteristics and interpretation of soil carbon dynamics. *PloS one*, *9* (1), e86440.
Modern Soils	Dümig, A., Schad, P., Rumpel, C., Dignac, M. F., & Kögel-Knabner, I. (2008). Araucaria forest expansion on grassland in the southern Brazilian highlands as revealed by 14C and δ13C studies. *Geoderma*, *145*(1-2), 143-157.
Modern Soils	Goh, K. M., Rafter, T. A., Stout, J. D., & Walker, T. W. (1976). The accumulation of soil organic matter and its carbon isotope content in a chronosequence of soils developed on aeolian sand in New Zealand. *Journal of Soil Science*, *27*(1), 89-100.
Modern Soils	Griffith, D. M., Cotton, J. M., Powell, R. L., Sheldon, N. D., & Still, C. J. (2017). Multi-century stasis in C3 and C4 grass distributions across the contiguous United States since the industrial revolution. *Journal of Biogeography*, *44*(11), 2564-2574.
Modern Soils	Hopkins, D. W., Sparrow, A. D., Gregorich, E. G., Elberling, B., Novis, P., Fraser, F., ... & Greenfield, L. G. (2009). Isotopic evidence for the provenance and turnover of organic carbon by soil microorganisms in the Antarctic dry valleys. *Environmental Microbiology*, *11* (3), 597-608.
Modern Soils	Krull, E. S., Skjemstad, J. O., Burrows, W. H., Bray, S. G., Wynn, J. G., Bol, R., ... & Harms, B. (2005). Recent vegetation changes in central Queensland, Australia: Evidence from δ13C and 14C analyses of soil organic matter. Geoderma, 126(3-4), 241-259.
Modern Soils	Lefroy, R. D., Blair, G. J., & Strong, W. M. (1993). Changes in soil organic matter with cropping as measured by organic carbon fractions and 13 C natural isotope abundance. *Plant and soil*, *155* (1), 399-402.
Modern Soils	McPherson, G. R., Boutton, T. W., & Midwood, A. J. (1993). Stable carbon isotope analysis of soil organic matter illustrates vegetation change at the grassland/woodland boundary in southeastern Arizona, USA. Oecologia, 93(1), 95-101.
Modern Soils	Minick, K. J., Fisk, M. C., & Groffman, P. M. (2017). Soil Ca alters processes contributing to C and N retention in the Ca/A horizon of a northern hardwood forest. Biogeochemistry, 132(3), 343-357.
Modern Soils	Motz, J. S., Driese, S. G., Breecker, D. O., & Ludvigson, G. A. (2011). Influence of changing hydrology on pedogenic calcite precipitation in Vertisols, Dance Bayou, Brazoria County, Texas, USA: implications for estimating paleoatmospheric pCO2. Journal of Sedimentary Research, 81(6), 394-400.
Modern Soils	Ohter, I., J., Matson, P. A., & Amundson, R. (2003). Effect of land use change on soil carbon in Hawaii. *Biogeochemistry*, *65*(2), 213-232.
Modern Soils	Rothstein, D. E., Troxel, B. R., Schwartz, R. J., & Grandy, A. S. (2018). Translocation of Carbon from Surface Organic Horizons to the Subsoil in Coarse Textured Spodosols: Implications for Deep Soil C Dynamics. Soil Science Society of America Journal, 82(4), 969-982.
Modern Soils	Ruf, A., Kuzyakov, Y. & Lopatovskaya, O. (2006). Carbon fluxes in soil food webs of increasing complexity revealed by 14C labelling and 13C natural abundance. *Soil Biology and Biochemistry*, *38*(8), 2390-2400.
Modern Soils	Sheldon, N. D., Smith, S. Y., Stein, R., & Ng, M. (2020). Carbon isotope ecology of gymnosperms and implications for paleoclimatic and paleoecological studies. Global and Planetary Change, 184, 103060.
Modern Soils	Stevenson, B. A., Kelly, E. F., McDonald, E. V., & Busacca, A. J. (2005). The stable carbon isotope composition of soil organic carbon and pedogenic carbonates along a bioclimatic gradient in the Palouse region, Washington State, USA. *Geoderma*, *124* (1-2), 37-47.
Modern Soils	Tabor, N. J., Myers, T. S., Sullivanmoon, E., Rasmussen, C., Sheldon, N. D., Driese, S. G., & Nordt, L. C. (2013). Carbon stable isotope composition of modern calcareous soil profiles in California: implications for CO2 reconstructions from calcareous paleosols. In *New Frontiers in Paleopedology and Terrestrial Paleoclimatology* (Vol. 104, pp. 17-34). SEPM (Society for Sedimentary Geology).
Modern Soils	Tabor, N. J., Sidor, C. A., Smith, R. M., Nesbitt, S. J., & Angielczyk, K. D. (2017). Paleosols of the Permian-Triassic: proxies for rainfall, climate change and major changes in terrestrial ketapod diversity. Journal of Vertebrate Paleontology, 37(sup1), 240-253.
Modern Soils	Tom, M. S., Lapenis, A. G., Timofeev, A., Fischer, M. L., Babikov, B. V., & Harden, J. W. (2002). Organic carbon and carbon isotopes in modern and 100 year old soil archives of the Russian steppe. Global Change Biology, 8(10), 941-953.
Modern Soils	Townsend, A. R., Vitousek, P. M., Desmarais, D. J., & Tharpe, A. (1997). Soil carbon pool structure and temperature sensitivity inferred using CO 2 and 13 CO 2 incubation fluxes from five Hawaiian soils. *Biogeochemistry*, *38* (1), 1-17.
Modern Soils	Volkoff, B., & Cerri, C. C. (1987). Carbon isotopic fractionation in subtropical Brazilian grassland soils. Comparison with tropical forest soils. *Plant and soil*, *102* (1), 27-31.
Modern Soils	von Fischer, J. C., & Tieszen, L. L. (1995). Carbon isotope characterization of vegetation and soil organic matter in subtropical forests in Luquillo, Puerto Rico. *Biotropica*, 138-148.
Modern Soils	von Fischer, J. C., Tieszen, L. L., & Schimel, D. S. (2008). Climate controls on C3 vs. C4 productivity in North American grasslands from carbon isotope composition of soil organic matter. *Global Change Biology*, *14*(5), 1141-1155.
Modern Soils	Wynn, J. G., Bird, M. I., & Wong, V. N. (2005). Rayleigh distillation and the depth profile of 13C/12C ratios of soil organic carbon from soils of disparate texture in Iron Range National Park, Far North Queensland, Australia. *Geochimica et cosmochimica acta*, *69* (8), 1961-1973.
Modern Soils	Wynn, J. G., Harden, J. W., & Fries, T. L. (2006). Stable carbon isotope depth profiles and soil organic carbon dynamics in the lower Mississippi Basin. Geoderma, 131(1-2), 89-109.
Modern Soils	Wynn, J. G. (2007). Carbon isotope fractionation during decomposition of organic matter in soils and paleosols: implications for paleoecological interpretations of paleosols. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *251* (3-4), 437-446.
Modern Soils	Yoneyama, T., Nakanishi, Y., Morita, A., & LIYANAGE, B. C. (2001). Classification of Cultivated Soils in Japan, Second Approximation Classification of Cultivated Soils in Japan, Second Approximation, 1983. *Soil science and plant nutrition*, *47* (1), 17-26.
Modern Soils	Zeller, B., Brechet, C., Maurice, J. P., & Le Tacon, F. (2007). 13 C and 15 N isotopic fractionation in trees, soils and fungi in a natural forest stand and a Norway spruce plantation. *Annals of Forest Science*, *64* (4), 419-429.
Paleosols	Andrzejewski, K. (2018). Cretaceous Dinosaurs And The World They Lived In A New Species Of Ornithischian Dinosaur From The Early Cretaceous (Aptian) Of Texas, Reconstruction Of The Brain Endocast And Inner Ear Of Malawisaurus Dixeyi, And Reconstruction Of The Paleoclimate And Paleoenvironment of Cretaceous Terrestrial Formations In Texas And Oklahoma Using Pedogenic Minerals.
Paleosols	Bown, T. M., & Kraus, M. J. (1981). Vertebrate fossil-bearing paleosol units (Willwood Formation, Lower Eocene, northwest Wyoming, USA): Implications for taphonomy, biostratigraphy, and assemblage analysis. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *34*, 31-56.
Paleosols	Caudill, M. R., Driese, S. G., & Mora, C. I. (1996). Preservation of a paleo-Vertisol and an estimate of Late Mississippian paleoprecipitation. *Journal of Sedimentary Research*, *66* (1), 59-70.
Paleosols	Cerling, T. E. (1992). Use of carbon isotopes in paleosols as an indicator of the P (CO2) of the paleoatmosphere. *Global Biogeochemical Cycles*, *6* (3), 307-314.
Paleosols	Daeschler, E. B., & Cressler III, W. L. (2011, March). Late Devonian paleontology and paleoenvironments at Red Hill and other fossil sites in the Catskill Formation of north-central Pennsylvania. In *From shield to the sea: Geological field trips from the 2011 Joint Meeting of the GSA Northeastern and North-Central Sections, Geological Society of America, Field Guide* (Vol. 20, pp. 1-16).
Paleosols	Driese, S. G., Mora, C. I., Cotter, E., & Foreman, J. L. (1992). Paleopedology and stable isotope chemistry of Late Silurian vertic Paleosols, Bloomsburg Formation, central Pennsylvania. *Journal of Sedimentary Research*, *62* (5), 825-841.
Paleosols	Dworowski, N. D., & Hembree, D. I. (2012). Examining local climate variability in the Late Pennsylvanian through paleosols: an example from the Lower Conemaugh Group of southeastern Ohio, USA. *Geosciences*, *2* (4), 265-276.
Paleosols	Gutierrez, K., & Sheldon, N. D. (2012). Paleoenvironmental reconstruction of Jurassic dinosaur habitats of the Vega Formation, Asturias, Spain. *GSA Bulletin*, *124* (3-4), 596-610.
Paleosols	Harris, E. B., Strömberg, C. A., Sheldon, N. D., Smith, S. Y., & Vilhena, D. A. (2017). Vegetation response during the lead-up to the middle Miocene warming event in the Northern Rocky Mountains, USA. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *485*, 401-415.
Paleosols	Hatté, C., Antoine, P., Fontugne, M., Lang, A., Rousseau, D. D., & Zöller, L. (2001). δ13C of loess organic matter as a potential proxy for paleoprecipitation. *Quaternary Research*, *55* (1), 33-38.
Paleosols	Hembree, D. I. & Bowen, J. J. (2017). Paleosols and ichnofossils of the Upper Pennsylvanian–Lower Permian Monongahela and Dunkard groups (Ohio, USA): a multi-proxy approach to unraveling complex variability in ancient terrestrial landscapes. *Palaios*, *32* (5), 295-320.
Paleosols	Hyland, E. G., & Sheldon, N. D. (2013). Coupled CO2–climate response during the early Eocene climatic optimum. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *369*, 125-135.
Paleosols	Jerzykiewicz, T., & Sweet, A. R. (1988). Sedimentological and palynological evidence of regional climatic changes in the Campanian to Paleocene sediments of the Rocky Mountain Foothills, Canada. *Sedimentary geology*, *59* (1-2), 29-76.
Paleosols	Kumaravel, V., Sangode, S. J., Siddiqui, N. S., & Kumar, R. (2009). Major element geochemical variations in a Miocene-Pliocene Siwalik paleosol sequence: Implications to soil forming processes in the Himalayan Foreland Basin. *Journal of the Geological Society of India*, *73* (6), 759.
Paleosols	Lukene, W. E., Lehmann, T., Peppe, D. J., Fox, D. L., Driese, S. G., & McNulty, K. P. (2017). The Early Miocene critical zone at Kerungo, western Kenya: An equatorial, open habitat with few primate remains. *Frontiers in Earth Science*, *5*, 87.
Paleosols	Mora, C. I., Driese, S. G., & Colarusso, L. A. (1996). Middle to late Paleozoic atmospheric CO2 levels from soil carbonate and organic matter. *Science*, *271* (5252), 1105-1107.
Paleosols	Nordt, L., Atchley, S., & Dworkin, S. I. (2002). Paleosol barometer indicates extreme fluctuations in atmospheric CO2 across the Cretaceous-Tertiary boundary. *Geology*, *30* (8), 703-706.
Paleosols	Quade, J., Solounias, N., & Cerling, T. E. (1994). Stable isotopic evidence from paleosol carbonates and fossil teeth in Greece for forest or woodlands over the past 11 Ma. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *108* (1-2), 41-53.
Paleosols	Sheldon, N. D. (2006). Quaternary glacial–interglacial climate cycles in Hawaii. *The Journal of Geology*, *114* (3), 367-376.
Paleosols	Tabor, N. J., Sidor, C. A., Smith, R. M., Nesbitt, S. J., & Angielczyk, K. D. (2017). Paleosols of the Permian-Triassic: proxies for rainfall, climate change and major changes in terrestrial ketapod diversity. *Journal of Vertebrate Paleontology*, *37* (sup1), 240-253.
Paleosols	Terfiorst, B., & Puskovskyi, K. (2004). An isotopic study of a late Quaternary loess-paleosol sequence in SW Germany. *Revista Mexicana de Ciencias Geológicas*, *21* (1), 88-93.

Figure C1 $\delta^{13}C_{SOM}$ and Δ_{SOM} versus climate variables (a-b) elevation, (c-d) mean annual temperature, (e-f) Vapor Pressure Deficit Maximums, (g-h) Vapor Pressure Deficit Minimums.

