# NATURE AND NURTURE

## FARM DESIGN AND MANAGEMENT PLAN

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# ABSTRACT

This master's project intends to explore the design process and management of restoration agriculture in Southeast Michigan. Our client, Nature and Nurture LLC. is a multi-faceted business owned and operated by Mike Levine and Erica Kempter. Between the two of them, they provide organic landscaping services, teach classes, sell organic, locally-adapted seeds, fruits, vegetables, and mushrooms to restaurants and stores throughout Southeast Michigan. The Levine and Kempter extended family has recently acquired 120 acres of property in Scio Township, near Dexter, Michigan. Much of the property has been conventionally farmed for 50 or more years, while other portions of the property are high-quality woodland and wetland. Ultimately, our clients would like to derive their income primarily from the farm. Moreover, they are committed to ecologically responsible farming and are interested in using organic practices, restoration agriculture, and agroecological techniques throughout the property. To that end, our role was to create a site plan that: does not damage the existing high-quality ecosystems on the site, is able to increase the quality of the soils in the conventionally farmed areas (metrics for quality include but are not limited to: soil organic matter, amount of organic nitrogen, phosphorous, and potassium), and is able to increase the site's overall habitat quality. Furthermore, we included a management plan for the natural areas on the site that will conserve existing ecosystems, and expand the range and value of ecosystem services. Through a series of field surveys and interviews, we attempted to determine the existing character of the site, which influenced the site plan and management recommendations. We provide a description of the floral and faunal composition, soil profiles, site history, and the needs of the different site users. A literature review of agroecology, conservation and restoration ecology in addition to a case study analysis, including visits to other farms, guided the formation of our site design and management plan. Our final plan will improve Nature and Nurture's farm productivity and income, restore the soil quality on site, balance competing land uses, and expand the site's potential for community outreach.

# ACKNOWLEDGMENTS

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# INTRODUCTION

## SUMMARY OF CONTENTS

The basis of this project could be summarized in three problem statements. First, industrialized agricultural practices yield large quantities of food for society, but at a severe environmental cost in terms of pollution, fragmentation of wildlife habitats and depletion of topsoil, water and energy. Agricultural land has become less biologically diverse and more intensively managed by humans, particularly over the last century. Indeed, the impacts of industrial agriculture on the planet are fairly well-documented and by many measures, unsustainable.[1,2,3,4,5,6] Agriculture dominates the landscape because nutrition is a fundamental human concern. However, the cumulative impact of widespread, intensive agriculture threatens the well-being of future generations through the destruction of our environment. In response to industrial agriculture's ecological implications, several systems innovations have emerged which draw knowledge across disciplines to shape ecologically restorative agriculture techniques. For example, Perfecto and Vandermeer describe a new conservation paradigm, in which small farmers collectively create a landscape matrix rich in planned diversity that connects patches of native vegetation that in turn contribute their own associated biodiversity.[7] New innovations in the food system are centered around local food production, ecologically mindful practices, and fostering community.

Second, while viable alternatives to conventional agriculture can be transformative in many ways, they are still relatively rare across the landscape and potentially difficult to implement. Among many communities, there is an interest in redesigning the landscape to reconnect people with the source of their food and to improve the sustainability of agricultural practices. However, there are benefits and costs associated with agricultural strategies that deviate from the modern convention. Economically, there is less institutional support for diversified crop systems. Specifically, many of the United States Department of Agriculture farm policies, such as crop insurance and direct payments, are primarily in support of commodity crop and industrial livestock farmers.

1. Smith et al. (2014).
2. Nickerson et al. (2011).
3. Millennium Ecosystem Assessment. (2005).
4. Smith et al. (2014).
5. Mitsch et al.(2001).
6. Pogue & Schnell. (2001).
7. Perfecto & Vandermeer. (2008).



Third, successful application of a transformative land management plan requires diverse skill sets and a thorough understanding of the specific parcel to be managed. The transition away from conventional agriculture can influence the structure and function of ecosystems, both above and below ground. Farms that utilize techniques such as agroforestry or permaculture demonstrate a thorough understanding of their farm's ecological and social context, and have shown promising results. New Forest Farm[8], Versaland[9], and other farms serve as precedents for sustainable and alternative agricultural approaches. Broader public awareness and education will certainly help these non-conventional methods gain popularity, but many willing participants are still in the challenging initial stages of landscape development. There are also some government programs that promote and finance conservation practices to reduce erosion and build soil organic matter, but grassroots efforts are required to bring about large scale change from the ground up. By working with our clients, Nature and Nurture, we aim to understand how a restorative agriculture business can develop the skills and resources needed to survive and grow during their early stages.