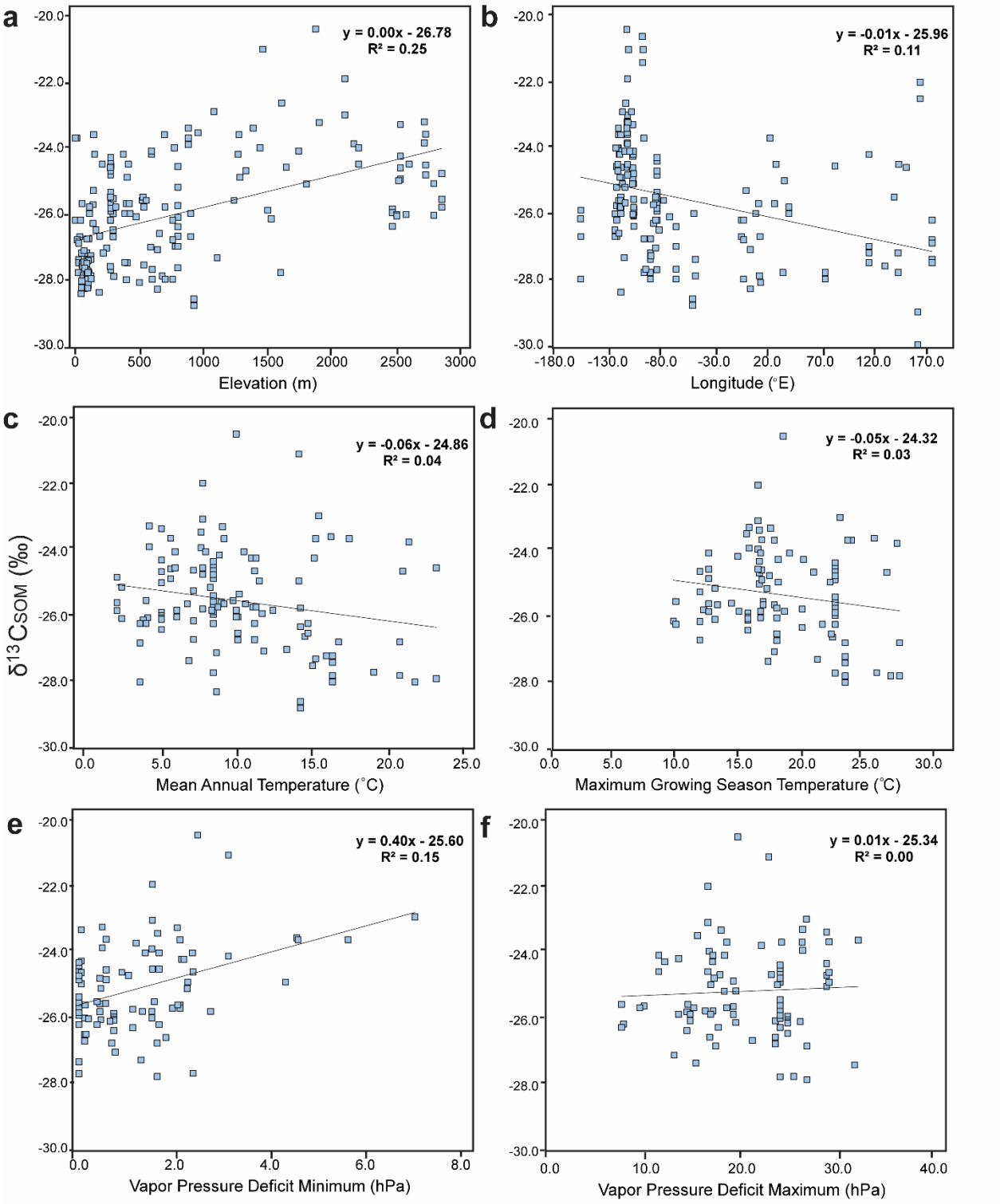


Figure C2 (a) $\delta^{13}C_{SOM}$ values compared to growing season precipitation for modern soils (mm yr^{-1}). All soils for which growing season precipitation was available are shown in light blue squares. The best fit logarithmic trend line had an equation of $\delta^{13}C_{SOM}$ = -0.99ln(GSP) – 19.65 and R^2 = 0.27. (b) Shows the relationship between mean annual precipitation and growing season precipitation.

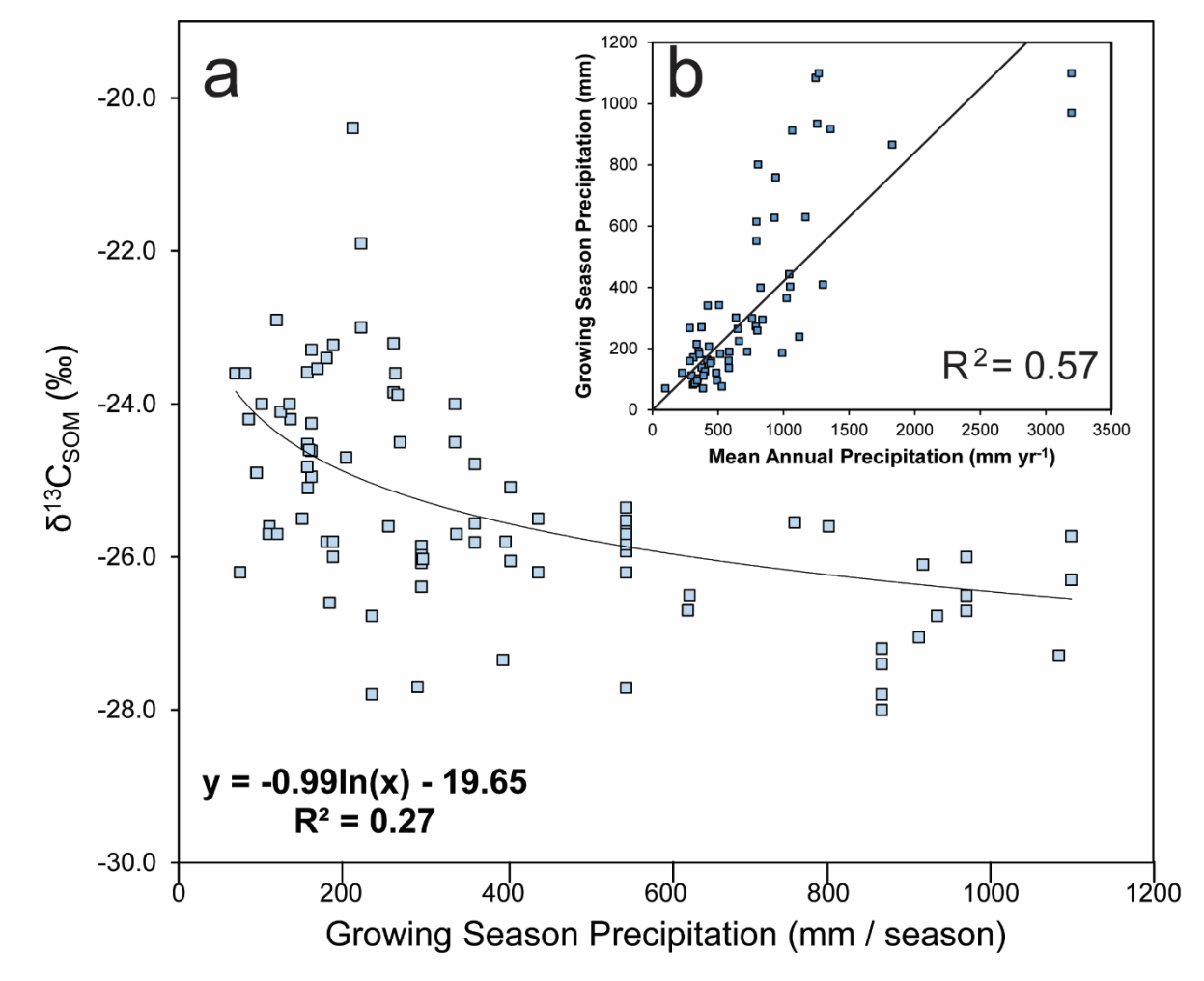


Figure C3 Actual mean annual precipitation values (in mm yr^{-1}) as collected from PRISM and extra-contiguous United States data sources as compared to reconstructed mean annual precipitation values (in mm yr^{-1}) using Equation 4.1. Data from this study are shown in yellow squares, soils from literature data are shown in blue squares, and outliers from our dataset (MAP = 3350 mm yr^{-1}) are shown in yellow circles ($y = 1.02x + 44.85$; $R^2 = 0.68$, p-value < 0.001.

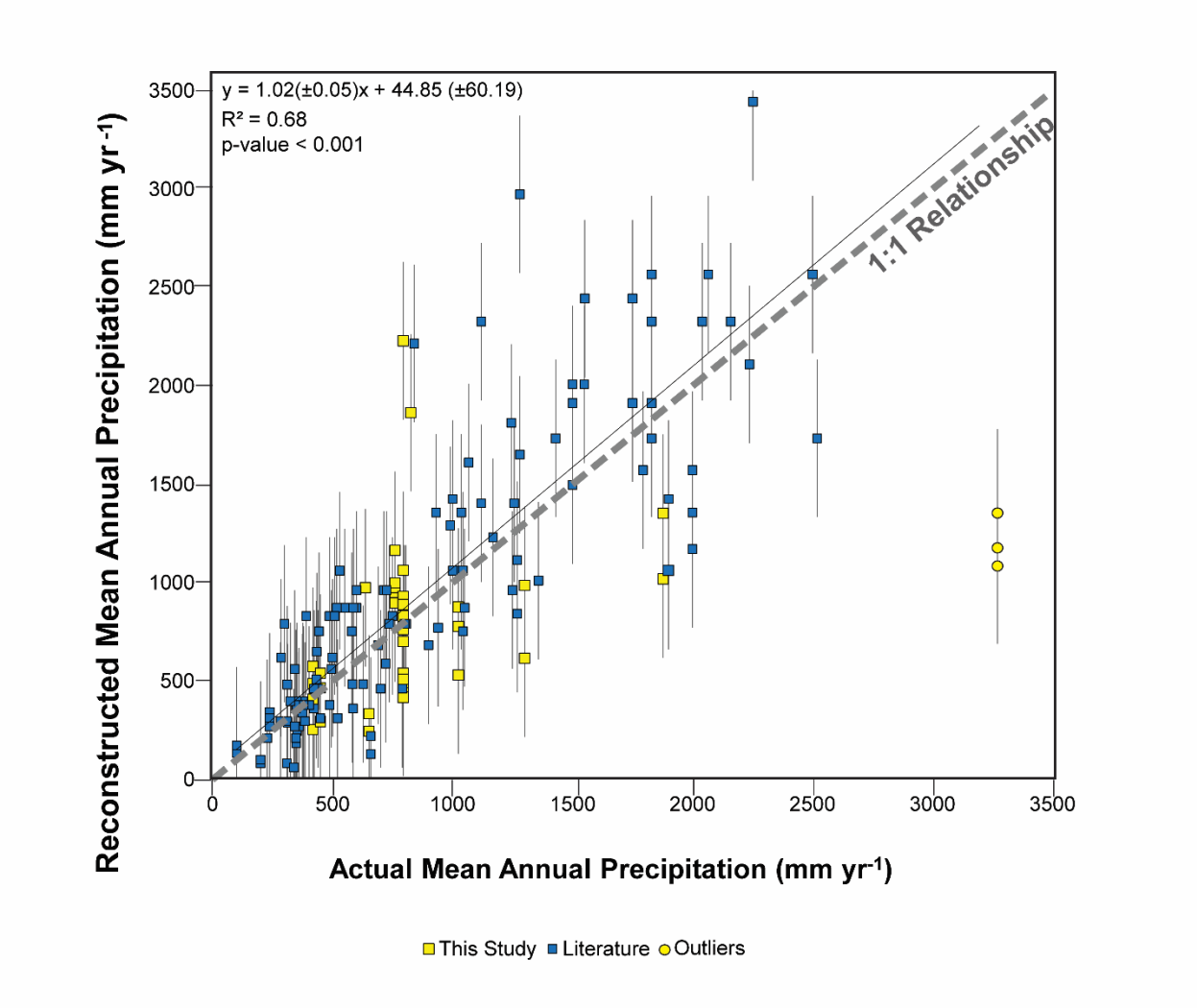


Figure C4 (a) $\delta^{13}C_{SOM}$ values compared to mean annual precipitation (mm yr^{-1}) for modern soils divided by soil order. (b) Actual mean annual precipitation compared to reconstructed mean annual precipitation using the logarithmic relationship modeled divided by soil order (Equation 4.5). The 1:1 relationship is shown by the dashed line. This supplements Figure 2 and Supplemental Figure 3 with more information on soil order.

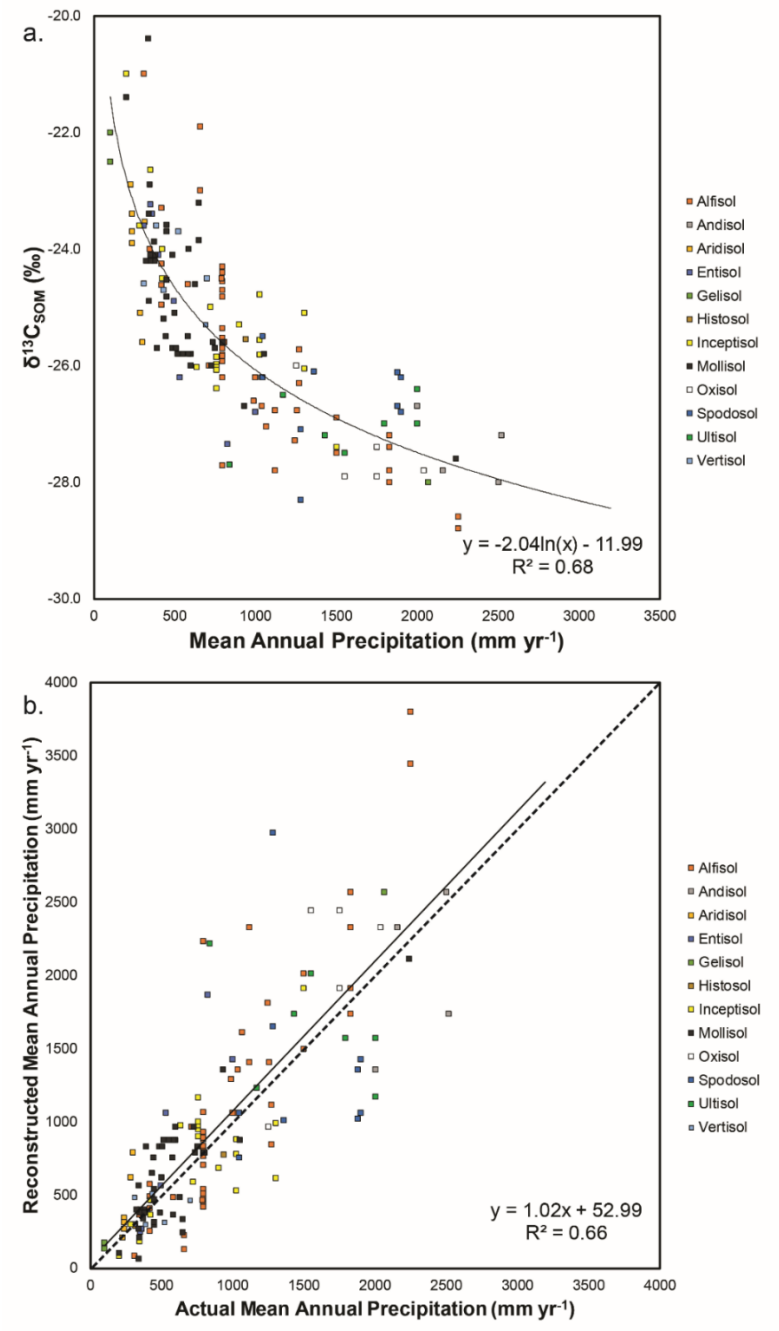


Figure C5 Map of paleosol sites. Red squares represent soils from the Paleozoic, orange squares represent soils from the Mesozoic, and yellow soils represent soils from the early Cenozoic (Paleocene) through the Quaternary (but not modern).

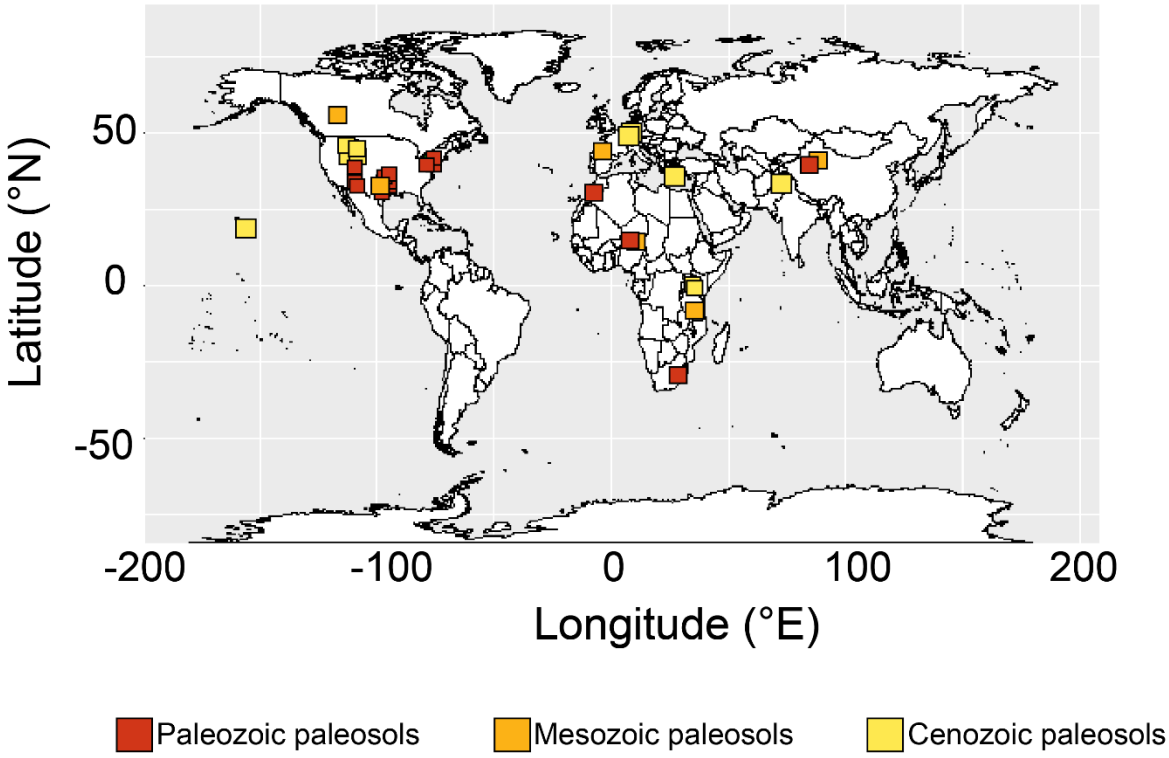


Figure C6 Violin plots showing the distribution of $\delta^{13}C_{SOM}$ values in angiosperm- and gymnosperm- dominated ecosystems. The mean $\delta^{13}C_{SOM}$ value for angiosperm dominated ecosystems was -25.68‰, and the mean $\delta^{13}C_{SOM}$ value for gymnosperm dominated ecosystems was -25.52‰ and are not statistically different (p-value = 0.27).

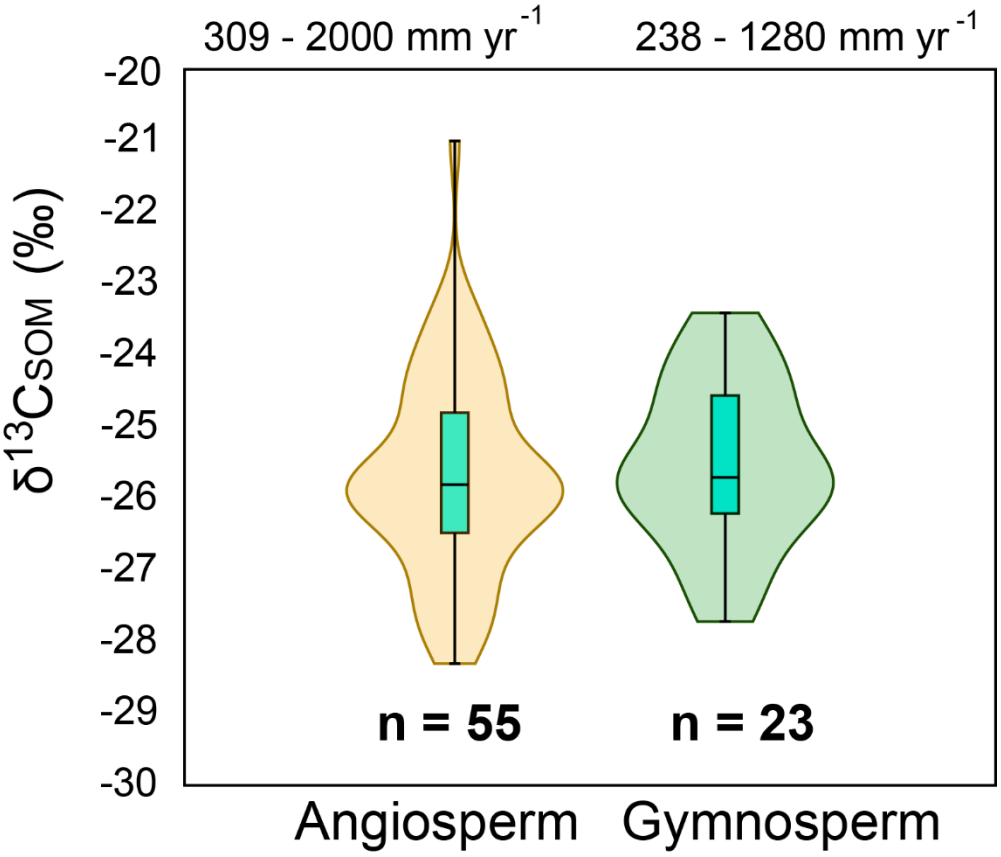
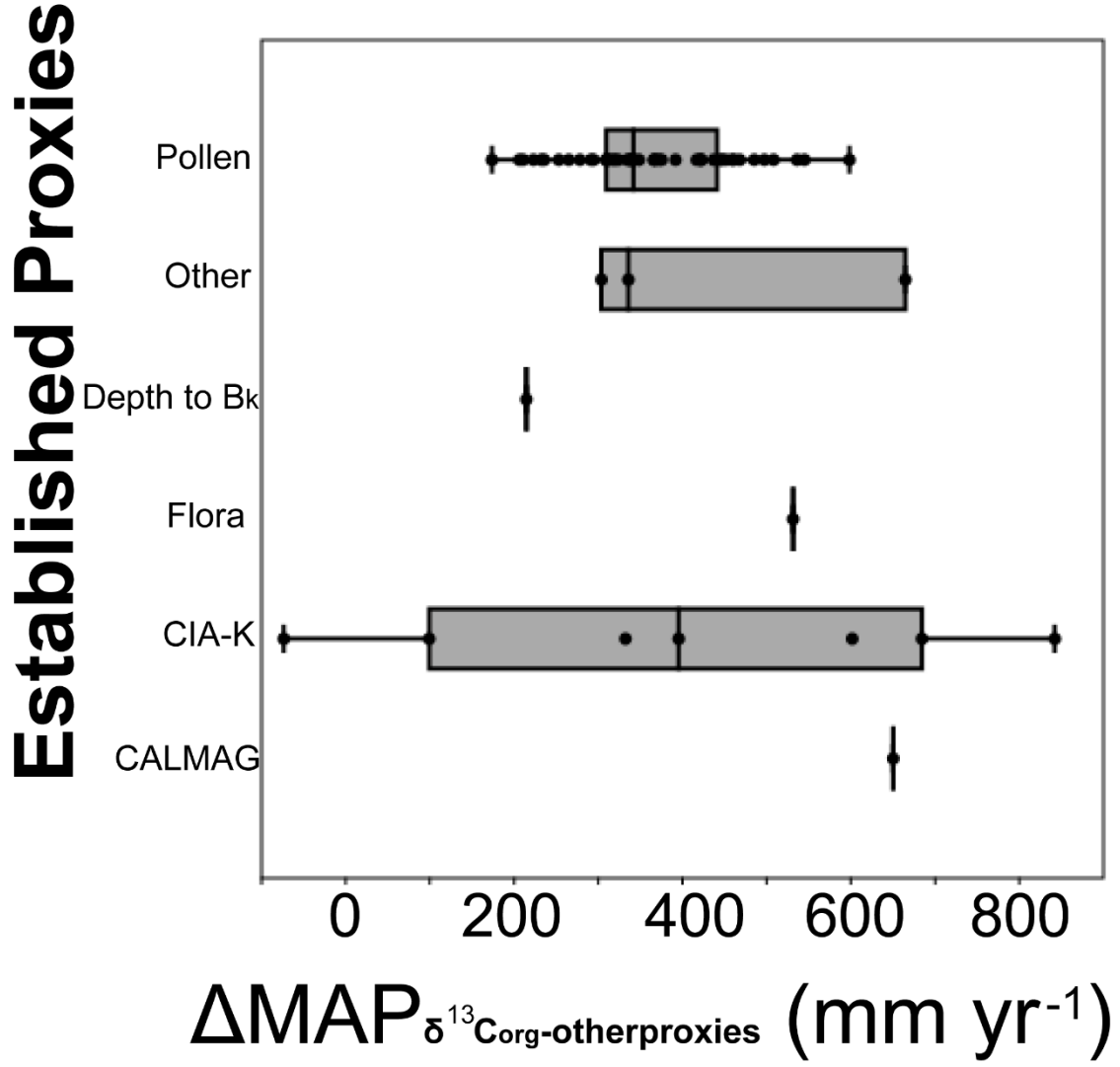


Figure C7 Box plots showing the range of residual values between precipitation reconstructed using the $\delta^{13}C_{SOM}$-paleoprecipitation proxy in this study, and other established proxies, divided by proxy. The whiskers show standard error and points show actual residual values as calculated by subtracting $MAP_{\delta 13CSOM} - MAP_{other}$.



APPENDIX D

Supplemental Table, Figures, and Methods for Chapter V

Table D1: Paleosol features, including color, evidence of disturbance, texture and depth.

Sample ID	Paleosol #	Depth (cm)	Horizon	Root traces, rhizoliths	Redox Haloes	Burrows	Peds	Color (descriptive + Munsell)	Texture
19BRWY1UA	1	0	A	Yes				5Y 6/1	
19BRWY1LA	1	-12	A	Yes			Yes	2.5Y 6/1	silt sandstone
19BRWY1LC	1	-18	C					dark brown, 10YR 5/2	silt sandstone, no bedding, not laminated
19BRWY2UA	2	0 to -5	A	Yes	Yes			green grey, 2.5Y 7/3	
19BRWY2UB	2	-25	B			Yes, up to 1cm		5Y 7/2	
19BRWY2MB	2	-50	B			Yes, up to 1cm		olive, 5Y 7/2	mudstone
19BRWY2LB	2	-75	B					2.5YR 7/3	
19BRWY2C	2	-85	C	Yes, very fine				dark grey, GLEY1 7/10Y	clay-silt to silty clay, laminated
19BRWY3UA	3	0	A	Yes				brown green, 5Y 7/2	
19BRWY3UB	3	-35	B					grey-brown, 5Y 8/1	silty mudstone
19BRWY3MB	3	-45	B					10YR 7/1	
19BRWY3C	3	-75	C					dark grey, 5Y 7/1	mudstone
19BRWY4UB1	4	0	B	Yes	Yes			10YR 7/2	sandy
19BRWY4UB2	4	-15	B					GLEY1 7/10Y	sandy mudstone
19BRWY4LB	4	-30	B					2.5Y 6/2	shale, mudstone
19BRWY4C	4	-60	C					5Y 8/1	shale, mudstone
19BRWY5UA	5	0	A	Yes				dark grey, green	silty mudstone
19BRWY5UB	5	-20	B	Yes				5Y 7/1	siltstone
19BRWY5MB	5	-35	B					5Y 7/2	
19BRWY5C	5	-80	C					dark grey, 5Y 6/1	massive fine sand mudstone
19BRWY6UA	6	0	A					10YR 7/1	
19BRWY6UB	6	-42	B					5Y 7/1	
19BRWY6MB	6	-72	B					5Y 7/2	shale, mudstone
19BRWY6C	6	-112	C					2.5Y 5/1	shale, mudstone

Table D2: All bulk geochemical and carbon isotope data from the Blue Rim escarpment. Includes climate reconstructions for the stratigraphic sections and paleosols, as well as $\delta^{13}C_{atm}$ values reconstructed from $\delta^{13}C_{fossil}$ values.