*"Odd as I am sure it will appear to some, I can think of no better form of personal involvement in the cure of the environment than that of gardening. A person who is growing a garden, if he is growing it organically, is improving a piece of the world"*

-Wendell Berry, The Art of the Commonplace: The Agrarian Essays

8. n.a. (2017).Forest Agriculture Enterprises. www.forestag.com
9. n.a. (2017). Farmscale Permaculture - Versaland. www.versaland.com

# CLIENTS

Our clients are the co-owners and founders of Nature and Nurture, LLC; Erica Kempter and Mike Levine. Erica is a graduate from the University of California Santa Cruz, while Mike is a University of Michigan School of Natural Resources alumnus. Together, the couple have used their horticultural expertise and business sense to build a successful, diverse company that has a positive influence on their community. The company began in 2001 primarily providing organic residential landscaping service, with other enterprises as a part of the business plan. Today, the company still generates the majority of its revenue by offering consulting, design, installation, and maintenance services as a licensed and insured landscaping operation. Landscaping clients of Nature and Nurture regularly include edible and/or native plants in their organically managed yards. Landscaping services have provided the financial support for our clients to expand side-operations of Nature and Nurture. Our clients own a fruit tree nursery that sells plants to landscaping customers. Erica and Mike have been paid to teach courses on organic gardening and fruit production. Additionally, Mike grows and sells shiitake mushrooms to restaurants and individuals around Ann Arbor. The couple also grows food for themselves, occasionally selling extra produce through Argus Farm Stop.


Erica Kempter and Mike Levine

In 2014, our clients began a new enterprise within the company, Nature and Nurture Seeds. The seed company sells heirloom, open-pollinated seeds, primarily online. Our clients have been experimenting with vegetable varieties for over 20 years before starting the company, with the mission to become a catalyst for the preservation and innovation of food seed biodiversity in the Great Lakes region, Midwest, and beyond. The transition from a landscaping business to a primarily agricultural one has coincided with the couple's physical transition from the urban area within Ann Arbor to the rural area of Scio Township. The acquisition of a farm property in 2013 provided new opportunities for Nature and Nurture to expand non-landscaping business, and some early work has been done to transition the property to meet these business needs. The site is a mix of agricultural fields, forest, and wetlands, with about half of the acreage under a conservation easement. The easement stipulates that the land must be "perpetually preserved in its scenic, agricultural and open space condition." The goal of the easement is to protect the natural resources and rich agricultural soils on the site. An independent forest management plan was conducted by Carl Burhop; this plan categorized canopy trees, informed by our client's goal to utilize the forest for sustainable mushroom harvest. Our clients are invested in the improvement of their property, but they recognize the challenges associated with land stewardship.

Nature & Nurture

NATURE AND NURTURE LLC

# GOALS

Our role was to draft a site design and management plan that addressed team and client goals across three broad categories: Ecological resilience, financial sustainability, and community engagement

**Ecological Goals**

- Ecological restoration and management of the site focused on habitat quality, connectivity, rainwater management, and ecosystem services
- Improve soils on site through restoration agriculture practices

**Economic Goals**

- Flexible site element placement for future development and agricultural expansion
- Identify opportunities for Mr. Levine and Ms. Kempter to increase the income derived from their fields, expand their seed business, expand their shiitake mushroom cultivation, and allow them to source most of the plants for their landscaping business on site.
- Acknowledge client flexibility to change their business strategy in response to unforeseeable events

**Social Goals**

- Provide opportunities for homesteading through crops for personal use
- Plan for community events and educational workshops through increased public access
- Create opportunities for collaboration with other farmers and strengthen ties with the University of Michigan

# CHALLENGES

A comprehensive, interdisciplinary study such as the one reported here often presents multiple challenges. Understanding the design and management implications of our ecological, historical, and business research was challenging. In particular, we identified the following seven factors as the most significant challenges to our project. First, the floral, faunal, and soil surveys conducted were rigorous, but because of limited time and resources, we were unable to fully capture the character of the site. Second, because we conducted our surveys over the course of a few months, our data was a mere snapshot of the site, and did not capture long-term trends on the site. This could be mitigated by future surveys to monitor long-term changes in the site's character. Third, though our design and management plan are based off agroecological literature and businesses with similar goals to Nature and Nurture, because of limited time, we could not fully capture all of the complexity of the literature within agroecology. Moreover, because of differences between our site's context, our chosen precedents, and the case studies in the literature, there are some recommendations that cannot be applied to our project. However, agroecology is a robust enough science that general principles can be extracted. Similarly, with respect to the use of precedents, we still expect that general patterns and lessons from other similar farms will provide invaluable insights in our design process and management recommendations. Fourth, though our client's are pursuing agricultural methods that are far less environmentally destructive than conventional practices, there is still a trade-off that is made between productive land and areas that are meant to be conserved. Fifth, because our client's are just starting to live at the site, it is hard to plan for both short and long term goals. Sixth, financial limitations and the seasonal availability of labor do constrain what our clients can reasonably expect to implement. Seventh, though our clients have expressed an interest in collaborating with other farmers in the area, finding partners, negotiating arrangements, and implementing the agreements may prove challenging.