Sample ID#	Strat Colun Height (m)	Paleosols Depth (cm)	Sample ID (DESCRIPTI	$\delta^{13}C_{org}$ ‰	C weight %C	N weight %N	Ag ppm	Al %	As ppm	Ba ppm	Be ppm	Bi ppm	Ca %	Cd ppm	Ce ppm	Co ppm	Cr ppm	Cs ppm	Cu ppm	Fe %	Ga ppm	Ge ppm	Hf ppm	In ppm	K %	La ppm	Li ppm	Mg %	Mn ppm	Mo ppm	Na %	Nb ppm	Ni ppm	P ppm	Pb ppm	Rb ppm	Re ppm	S %	Sb ppm	Sc ppm	Se ppm	Sn ppm	Sr ppm	Ta ppm	Te ppm	Th ppm	Ti %	Tl ppm	U ppm	V ppm	W ppm	Y ppm	Zn ppm	Zr ppm
19BRWY1 UA	1	0	Y995872	n/a	n/a	n/a	0.18	7.53	6.7	450	1.78	0.4	0.35	<0.02	52.2	6.2	67	11	28.4	3.87	19.75	0.1	2.3	0.073	2.37	28.2	19.1	0.91	60	2.09	0.35	12.1	12	110	28.3	124	<0.002	0.01	1.91	12.3	1	2.9	241	0.86	<0.05	15.3	0.359	0.79	2.7	100	12.7	11.3	63	86.5
19BRWY1 LA	1	-12	Y995873				0.11	7.53	8.4	470	2.12	0.37	0.41	0.03	70.5	20.2	66	12	35.5	4.42	20.3	0.16	2.7	0.074	2.53	36.9	25.1	1.02	90	1.97	0.35	12.9	18.7	140	21.7	148	<0.002	0.01	2.07	12	<1	3	256	0.89	0.08	15.55	0.353	0.9	2.6	90	63.6	19	72	84.4
19BRWY1 LC	1	-18	Y995874	n/a	n/a	n/a	0.1	7.75	8.8	540	2.24	0.4	0.3	0.05	89	14.4	63	11.3	32.3	4.66	20.6	0.16	3.1	0.063	2.92	39.7	34.8	1.41	165	0.52	0.42	12.3	36.6	430	19.7	152	<0.002	<0.01	2.36	11.6	<1	3	175	0.79	<0.05	15.1	0.322	0.95	2.6	85	17.9	25.2	98	76.7
19BRWY2 UA	1	0	Y995875	n/a	n/a	n/a	0.12	7.8	12.8	550	2.52	0.37	0.81	0.1	72	12	64	11.25	33.9	4.8	21.4	0.16	3	0.075	2.89	35.3	30.9	1.34	183	1.14	0.38	13.1	27.9	310	22.9	152	<0.002	0.01	2.47	11.9	<1	3.2	253	0.81	<0.05	13.55	0.332	0.9	2.5	87	14.7	19.5	100	87.1
19BRWY2 UB	1	-25	Y995876	n/a	n/a	n/a	0.24	6.09	6.4	400	1.69	0.31	10.25	1.02	65.2	12.7	44	9.32	27.3	3.5	16.45	0.14	1.9	0.063	2.11	32.7	28.9	1.45	1760	0.64	0.32	10.5	29	610	21.6	106	<0.002	0.01	2.01	9	<1	2.6	232	0.7	<0.05	10.95	0.26	0.7	2.8	76	16.7	25.5	88	61.1
19BRWY2 LB	1	-75	Y995878	n/a	n/a	n/a	0.12	5.33	2.6	550	1.4	0.23	5.38	0.44	62.3	22.5	42	5.69	21.9	1.82	13	0.21	1.8	0.042	1.97	29.9	24.9	1.34	852	0.39	0.74	9.3	24.4	840	16.5	86.6	0.002	0.01	0.61	7	<1	2	163.5	0.66	<0.05	9.59	0.248	0.61	3.5	57	141	18	72	54.5
19BRWY2 MB	1	-50	Y995877	n/a	n/a	n/a	0.08	4.08	1.8	290	1.09	0.19	18.5	0.84	47.3	10.3	32	5.49	20.2	1.66	10.6	0.13	1.2	0.035	1.38	23.9	19.6	1.13	2790	0.34	0.29	6.7	18.4	690	13.3	65.7	<0.002	0.01	0.66	5.8	<1	1.6	217	0.45	<0.05	6.77	0.172	0.46	4.1	55	18.4	18.5	62	39.1
19BRWY2 C	1	-85	Y995879	n/a	n/a	n/a	0.27	7.63	12.3	500	1.82	0.38	0.4	0.13	58.8	16.5	62	10.8	33.6	3.84	20.2	0.13	2.4	0.07	2.44	29.5	26.5	1.17	158	4.6	0.42	12.5	21.4	260	24.2	141	0.002	0.05	1.7	11.4	1	2.9	1045	0.84	0.08	12.5	0.395	0.91	2.9	98	97.1	14.1	97	75
19BRWY3 UA	1	0	Y995880	n/a	n/a	n/a	0.12	6.61	8.3	500	1.76	0.3	0.22	<0.02	106	15	56	9.42	39.1	4.03	17.7	0.18	2.1	0.063	2.44	46.7	20.7	0.99	112	1.73	0.5	11.7	21.5	230	18.1	131	<0.002	<0.01	2.03	9.9	1	2.7	138	0.79	<0.05	13.7	0.308	0.81	2.4	85	54.3	18.6	66	68.6
19BRWY3 UB	1	-35	Y995881	n/a	n/a	n/a	0.22	6.45	17.4	490	2.05	0.31	0.19	0.02	118	15	54	9.21	63.4	4.62	17.7	0.2	2.2	0.057	2.4	50.5	22.9	1.06	162	3.43	0.54	11.5	28.4	350	19.4	132	<0.002	<0.01	2.46	10	1	2.5	122	0.76	0.07	12.75	0.295	0.8	2.5	109	46	23.2	73	66.8
19BRWY3 MB	1	-45	Y995882	n/a	n/a	n/a	0.16	6.37	16.5	490	2.12	0.29	0.2	0.02	117	14.9	54	8.51	44.2	4.55	17.2	0.18	2	0.055	2.41	52.4	24.5	1.11	198	3.45	0.56	11.4	33.6	450	18.6	124.5	<0.002	<0.01	2.11	9.9	<1	2.4	114.5	0.73	<0.05	12.5	0.292	0.73	2.2	98	21.9	29.3	79	69.6
19BRWY3 C	1	-75	Y995883	n/a	n/a	n/a	0.13	6.77	7.4	510	1.9	0.32	2.35	0.26	84.9	18	55	9.55	35.9	4.14	17.85	0.21	2	0.065	2.48	39.5	29.7	2.33	365	0.91	0.55	11.5	37.5	750	18.3	131.5	<0.002	0.01	1.92	10.2	<1	2.8	165.5	0.74	<0.05	13.85	0.308	0.79	2.7	88	9.3	33	89	63.2
19BRWY4 UB1	1	0	Y995884	n/a	n/a	n/a	0.14	7.85	16.2	540	2.43	0.41	0.26	0.06	78.3	15.2	63	11.5	32.6	4.94	21.3	0.18	2.5	0.079	2.89	38.1	34.7	1.49	215	1.61	0.46	12.6	36	450	21.6	149	<0.002	<0.01	2.46	11.5	<1	3.1	140.5	0.82	0.07	14.45	0.327	0.9	2.3	107	8.8	21.4	103	82.1
19BRWY4 UB2	1	-15	Y995885	n/a	n/a	n/a	0.16	4.79	3	360	1.44	0.23	10.3	0.37	62	9.7	31	6.9	29.1	2.67	12.7	0.14	1.5	0.044	1.72	27.9	19.9	5.49	1310	1.37	0.27	8.1	16.7	420	18.9	87.8	<0.002	0.01	1.29	7.5	<1	2	491	0.54	0.07	8.64	0.208	0.55	4.4	50	14.7	31.4	61	52.3
19BRWY4 LB	1	-30	Y995886	n/a	n/a	n/a	0.31	7.8	8.5	410	1.81	0.2	0.49	0.21	45.9	6.4	70	11.5	40.6	3.53	20.8	0.12	2.4	0.059	1.94	26.2	19.6	0.89	58	6.12	0.21	13	12.8	180	18.3	136	<0.002	0.01	2.54	10.4	<1	2.7	222	0.87	<0.05	9.33	0.378	0.79	2.9	98	34.7	11.1	93	67.4
19BRWY4 C	1	-60	Y995887	n/a	n/a	n/a	0.36	8.16	9.6	460	2.04	0.21	0.63	0.16	50.1	4.9	71	11.8	45.3	3.47	22.3	0.12	2.4	0.061	1.92	26	20.1	0.93	59	6.61	0.24	13.7	13.3	470	18.8	139	<0.002	0.01	2.23	10.8	1	2.9	223	0.93	<0.05	9.56	0.394	0.75	3.2	88	9.3	19.5	96	76.5
19BRWY5 UA	1	0	Y995888	n/a	n/a	n/a	0.25	8	11.2	530	2	0.33	0.99	0.31	64.2	8.2	71	11.55	38.3	3.89	21.5	0.13	2.4	0.071	2.12	35	26.3	1.08	157	4.61	0.29	12.9	21.4	300	28.2	133	<0.002	0.01	2.62	11.6	<1	2.8	208	0.84	0.06	13.5	0.37	0.8	3.4	102	14.4	14.3	100	72.4
19BRWY5 UB	1	-20	B0173201	n/a	n/a	n/a	0.13	6.27	2.5	900	2.1	0.31	1.38	0.32	82.6	11.8	39	10.6	20.7	2.54	18.1	0.19	3.1	0.032	2.17	42.4	41.1	1.33	175	0.96	1.88	10.8	20.4	1250	30.6	117	0.007	0.12	0.59	7	3	2	413	0.73	0.05	11.05	0.265	0.51	2.6	61	10.1	20.8	94	102
19BRWY5 MB	1	-35	B0173202	n/a	n/a	n/a	0.17	6.57	4	1360	2.16	0.24	4.17	0.47	67.9	18.9	41	6.9	24.4	2.31	18.1	0.19	2.7	0.036	1.84	35.7	36.1	1.29	302	1	2.15	11	16.4	900	22	84.9	0.006	0.08	0.36	7	3	2	603	0.72	<0.05	11.15	0.261	0.4	2.8	46	8.3	15.7	72	90.7
19BRWY5 C	1	-80	B0173203	n/a	n/a	n/a	0.31	6.59	1.4	940	1.53	0.23	2.06	0.32	67.4	13.8	39	6.09	19.5	2.52	17.55	0.21	2.9	0.036	1.94	35.6	31.9	1.31	217	0.87	2.14	11.9	19.3	1340	18.3	91.4	0.01	0.07	0.37	6.7	2	2.1	375	0.76	<0.05	11.2	0.262	0.41	3.4	49	35.6	18	67	95.6
19BRY6UA	1	0	B0173204	n/a	n/a	n/a	0.06	7.24	3.2	960	1.39	0.12	2.57	0.11	99.3	16.8	94	2.91	9.7	3.69	19.6	0.22	3.4	0.049	1.71	53.2	22.1	1.4	310	1.46	2.76	14.1	29.4	960	16.5	67.9	0.002	0.14	0.41	13	<1	1.6	653	0.78	<0.05	12.4	0.512	0.22	3	115	17.7	17.2	86	111.5
19BRWY6 UB	1	-42	B0173205	n/a	n/a	n/a	0.09	6.49	2.9	970	2.12	0.27	1.89	0.19	52.9	10.4	42	8.54	15.1	2.59	17.9	0.15	3	0.032	2.21	26.8	45.7	1.31	193	1.04	2.1	11.8	18.7	390	21.2	101	<0.002	0.12	0.44	7.2	<1	2	442	0.76	<0.05	9.08	0.289	0.45	2.7	60	9.9	9.6	66	97.3
19BRWY6 MB	1	-72	B0173206	n/a	n/a	n/a	0.09	6.4	2.4	1020	2.17	0.33	1.39	0.21	58	11.3	41	10.65	17.5	2.56	17.95	0.16	3	0.039	2.23	31.3	49.2	1.35	173	1.04	1.84	11.4	20	550	20.6	121.5	0.003	0.09	0.44	7.4	1	1.9	466	0.75	0.05	10.6	0.27	0.47	2.2	62	8.4	13.2	69	103.5
19BRWY6 C	1	-112	B0173207	n/a	n/a	n/a	0.06	6.96	0.9	1110	2.04	0.23	1.79	0.1	70.4	10	39	5.9	12.9	2.45	19	0.17	2.8	0.045	1.79	36.4	34.7	1.33	156	0.85	2.45	12.1	17.3	760	19.3	87.8	<0.002	0.17	0.32	7	1	2	514	0.81	<0.05	10.7	0.264	0.31	3.1	50	19.4	13	62	87.5
BR919-01M	n/a	n/a	Y995843	n/a	n/a	n/a	0.05	6.75	2.7	720	1.85	0.2	2.21	0.1	61.7	9.2	43	6.4	15.6	3.18	16.5	0.11	3	0.043	2.54	32.4	31.9	1.58	235	0.62	1.47	12.7	18	800	16.6	105.5	0.005	0.09	0.34	8.5	1	1.7	393	0.7	<0.05	10.8	0.316	0.43	2.8	62	11.2	14.7	65	112.5
BR919-02	n/a	n/a	Y995844	-25.70681	0.6	0	0.1	7.32	6.5	660	1.81	0.29	1.04	0.1	58.9	5	41	7.51	27.5	1.85	17.75	0.08	3.4	0.051	3.88	30.9	27	0.83	81	10.85	1.14	13.5	7.2	620	15.8	105	0.006	0.16	0.41	10.2	1	1.8	266	0.78	<0.05	12.55	0.333	1.22	3.2	73	8.1	11	46	128
BR919-03	n/a	n/a	Y995845	-29.18366	5.4	0	0.02	1.16	4	1080	0.35	0.04	23.1	0.04	13.75	2.5	10	1.56	5.6	0.7	2.81	0.11	0.5	0.009	0.62	6.8	16.6	0.44	5340	12.15	0.53	2	4.4	610	3.6	19.2	0.006	0.37	0.15	1.6	2	0.3	288	0.1	<0.05	2.22	0.05	0.44	1.2	14	7.3	4	14	20.7
BR919-06b	n/a	n/a	Y995846	-24.94642	8.5	0.1	<0.01	0.05	4.3	10	0.28	<0.01	13.65	<0.02	1.88	2.4	2	<0.05	0.8	0.19	1.38	0.1	0.1	<0.005	0.01	1.1	11.6	0.25	5920	17.2	0.18	1	0.3	180	<0.5	0.4	0.005	0.22	0.19	0.2	1	<0.2	138.5	<0.05	<0.05	0.08	0.005	1.48	1.2	6	39	1.3	20	13.6
BR919-07	n/a	n/a	Y995847		n/a	0.1	0.09	6.19	5.9	610	1.56	0.22	8.55	0.14	61.3	8.6	24	6.49	19.5	2.64	14.3	0.13	2.8	0.034	2.56	34.6	28.6	1.32	2150	0.64	1.45	9.3	11.7	1070	14.2	110.5	<0.002	0.14	0.32	6.5	<1	1.3	436	0.56	<0.05	7.62	0.258	0.39	2.5	42	6.9	16.3	54	100.5
BR919-08	7.25		Y995848	-27.5432	0.5	0	0.04	2.75	20.7	490	0.92	0.1	17.55	0.1	38.7	4.1	21	3.22	7.8	1.2	6.48	0.12	1.2	0.017	1.09	20.1	20.6	1.05	1980	2.9	0.74	4.7	8.1	1130	6.2	43.3	0.002	0.14	0.21	3.7	1	0.6	670	0.27	<0.05	4.23	0.128	0.68	5.7	31	7.2	12.5	27	44.9
BR919-09	6.25		Y995849		n/a	0	0.04	6.58	1.3	590	1.75	0.19	1.58	0.09	64.1	10.2	38	6.75	13.4	2.83	15.6	0.19	2.8	0.035	2.42	34	38	1.46	221	0.6	2.32	12.1	18.6	560	16.4	111.5	0.007	0.16	0.28	6.6	1	1.7	295	0.71	<0.05	9.71	0.279	0.38	2.2	57	7.5	19	61	98.8
BR919-10	0		Y995850		n/a	0	0.06	6.31	1.2	740	1.88	0.21	1.39	0.09	62.8	11.8	40	8.04	14.8	2.63	15.45	0.15	2.6	0.036	2.23	33.5	40.1	1.48	187	0.19	2.39	11	19.7	580	15.4	106.5	0.003	0.26	0.28	7.6	1	1.7	329	0.6	<0.05	10.4	0.267	0.38	2.1	53	10.7	14.7	61	90.4
BR919-11	31		Y995851	-23.70409	0.1	0	0.16	7.52	3.7	710	2.05	0.33	1.48	0.28	93.7	11.6	64	10.3	46.6	3.09	18.55	0.15	1.9	0.065	2.39	45.3	38.7	1.46	438	0.53	0.63	13.3	30.4	570	33.6	118.5	0.003	0.04	0.79	9.9	1	2.5	178	0.84	<0.05	16	0.343	0.7	14.3	111	14.5	23.7	150	64.4
BR919-12	31.5		Y995852	-25.6222	0.5	0	0.18	8.43	15.9	510	2.62	0.42	0.55	0.22	102.5	15.6	74	12.9	36	5.04	21.8	0.14	2	0.077	2.6	50.1	45.3	1.64	194	1.63	0.49	15.2	35.8	470	43.9	135	0.005	0.02	1.88	12.6	1	2.9	172	0.94	0.05	18.7	0.377	0.81	4.1	112	21.7	22.1	148	67.6
BR919-14	31		Y995853	-25.14093	0.3	0	0.29	8.45	15.2	470	2.71	0.45	0.38	0.11	68.2	12.4	80	13.25	36.7	5.43	22.3	0.11	2.2	0.076	2.71	31.4	48.4	1.63	173	1.4	0.47	15.4	36.1	310	45.1	114	0.005	0.01	2.22	13.1	1	3	172	0.96	0.05	15.35	0.395	0.85	3.4	119	7.3	15.5	159	70.9
BR919-15	31.25		Y995854		0.8	0.1	0.21	8.57	23.7	440	2.34	0.43	0.32	0.09	96.5	12.4	86	12.7	46.4	5.63	23.7	0.22	2.3	0.077	2.51	48.7	41.7	1.64	194	2.41	0.45	14	40	230	24.9	157	0.005	0.01	3.3	13.3	1	3.1	147	0.89	0.07	19.25	0.344	0.97	3	117	7.1	16.5	121	72.9
BR919-16	51.5		Y995855	-25.94989	1	0.1	0.2	8.51	29.5	420	2.51	0.44	0.32	0.11	91.9	14.4	77	12.45	39.4	5.68	23.1	0.19	2.6	0.073	2.41	47.6	41.4	1.63	204	2.7	0.43	14.3	40	370	27.2	150	<0.002	0.02	3.14	12.4	1	3.1	137.5	0.94	0.05	19.45	0.353	0.95	3.2	121	13.6	19.5	145	80.7
BR919-18	12.5		Y995856	-24.86143	0.2	0.1	0.2	8.7	30.2	450	2.74	0.44	0.44	0.1	102.5	13.9	73	12.4	37.6	5.43	23.8	0.19	2.6	0.073	2.5	49.1	40.6	1.68	201	2.75	0.47	14.3	41.2	610	35.4	143.5	0.005	0.01	2.75	12.1	1	3.2	136	0.97	0.06	20.2	0.367	0.97	3.3	120	12.4	25.8	133	78.4
BR919-18t	13.25		Y995857	-23.2504	0.1	0.1	0.39	8.26	35.5	410	2.58	0.46	0.41	0.17	68.8	11.4	70	12.5	41.8	5.13	24.2	0.16	2.4	0.08	2.44	35.6	39	1.57	172	3.1	0.48	14.3	36.4	550	34.3	120.5	0.005	0.02	3.45	11.7	1	3.1	238	0.91	0.09	17.3	0.33	1.06	3.1	125	11.9	18	105	76.7
BR919-20	26		Y995858	-24.33197	0.2	0	0.49	8.53	18.4	450	2.32	0.5	0.47	0.92	83.6	9.9	69	13.3	41.3	4.06	23.1	0.17	2.7	0.068	2.55	48.6	34.3	1.52	149	2.41	0.45	13.4	25.9	380	36.9	138.5	0.004	0.01	2.1	11.6	1	3.2	171	0.97	0.06	18.4	0.328	0.92	4.7	136	13.4	17.5	91	77.3
BR919-21	28.25		Y995859	-24.5593	0.2	0.1	0.55	7.87	17.8	450	2	0.38	0.38	0.41	78	11	64	10.7	39.7	3.92	20.9	0.12	2.3	0.072	2.44	42.5	31.6	1.36	142	1.82	0.52	13.5	26.7	470	28.5	141.5	0.006	0.02	1.72	10.7	2	2.9	181	0.89	0.05	16.8	0.329	0.87	4.4	105	27.3	18	97	77.5
BR919-22	29		Y995860	-29.49279	2.9	0.1	0.18	6.29	5	470	1.86	0.21	0.39	0.12	82.4	17.4	56	7.13	27.8	3.13	16.9	0.18	2	0.054	2.22	39.8	26.9	1.23	166	0.41	0.65	12.1	35.9	500	17.2	115	<0.002	0.05	0.9	8.9	<1	2.3	124	0.82	<0.05	12.05	0.302	0.69	3	76	86.8	18.4	96	71.1
BR919-23	30.5		Y995861	-23.09982	0.1	0.1	0.15	6.65	3.6	460	1.65	0.26	4.13	0.15	66.2	8.8	54	10.45	18.8	3.27	17.55	0.18	2.1	0.055	2.24	34.4	29.2	1.21	560	0.83	0.51	10.9	22	350	21.9	118	<0.002	0.03	1.45	9.8	1	2.3	206	0.78	<0.05	13.25	0.313	0.81	3.1	67	16.7	15.5	84	64
BR919-24	32		Y995862	-22.12946	0.1	0.1	0.1	5.75	4.6	450	1.68	0.23	4.84	0.15	73.6	11.9	49	7.27	30.5	3.07	15.2	0.18	2	0.045	2.06	35	25.7	1.12	648	0.99	0.56	10.5	24.2	270	17.8	101	<0.002	0.02	1.24	8.9	1	2.2	173.5	0.68	<0.05	12	0.286	0.62	3.1	66	26.4	15.4	75	62.6
BR919-25	33.5		Y995863		n/a	0	0.09	5.98	2.8	490	1.65	0.22	2.88	0.2	80.9	12.1	53	7.46	27.4	2.9	15.95	0.17	2	0.048	2.12	38.2	26.2	1.17	395	0.62	0.64	10.8	30.2	440	18	102	<0.002	0.01	1.06	9.3	<1	2.2	226	0.77	<0.05	12.1	0.295	0.63	3.2	65	26.5	20.2	77	62.6
BR919-26	36		Y995864		n/a		0.07	5.69	5.5	450	1.72	0.24	5.9	0.56	75.9	11.6	49	7.27	23.7	3.23	15.35	0.2	1.9	0.053	2	36.6	25.3	1.36	770	1.07	0.6	10.9	25.6	610	17.9	99.1	<0.002	0.02	1.42	9	<1	2.3	166.5	0.68	<0.05	11.7	0.283	0.59	2.8	70	21.4	22	72	70.2
BR919-27	42.5		Y995865	-23.23079	0.1	0.3	0.07	6.14	9.5	520	1.82	0.3	2.16	0.22	71.5	14.9	53	7.59	24.3	3.59	16.5	0.15	1.9	0.056	2.17	34.3	27.9	1.84	321	1.49	0.76	11.4	29.2	860	20.2	101	<0.002	0.01	1.31	9.5	1	2.5	174.5	0.74	0.05	12.35	0.302	0.65	2.6	76	36.1	20.5	75	61.8
BR919-28	45.5		Y995866		n/a	0	0.1	6.05	9.4	490	1.9	0.28	2.87	0.24	66.4	17.6	51	7.49	27	3.61	16.05	0.15	2.3	0.064	2.13	32.6	27.3	1.82	434	1.61	0.73	10.8	27.4	780	16.9	108.5	<0.002	0.01	1.4	9.6	<1	2.3	137	0.69	0.09	12.2	0.291	0.62	2.7	81	32	17.4	75	61.7
BR919-29	50		Y995867		n/a	0	0.07	6.37	5.1	500	1.73	0.3	3.37	0.2	78.6	19.2	54	8.12	28.2	3.18	17.15	0.18	2.2	0.051	2.25	37.3	28.5	1.87	494	0.95	0.72	11.7	28.5	860	16.4	117.5	<0.002	0.01	0.99	10	<1	2.6	149	0.78	0.08	13	0.309	0.71	3.4	81	59.5	22.1	78	66.7
BR919-31	51.5		Y995868	-28.6425	0.6	0	0.04	2.59	2.4	210	0.87	0.13	24.3	3.99	51.1	8.7	20	3.51	11	1.49	7.1	0.12	0.9	0.025	0.93	30.3	12.6	0.81	3120	0.62	0.26	4.7	11.4	540	16.6	45.6	0.002	<0.01	0.6	4.6	1	1	95	0.32	<0.05	5.3	0.127	0.34	1.4	37	29.9	22.6	34	29.3
BR919-32	56		Y995869	-22.91876	0.1	0	0.16	6.93	2.8	520	1.77	0.37	2.86	0.16	68.6	20.6	59	10.1	31	3.11	18.75	0.2	1.9	0.062	2.49	32	31.2	1.98	505	0.52	0.64	12.2	30.8	730	22.6	116	<0.002	0.02	0.83	10.6	<1	2.8	407	0.77	0.06	13.2	0.343	0.84	2.6	85	25.5	18.2	84	62.5

	Strat Colun	Paleosols	CIA	CIA-K	MAP mm yı	PWI	Temperatu	SAL	T from Sal	Provenanc	Provenance	Hydrolosis	Leaching	Parent Mat	Parent Mat	Leaching
Sample ID#	Height (m)	Depth (cm)	Molar Ratio	Molar Ratio	from CIA-K	Gallagher &	from PWI	(Na+K/Al)	(T = -18.5S+	Ti/Al	Zr/Al	Bases / Al	Bases/Ti	La/Ce	U/Th	Ba/Sr
19BRWY1 UA	1	0	74.944715	89.514881	n/a	n/a	n/a	0.2717351	n/a	0.0268739	3.31516E-05	0.6026127	11.214908	0.5168947	0.1720291	1.1913594
19BRWY1 LA	1	-12	73.545233	88.663408	n/a	n/a	n/a	0.2863974	n/a	0.0264247	2.92719E-05	0.6604345	12.499913	0.5007958	0.1629943	1.1714
19BRWY1 LC	1	-18	72.689671	89.62809	n/a	n/a	n/a	0.3235925	n/a	0.0234199	3.39765E-05	0.7796215	16.648938	0.4267995	0.1678518	1.9688065
19BRWY2 UA	1	0	68.83903	83.54252	n/a	n/a	n/a	0.3128456	n/a	0.0239924	2.90733E-05	0.8340616	17.386475	0.4691002	0.1798582	1.3870416
19BRWY2 UB	1	-25	28.035873	30.050058	n/a	n/a	n/a	0.3007465	n/a	0.024065	3.02431E-05	3.0954478	64.331599	0.47987	0.249272	1.1000675
19BRWY2 MB	1	-50	13.473773	13.911244	n/a	n/a	n/a	0.3168156	n/a	0.0237629	3.30279E-05	7.0366995	148.10088	0.4834596	0.5903706	0.852679
19BRWY2 LB	1	-75	36.009847	39.651465	n/a	n/a	n/a	0.4179855	n/a	0.0262274	2.83449E-05	2.3351605	44.529641	0.459205	0.3557779	2.146309
19BRWY2 C	1	-85	73.754133	88.09115	n/a	n/a	n/a	0.2852716	n/a	0.0291812	2.96744E-05	0.6962869	11.933631	0.4800297	0.2261609	0.3052819
19BRWY3 UA	1	0	72.03009	88.215427	n/a	29.692129	12.098983	0.3434965	n/a	0.0262651	3.06959E-05	0.7208159	13.725622	0.4215358	0.1707734	2.311736
19BRWY3 UB	1	-35	71.701149	87.879767	1174.1863	30.105263	12.061122	0.3550163	10.732198	0.0257806	3.06319E-05	0.7595271	14.734585	0.4094801	0.1911434	2.5626162
19BRWY3 MB	1	-45	71.097649	87.302013	1161.3673	30.749262	12.003127	0.364243	10.561504	0.0258389	3.23167E-05	0.7933737	15.356466	0.4285178	0.1715703	2.7304731
19BRWY3 C	1	-75	55.081669	63.991448	n/a	50.017213	10.670114	0.3481233	n/a	0.0256444	2.76112E-05	1.5795586	30.805667	0.4451566	0.1900393	1.9661629
19BRWY4 UB1	1	0	73.131081	89.817636	1218.225	36.125421	11.561629	0.3228134	11.327951	0.0234806	3.09336E-05	0.7887974	16.801355	0.4655718	0.1551635	2.45225
19BRWY4 UB2	1	-15	23.757925	25.243978	357.18386	102.5982	8.7015521	0.3139351	11.492201	0.024477	3.22941E-05	5.753632	117.56314	0.4305623	0.4964419	0.4678087
19BRWY4 LB	1	-30	77.651518	89.591345	1212.9985	24.140455	12.666144	0.2032231	13.540372	0.0273167	2.55578E-05	0.5411209	9.9072712	0.5461501	0.3030023	1.1783606
19BRWY4 C	1	-60	76.87393	87.837298	n/a	25.231752	12.544997	0.1968809	n/a	0.0272168	2.77287E-05	0.5538542	10.177622	0.4965455	0.3263034	1.3161345
19BRWY5 UA	1	0	71.837944	82.701962	n/a	29.893183	12.080493	0.2254047	n/a	0.0260701	2.67674E-05	0.691732	13.27037	0.5216227	0.2455131	1.6257728
19BRWY5 UB	1	-20	52.992616	60.670873	700.19697	48.389334	10.760774	0.590718	6.3717168	0.0238237	4.81161E-05	1.3579801	28.508344	0.4911445	0.2293721	1.3904
19BRWY5 MB	1	-35	41.120416	44.670208	516.64141	61.910922	10.085591	0.5773161	6.6196519	0.0223927	4.08319E-05	1.8677869	41.716618	0.5030624	0.2448007	1.4390269
19BRWY5 C	1	-80	49.872015	55.494064	n/a	52.329203	10.5463	0.5842541	n/a	0.0224102	4.29072E-05	1.4464522	32.280863	0.5053748	0.295931	1.5993514
19BRY6UA	1	0	47.885415	51.938899	n/a	59.476114	10.195525	0.6103829	n/a	0.0398623	4.55506E-05	1.5176145	19.04088	0.5126085	0.2358463	0.9380055
19BRWY6 UB	1	-42	49.829928	56.438166	646.09092	53.043886	10.509132	0.6147305	5.927486	0.0251006	4.43431E-05	1.4549457	28.990157	0.484733	0.2898728	1.4002216
19BRWY6 MB	1	-72	53.468079	61.355767	709.36816	48.634582	10.746923	0.577853	6.6097188	0.0237801	4.78319E-05	1.3385716	28.152355	0.5163448	0.2023235	1.3965663
19BRWY6 C	1	-112	51.629703	56.837489	n/a	52.912362	10.515935	0.5905966	n/a	0.0213809	3.7184E-05	1.3611078	31.838658	0.4947117	0.2824278	1.3778666
BR919-01M	n/a	n/a	51.122884	58.947968	564.34657	n/a	9.2190337	0.5152491	7.767892	0.0263884	4.92954E-05	1.4757329	27.969285	0.5024389	0.2527341	1.1689267
BR919-02	n/a	n/a	57.476911	72.776515	777.81666	n/a	9.1599577	0.5485369	7.1520668	0.0256427	5.17198E-05	0.9915587	19.339365	0.5019571	0.2485626	1.5831046
BR919-03	n/a	n/a	3.4822558	3.5275605	156.00922	n/a	7.8571539	0.9050397	0.5567648	0.0242964	5.27801E-05	28.559114	587.88129	0.4731836	0.5269359	2.3926467
BR919-06b	n/a	n/a	0.2681462	0.2682455	144.64739	n/a	9.561629	4.3630544	-63.41651	0.0563677	0.000804501	n/a	n/a	0.5598327	14.622471	0.0460678
BR919-07	n/a	n/a	29.23949	31.90147	301.32511	n/a	8.3766988	0.5603004	6.9344421	0.0234941	4.80212E-05	2.8934567	61.594913	0.5400563	0.3198266	0.8926694
BR919-08	7.25	n/a	9.821433	10.092542	181.6756	n/a	8.1406807	0.5893187	6.3976043	0.0262366	4.82916E-05	10.029478	191.18683	0.4969452		0.4666256
BR919-09	6.25	n/a	50.228922	57.567183	546.55467	n/a	8.9202509	0.6675846	4.9496848	0.0239006	4.44108E-05	1.4834848	31.042859	0.5075097	0.2208681	1.2760783
BR919-10	0	n/a	50.378228	57.43433	544.87268	n/a	8.9860767	0.6883919	4.5647507	0.0238513	4.23737E-05	1.505699	31.572807	0.5103976	0.196841	1.4351032
BR919-11	31	n/a	63.186606	73.351122	788.25506	n/a	10.041457	0.3176305	11.423837	0.0257103	2.53294E-05	1.0136388	19.718046	0.4625749	0.8712556	2.5449876
BR919-12	31.5	n/a	73.052136	86.500601	1069.4391	n/a	10.180345	0.2810418	12.100727	0.0252083	2.37179E-05	0.8007858	15.887644	0.4676676	0.2137331	1.8918602
BR919-14	31	n/a	74.231894	88.823612	1128.6568	n/a	10.168669	0.2865816	11.998241	0.0263494	2.48169E-05	0.7753807	14.717415	0.4405231	0.2159236	1.743479
BR919-15	31.25	n/a	76.103485	89.936178	1158.1683	n/a	10.33017	0.2637262	12.421065	0.022626	2.51596E-05	0.7388452	16.331751	0.4828643	0.1519218	1.909777
BR919-16	51.5	n/a	76.607963	90.095746	1162.4638	n/a	10.421217	0.2547188	12.587702	0.0233817	2.8048E-05	0.7305788	15.627117	0.4955813	0.1603836	1.9489195
BR919-18	12.5	n/a	75.20017	88.378526	1117.0622	n/a	10.276945	0.2616903	12.458729	0.0237781	2.66535E-05	0.7584881	15.953607	0.4583329	0.1592546	2.1111589
BR919-18t	13.25	n/a	74.689862	88.103242	1109.9507	n/a	10.352595	0.2720387	12.267284	0.0225198	2.74646E-05	0.760845	16.897375	0.495091	0.1746808	1.099143
BR919-20	26	n/a	74.494275	88.020358	1107.8184	n/a	10.305389	0.2681987	12.338323	0.0216748	2.68033E-05	0.7379902	17.028747	0.5562288	0.2490059	1.6790503
BR919-21	28.25	n/a	73.71939	87.523047	1095.1103	n/a	10.394726	0.2914847	11.907533	0.0235641	2.91263E-05	0.740142	15.709082	0.5213361	0.255313	1.5862851
BR919-22	29	n/a	69.046192	83.003952	986.10945	n/a	10.474094	0.3648246	10.550745	0.0270637	3.34331E-05	0.8824378	16.307401	0.4621461	0.2426966	2.4183741
BR919-23	30.5	n/a	46.325704	51.915852	479.3943	n/a	9.7317256	0.3224421	11.334821	0.026531	2.84653E-05	1.5625821	29.456223	0.4971917	0.2280738	1.4247476
BR919-24	32	n/a	40.082811	44.491501	403.54116	n/a	9.6785718	0.3615154	10.611964	0.0280368	3.22006E-05	1.9272667	34.379579	0.4550024	0.2518314	1.6548565
BR919-25	33.5	n/a	49.537574	56.368521	531.56494	n/a	9.9753117	0.3702352	10.45065	0.0278068	3.09621E-05	1.453032	26.134323	0.4517917	0.2578067	1.3833592
BR919-26	36	n/a	36.200465	39.684897	360.95933	n/a	9.4257887	0.3663016	10.52342	0.0280353	3.64907E-05	2.2930282	40.906483	0.4613842	0.233293	1.7244301
BR919-27	42.5	n/a	53.682721	61.769485	602.52414	n/a	9.8185949	0.3891438	10.100839	0.0277248	2.97699E-05	1.5280957	27.565692	0.4589988	0.2052277	1.9013201
BR919-28	45.5	n/a	49.425248	56.16976	529.1194	n/a	9.7246623	0.3845509	10.185809	0.0271124	3.01639E-05	1.6911143	31.195523	0.4697567	0.2157414	2.2820378
BR919-29	50	n/a	47.87682	54.201764	505.50433	n/a	9.5584627	0.3763896	10.336793	0.0273432	3.09702E-05	1.7404262	31.834167	0.4540563	0.2549559	2.1410709
BR919-31	51.5	n/a	7.1439492	7.2726825	170.17068	n/a	7.7021814	0.3655909	10.536569	0.0276398	3.346E-05	13.692169	247.75658	0.5673423	0.2575026	1.4104023
BR919-32	56	n/a	52.30176	60.094538	579.55987	n/a	10.099254	0.3563234	10.708017	0.0278992	2.6675E-05	1.5462883	27.719571	0.446323	0.1920122	0.8151851

ALS Barcode	Sample ID	Depth	ENPP	EPPT	DT	dT x 4.18	Peff	ET	ET/MAP	Source for climate data
		cm	kJ m yr^{-1}	kJ m yr^{-1}				cm	n/a	
Y995876	19BRWY2UB	-25	36739.85	9625.8407	11.536902	48.224252	15.861734	25.201334	0.6137226	
Y995877	19BRWY2MB	-50	32739.896	8577.8526	10.745266	44.91521	5.3784304	24.132788	0.8177496	
Y995878	19BRWY2LB	-75	38530.547	10095.003	12.331621	51.546174	23.781642	26.008597	0.5223634	
AVERAGE 2B				9432.8989				25.11424	0.6512785	
Y995881	19BRWY3UB	-35	43482.535	11392.424	13.514406	56.490216	95.249239	33.293173	0.2590054	
Y995882	19BRWY3MB	-45	43437.824	11380.71	13.477087	56.334225	93.92485	33.15818	0.2609175	
AVERAGE 3B				11386.567				33.225677	0.2599614	
Y995884	19BRWY4UB1	0	43584.584	11419.161	13.054671	54.568524	99.91481	33.768727	0.252602	
Y995885	19BRWY4UB2	-15	35659.591	9342.8128	11.222093	46.90835	12.387616	24.847223	0.6673111	
Y995886	19BRWY4LB	-30	43857.343	11490.624	14.137247	59.093693	99.699533	33.746784	0.2528866	
AVERAGE 4B				10750.866				30.787578	0.3909332	
B0173201	19BRWY5UB	-20	41468.114	10864.646	12.575261	52.564589	46.754295	28.350162	0.3774764	
B0173202	19BRWY5MB	-35	39523.248	10355.091	12.078631	50.488677	28.35858	26.475117	0.4828257	
AVERAGE 5B				10609.868				27.41264	0.4301511	
B0173205	19BRWY6UB	-42	40999.535	10741.878	12.348014	51.614699	41.308812	27.795113	0.4022219	
B0173206	19BRWY6MB	-72	41536.889	10882.665	12.551417	52.464925	47.7003	28.446587	0.3735752	
AVERAGE 6B				10812.272				28.12085	0.3878985	
		Present	16679.919	833.99595	6.3333	26.473194	3.485785	18.129215	0.8387331	PRISM Climate Group 2004
		PETM	60062.895	15736.479	19.5	81.51	107.367	29.633	0.2162993	Wing et al. 2005
		Early Eocen	58749.252	15392.304	12.8	53.504	74.6574	26.9426	0.2651831	Wing & Currano 2013
		Mid Eocene	57449.812	15051.851	14	58.52	62.9226	25.9774	0.2922092	Leopold & MacGinitie 1972, Roehler 1993
		Allen 2017	59887.454	15690.513	16.54	69.1372	128.02764	31.33236	0.1966137	Allen 2017

Sample ID	$\delta^{13}C$ (‰ VPDB)	Notes, Identification	Taxon-specific $\delta^{13}C_{atm}$ (‰)	Generalized $\delta^{13}C_{atm}$ (‰)
006_001	-23.93	*Lygodium,* 26m in column	-3.94	-4.78
006_002	-23.90	*Lygodium,* 26m in column	-3.91	-4.75
006_003	-24.04	*Lygodium*	-4.05	-4.88
006_004	-23.82	*Lygodium,* leaf mat	-3.83	-4.68
006_005	-24.68	*Lygodium,* 26m in column	-4.69	-5.47
009_001	-24.40	plant mat	n/a	-5.21
009_002	-23.59	Sept 2019 roots and stems	n/a	-4.47
009_003	-24.82	Bag 4, charcoal wood and st	n/a	-5.59
009_005SP	-24.64	Sporangia	n/a	-5.43
009_005DI	-24.77	*Acer*	-5.40	-5.55
009_006	-24.55	Wood, leaf hash/plant mat	n/a	-5.35
009_017	-24.48	charcoalified wood	n/a	n/a
009_016	-22.81	charcoalified wood	n/a	n/a
009_015	-23.32	plant mat	n/a	-4.23
009_010	-23.87	plant mat	n/a	-4.73
009_011	-24.28	plant mat	n/a	-5.10
919-6B	-24.95	charcoalified wood	n/a	-5.71
009_014	-24.56	plant hash/mat	n/a	-5.35
006_007	-24.72	Leaf mat, 26m	n/a	-5.50
006_008	-25.24	Leaf mat, 26m	n/a	-5.97
006_009	-25.47	Dicots (*Acer*), 26m	-6.10	-6.19
006_010	-25.22	Dicot (*Acer)*, *Lygodium,* leaf	-5.85	-5.95
006_011	-23.29	Dicots (*unspecified),* 26m	n/a	-4.20
006_012	-24.93	Leaf mat, 26m	n/a	-5.69
006_013	-23.90	Leaf mat, 26m	n/a	-4.75
006_014	-23.13	Leaf mat, 26m	n/a	-4.06
006_015	-22.79	Leaf mat, 26m	n/a	-3.75
009_012	-25.00	Wood, leaf hash/plant mat	n/a	-5.76
009_013	-24.01	Stems	n/a	-4.85
009_009	-26.17	charcoalified wood, bag 6	n/a	-6.82
009_007	-25.03	Leaf mat	n/a	-5.78
009_004DI	-24.94	Angiosperms	-5.57	-5.70
009_008	-24.43	Angiosperms	n/a	-5.24
009_004SP	-24.89	sporangia	n/a	-5.65

Sample ID	Profile #	Depth (cm)	*C jw* Ti %		*Epsilon*	*Cjw* Al %	*Cjw* Al tau	*Cjw* Na %	*Cjw* Na tau	*Cjw* Ca %	*Cjw* Ca tau	*Cjw* K %	*Cjw* K tau	*Cjw* Fe %	*Cjw* Fe tau	*Cjw* Zr ppm	*Cjw* Zr tau	*Cjw* Rb ppm	*Cjw* Rb tau
19BRWY1LA	1	-12	0.353	*0.64193*	0.64	7.53	-0.28	0.35	-0.38	0.41	0.02	2.53	-0.35	4.42	-0.29	84.4	-0.18	148	-0.27
19BRWY1LC	1	-18	0.322	*0.8*	0.80	7.75	-0.18	0.42	-0.18	0.3	-0.18	2.92	-0.18	4.66	-0.18	76.7	-0.18	152	-0.18
19BRWY1UA	1	0	0.359	*0.61448*	0.61	7.53	-0.29	0.35	-0.39	0.35	-0.15	2.37	-0.41	3.87	-0.39	86.5	-0.17	124	-0.40
19BRWY2C	2	-85	0.395	*0.8*	0.80	7.63	-0.18	0.42	-0.18	0.4	-0.18	2.44	-0.18	3.84	-0.18	75	-0.18	141	-0.18
19BRWY2LB	2	-75	0.248	*1.86694*	1.87	5.33	-0.09	0.74	1.30	5.38	16.55	1.97	0.05	1.82	-0.38	54.5	-0.05	86.6	-0.20
19BRWY2MB	2	-50	0.172	*3.13372*	3.10	4.08	0.00	0.29	0.29	18.5	85.19	1.38	0.05	1.66	-0.19	39.1	-0.03	65.7	-0.13
19BRWY2UA	2	0	0.332	*1.14157*	1.10	7.8	-0.02	0.38	-0.14	0.81	0.93	2.89	0.13	4.8	0.19	87.1	0.11	152	0.03
19BRWY2UB	2	-25	0.26	*1.73462*	1.70	6.09	-0.02	0.32	-0.06	10.3	30.45	2.11	0.06	3.5	0.12	61.1	0.00	106	-0.08
19BRWY3UA	3	0	0.308	0.8	0.80	6.61	-0.20	0.5	-0.26	0.22	-0.92	2.44	-0.20	4.03	-0.20	68.6	-0.11	131	-0.18
19BRWY3UB	3	-35	0.295	0.87932	0.88	6.45	-0.19	0.54	-0.16	0.19	-0.93	2.4	-0.17	4.62	-0.05	66.8	-0.10	132	-0.14
19BRWY3MB	3	-45	0.292	0.89863	0.90	6.37	-0.19	0.56	-0.12	0.2	-0.93	2.41	-0.16	4.55	-0.05	69.6	-0.05	124.5	-0.18
19BRWY3C	3	-75	0.308	0.8	0.80	6.77	-0.18	0.55	-0.18	2.35	-0.18	2.48	-0.18	4.14	-0.18	63.2	-0.18	131.5	-0.18
19BRWY4UB 1	4	0	0.327	1.16881	1.20	7.85	-0.04	0.46	0.92	0.26	-0.59	2.89	0.51	4.94	0.42	82.1	0.07	149	0.07
19BRWY4UB 2	4	-15	0.208	2.40962	2.40	4.79	-0.09	0.27	0.74	10.3	24.27	1.72	0.38	2.67	0.19	52.3	0.06	87.8	-0.02
19BRWY4LB	4	-30	0.378	0.87619	0.88	7.8	-0.18	0.21	-0.25	0.49	-0.34	1.94	-0.14	3.53	-0.13	67.4	-0.25	136	-0.16
19BRWY4C	4	-60	0.394	0.8	0.80	8.16	-0.18	0.24	-0.18	0.63	-0.18	1.92	-0.18	3.47	-0.18	76.5	-0.18	139	-0.18
19BRWY5UA	5	0	0.37	*0.27459*	0.27	8	-0.30	0.29	-0.92	0.99	-0.72	2.12	-0.37	3.89	-0.11	72.4	-0.56	133	-0.16
19BRWY5UB	5	-20	0.265	*0.77962*	0.78	6.27	-0.23	1.88	-0.29	1.38	-0.46	2.17	-0.09	2.54	-0.18	102	-0.14	117	0.04
19BRWY5MB	5	-35	0.261	*0.8069*	0.81	6.57	-0.18	2.15	-0.17	4.17	0.67	1.84	-0.22	2.31	-0.25	90.7	-0.22	84.9	-0.24
19BRWY5C	5	-80	0.262	*0.8*	0.80	6.59	-0.18	2.14	-0.18	2.06	-0.18	1.94	-0.18	2.52	-0.18	95.6	-0.18	91.4	-0.18
19BRY6UA	6	0	0.512	*-0.0719*	-0.70	7.24	-0.86	2.76	-0.85	2.57	-0.80	1.71	-0.87	3.69	-0.79	111.5	-0.83	67.9	-0.89
19BRWY6UB	6	-42	0.289	*0.64429*	0.64	6.49	-0.30	2.1	-0.36	1.89	-0.21	2.21	-0.08	2.59	-0.21	97.3	-0.17	101	-0.14
19BRWY6MB	6	-72	0.27	*0.76*	0.76	6.4	-0.26	1.84	-0.40	1.39	-0.38	2.23	0.00	2.56	-0.16	103.5	-0.05	121.5	0.11
19BRWY6C	6	-112	0.264	*0.8*	0.80	6.96	-0.18	2.45	-0.18	1.79	-0.18	1.79	-0.18	2.45	-0.18	87.5	-0.18	87.8	-0.18
"parent"				0.263															

	Cjp - avg
Al	6.775
Na	2.295
Ca	1.925
K	1.865
Fe	2.485
Zr	91.55
Rb	89.6

Variables

rho w	1.5	Density of weathered material (paleosol)
C jw		Weight % of element j (Al) in weathered material
rho p	3.3	Density of parent material (sand)
C jp (Ti)	0.263	Weight % of element j (Ti) in parent material (avg)
Ep		Solve for separately; assume tau is 0, bypassing volume

* Values are actually. Using rho=2.7

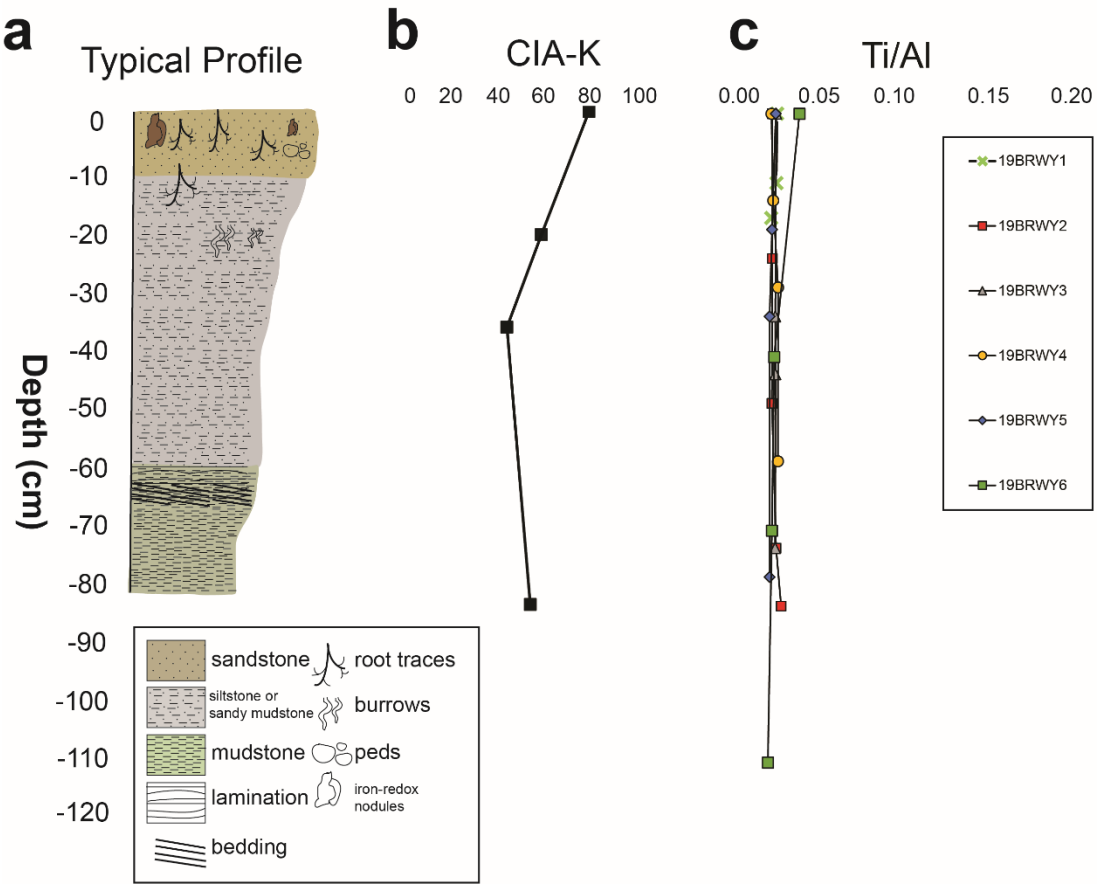


Figure D1 Geochemistry and features of a typical paleosol profile at Blue Rim escarpment. (a) Average paleosol profile at Blue Rim escarpment, (b) typical CIA-K over profile, (b) Ti/Al ratio (molar) for all paleosol profiles.

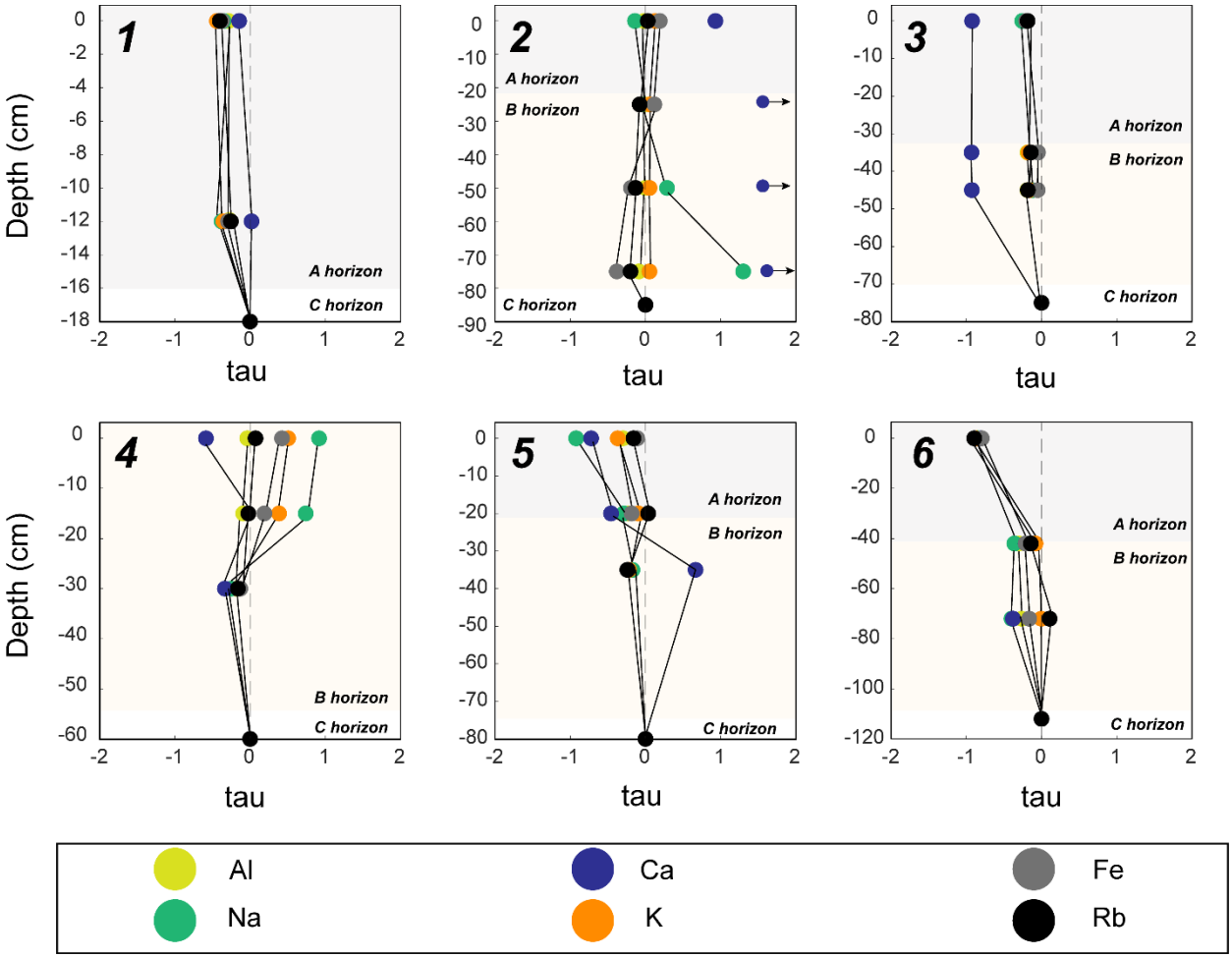


Figure D2 Paleosol profile changes in mobile element transport calculations. Up profile changes in tau (mobile element transport, see equations 5.2 and 5.3, per Chadwick et al. 1990) for Paleosols #1 through #6.

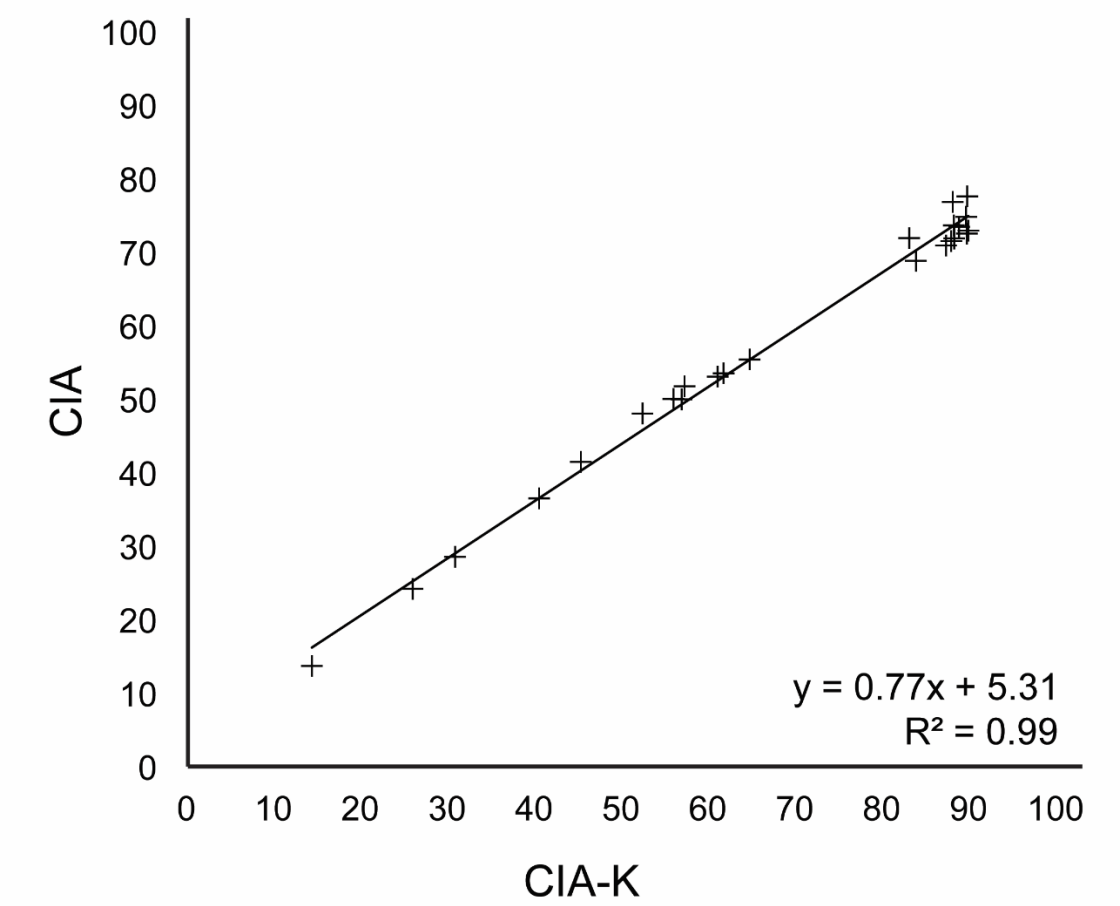


Figure D3 Relationship between CIA-K and CIA for all paleosol bulk geochemistry data, measured by ALS Laboratories.

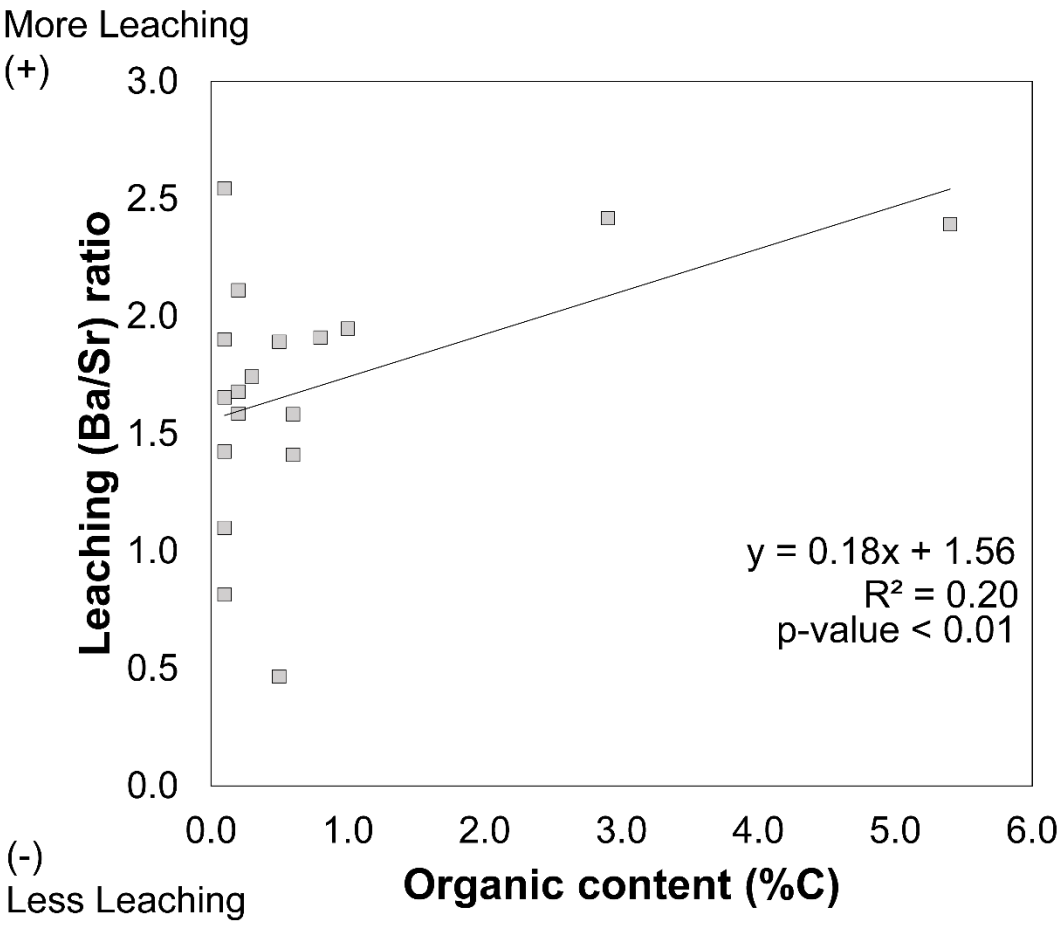


Figure D4 Comparison between organic content in stratigraphic units (%C) and leaching (Ba/Sr ratio).

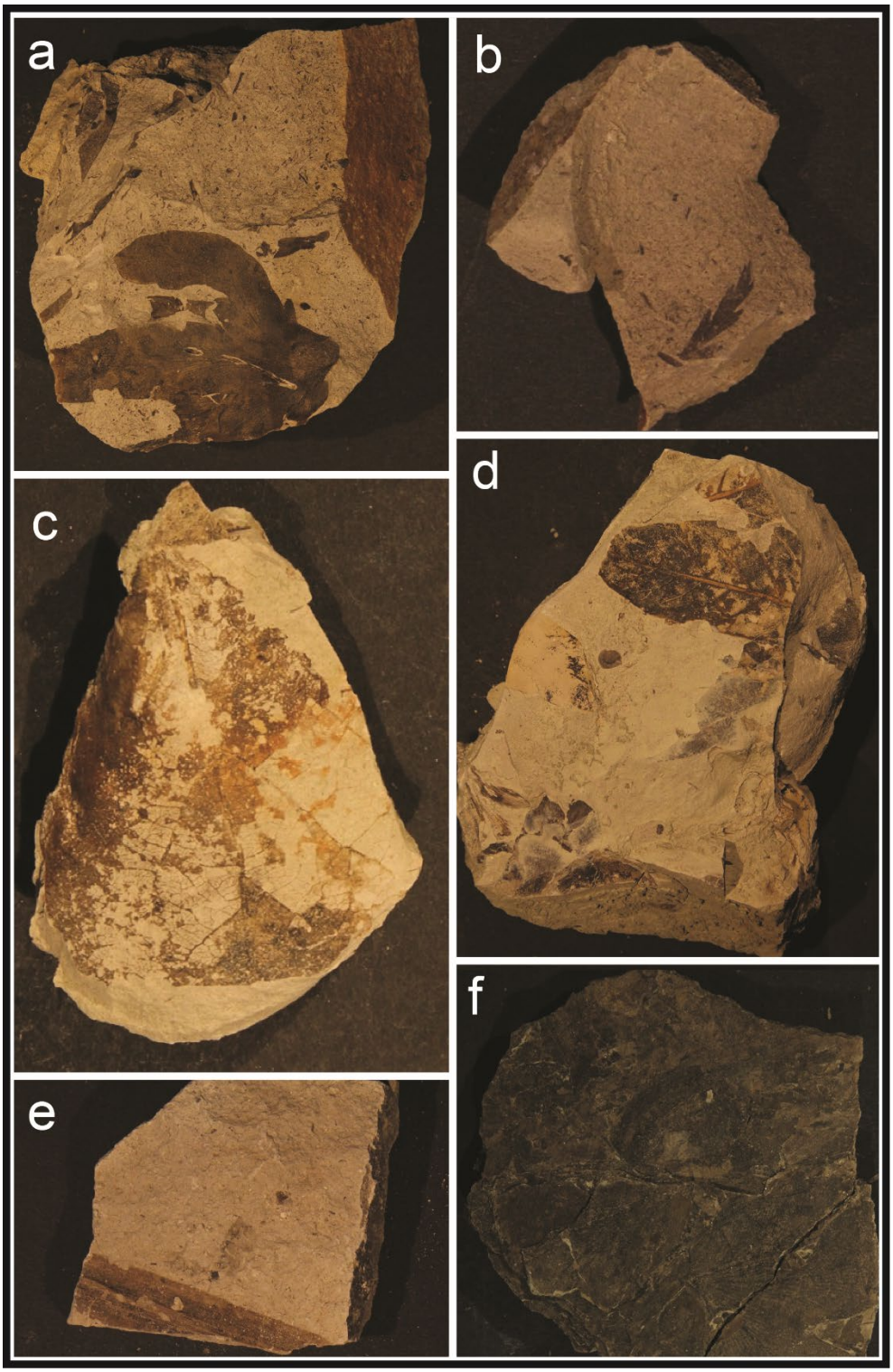


Figure D5 Common fossil formats and taxa found at Blue Rim Escarpment (2019): (a) *Lygodium kaulfussi,* (b) *Asplenium sp.* (c) *Populus cinnamomoides,* (d) *Cedrella sp.* (e) unidentified monocot, (f) unidentified organ carbon-rich leaf mat

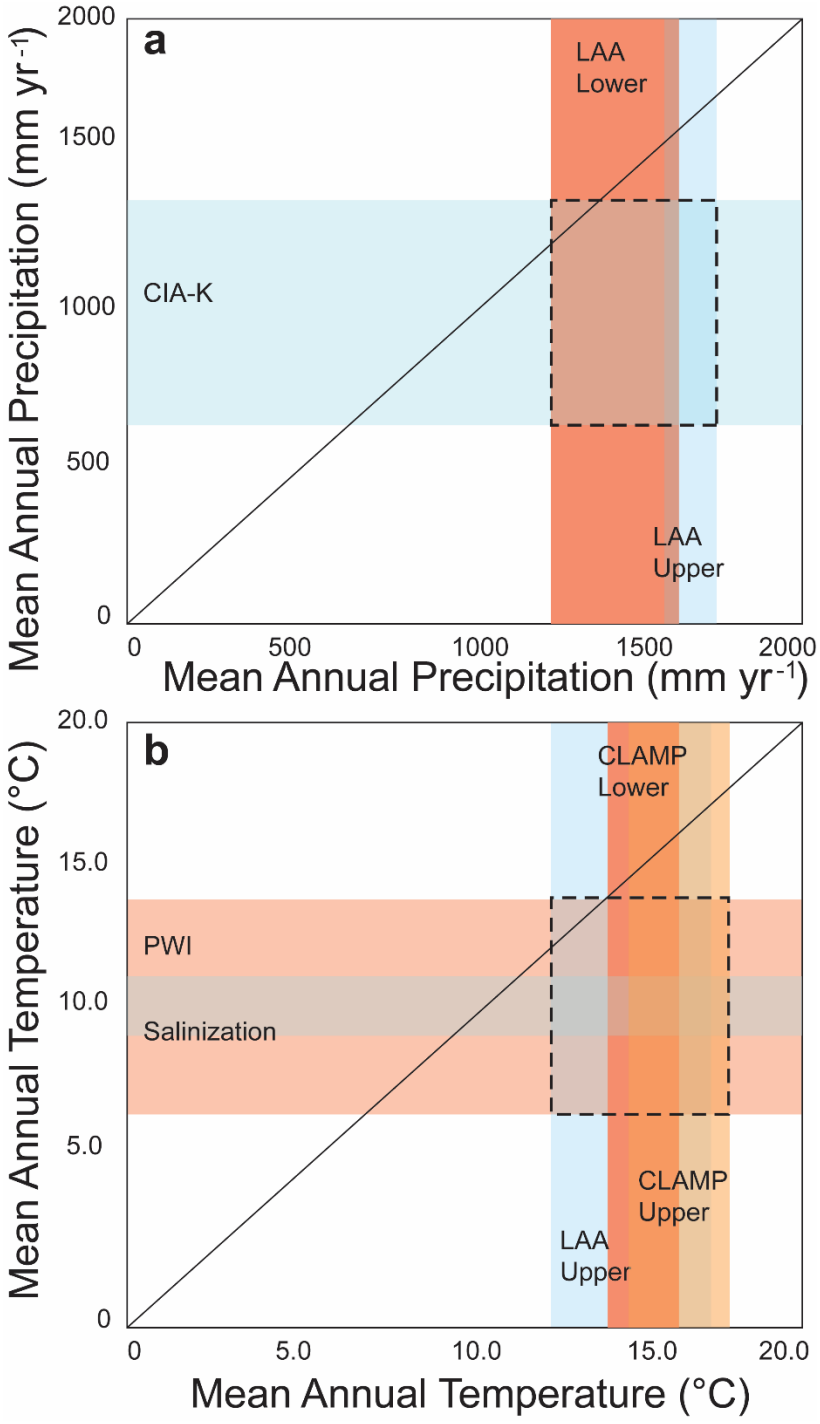


Figure D6 Comparisons of climate reconstructed using multiple proxies. Regression comparing climate values (a) precipitation and (b) temperature, with previous reconstructions on the x-axis and reconstructions in this study on the y-axis). Error is shown for both x and y-values, and the 1:1 relationship is shown with a dashed line. The range represented by both prior estimates and this study is shown in the overlapping boxes, outlined in dashed lines.

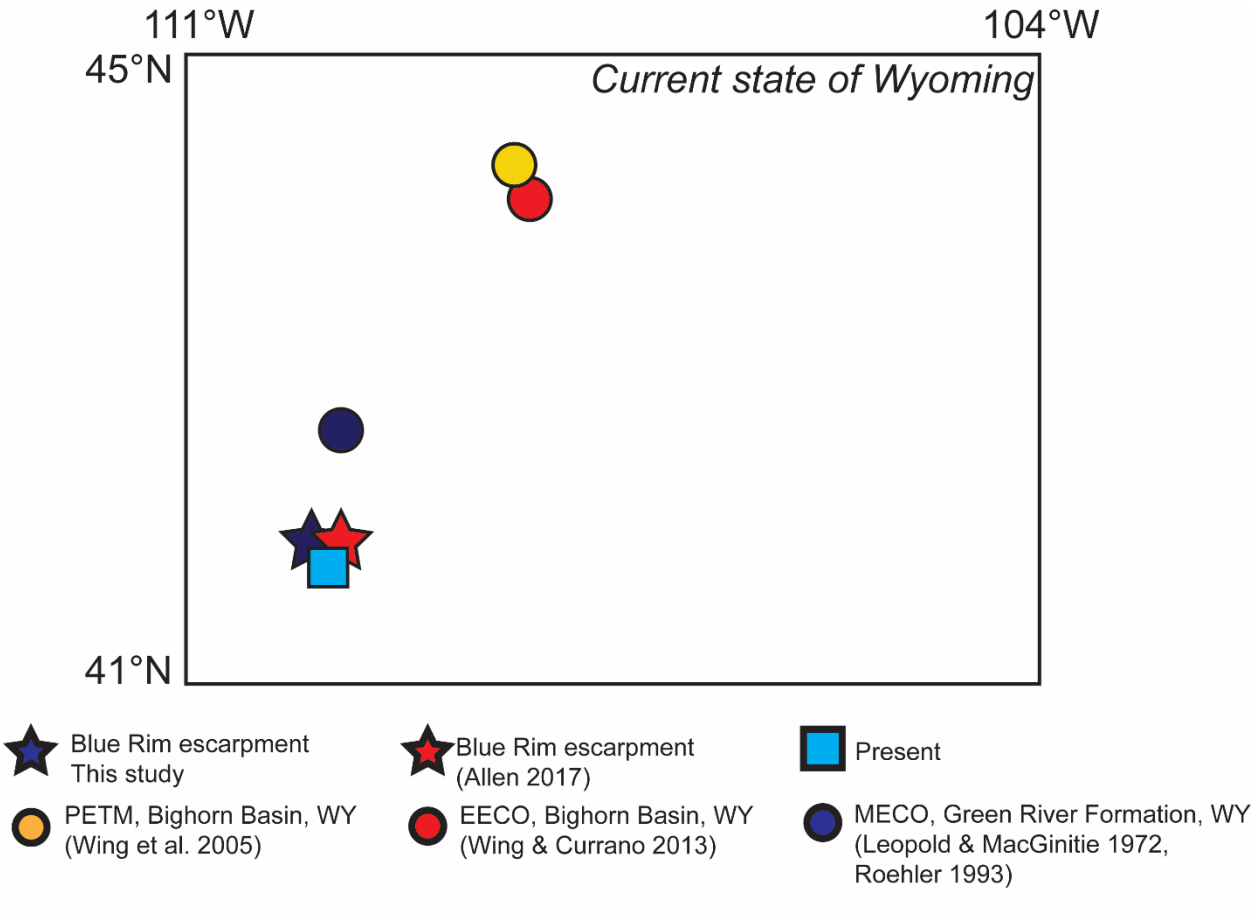


Figure D7 Current boundaries of Wyoming, USA with paleoenvironments plotted. Blue Rim escarpment is plotted in stars (blue for this study, red for Allen 2017). The Paleocene-Eocene Thermal Maximum record from Bighorn Basin is plotted in a yellow circle, while the EECO record from the Bighorn Basin is plotted in a red circle. The MECO is plotted in a blue circle.

Supplemental Methods:

Calculation of MAP

Mean annual precipitation was reconstructed using chemical index of alteration minus potassium (CIA-K).

$$CIA - K = \left(\frac{Al_2O_3}{Al_2O_3 + CaO + Na_2O}\right) * 100 \text{ (Equation 5.4)}$$

$$MAP\ (mm\ yr^{-1}) = 221.1e^{0.0197(CIA-K)} \text{ (Equation 5.5)}$$

Calculation of MAT

$$PWI = [(4.20\ x\ Na) + (1.66\ x\ Mg) + (5.54\ x\ K) + (2.05\ x\ Ca)] * 100 \text{ (Equation 5.2)}$$

$$MAT\ (°C) = -2.74\ x \ln(PWI) + 21.39 \text{ (Equation 5.6)}$$

Floral humidity province

To contextualize climate variables (temperature, precipitation) to ecoregion and humidity, Gulbranson et al. (2011) developed a life-zone proxy based on Rasmussen et al. (2005) and Rasmussen and Tabor's (2007) pedogenic energy model. This energy quantifies energy influxes due to solar radiation (and subsequent net primary productivity: NPP) and precipitation. The total energy input into a soil (E_{in}) is related to energy supplied by NPP (E_{NPP}) and precipitation (E_{PPT}). EPPT and E_{NPP} are calculated using weathering indices (CIA). E_{PPT} is plotted against evapotranspiration (ET) and divided into humidity zones using Equation 5.9:

$$ET = MAP - E_{PPT}\ [4.18(\Delta T)]^{-1} \text{ (Equation 5.9)}$$

Where ΔT is the temperature difference between 273.16°K and mean annual temperature.

Mean annual precipitation calculated using the relationship between CIA-K and precipitation was used in this relationship (Equation 5.5).

In modern environments, effective precipitation (P_{eff}) is a linear function of MAP and ET (Equation 5.10):

$$P_{eff} = MAP - ET \text{ (Equation 5.10)}$$

And P_{eff} can be calculated using Equation 5.11.

$$P_{eff} = 0.9075(MAP) - 21.403 \text{ (Equation 5.11)}$$

Paleolatitude has been described as anywhere between 35°N and 44°N (Allen 2017), but temperature was consistently been described as 17-20°C during this time, so we use Equation 5.12 determined by ranges of MAT in Gulbranson et al. (2011), which corresponds to 33°N at present, and latitudinal temperature gradients ranging from 17-20°C.

$$E_{NPP} = -1.943(CIA)^2 + 352.41(CIA) + 28197 \text{ (Equation 5.12)}$$

For reconstructed MAT and MAP values from alternate proxy data (non-paleosol estimates), CIA was back calculated estimating CIA-K using given precipitation values and Equation 5.5, then translated into CIA values using Equation 5.13.

This relationship was calculated using the relationship between CIA and CIA-K for all paleosol bulk geochemistry measurements at this site (Supplemental Fig. D1; $R^2 = 0.99$)

$$CIA = 0.78(CIA - K) + 5.23 \text{ (Equation 5.13)}$$

Holdridge Life Zones

The Holdridge Life Zone classification system (Holdridge 1947) matches climate with vegetation. Higher precipitation adds energy to a soil system, which mobilizes elements and weathers the soil. Evapotranspiration, represented on the other axis of the Holdridge biome diagram (Fig. 7b) represents energy loss from the soil profile. These two plotted together can then be divided into biome space, allowing for estimation of climate and vegetation through the same diagram.