# BACKGROUND

Our team conducted a literature review to explore varying agricultural practices and their ecological, economic, and social impacts. We used this research as a jumping off point for discussing the client's property and farm design. Listed below are the systems we chose to examine in depth due to their ability to act as model systems for the Nature and Nurture farm and property. Our clients have also expressed interest in these systems and have worked towards a homesteading lifestyle, for example. Following the discussion of various farming systems is a look into their greater environmental, economic, and human context and a greater look at the whole system. The other goal of this background section is to introduce concepts and vocabulary used throughout the report.

# ECOLOGICAL AND ENVIRONMENTAL

## CONVENTIONAL AND ORGANIC AGRICULTURE

Organic agriculture has a historically contentious reputation, mainly driven by whether or not these systems could yield an adequate amount of food to "feed the world".[10] A corollary claim implied by the inferior yields of organic agriculture is that more land would have to be put into agricultural production to make up the difference, thereby undermining the conclusion that organic agriculture is better for the environment than conventional systems. However, a vibrant literature exists casting doubt on these historical conclusions.

A 2006 meta-analysis examined nearly 300 case studies examining the relative yields of organic to non-organic systems.[11] They concluded that organic systems could produce as much or more food per capita on a global scale, without significantly increasing the amount of land needed to do so. Further, by analyzing the rates of nitrogen fixation in temperate and tropical agroforestry systems, they further concluded that leguminous nitrogen fixers could replace nearly all the synthetic nitrogen fertilizers currently used in conventional systems. Together, these arguments suggest that more widespread adoption of organic practices could have a significant impact on global food production. Further, a 2016 study conducted by Reganold and Watcher concluded that organic systems are more profitable, yield higher ecological and social benefits, although they have a lower per area yield than conventional systems.[12] Their conclusion is that no single practice is a panacea, and that a diversity of approaches will be required to best meet the food demands of the planet.

Conventional agriculture is defined by large monocultural crops and a dependence on synthetic fertilizers, pesticides, and fossil fuels. Most labor is highly mechanized, and the emphasis is maximizing yield per unit area.

10. Reganold and Watcher. (2016).
11. Badgley et al. (2006).
12. Reganold and Watcher (2016).



Pimentel et al. conducted a 22 year study comparing conventional, organic, and organic with legume systems.[13] They concluded that yield and economic viability of the system varies based on crops, region, and technology employed. However, environmental metrics, specifically soil erosion, chemical inputs, water conservation, soil organic matter, and biodiversity are consistently and significantly better in the organic systems. Liebman et al. performed a comparison of three cropping systems: Marsden Farm Cropping System, STRIP system, and Comparison of Biofuels System (COBS).[14] Among their conclusions are that: 1. diversifying rotations with legumes and small grains can significantly reduce chemical and petrochemical usage. 2. Conversion of cropland to prairie (where appropriate) can yield disproportionate advantages in soil and water conservation, nutrient retention, and densities of native animals and plants. 3. Perennials provide valuable fuel and feedstock in addition to sequestering carbon, and reducing nitrogen runoff.

These and other studies suggest that alternative agricultural systems have an important role to play in redefining global food systems. While these systems may never obviate the need for conventional systems, diverse farming systems can and ought to take on a much larger role than at present, and this transition would be of benefit to farmers, society, and the environment.

Agroforestry relies on soil management that minimizes disturbance. The plantings are diverse and take advantage of vertical layering. Water management through earthworks is a common feature of these systems, and multiple metrics are used to assess their productivity, including calories and number of crops per unit area.

13. Pimentel et al. (2005).
14. Liebman et al. (2013).

# ECOSYSTEM SERVICES AND CLIMATE CHANGE

Ecosystem services are the sum of all goods and services that natural and managed ecosystems provide to humanity. The study of ecosystem services stems from a combination of ecosystem ecology and environmental economics. Research about ecosystem services was triggered by the Millennium Ecosystem Assessment, which was conducted in 2000 and commissioned by the United Nations.[15] It concluded that in the past 50 years, humans have changed the functioning of ecosystems more rapidly and extensively than in any comparable period in human history. Ecosystem change has led to substantial gains in human well-being and economic development, but these gains have degraded nearly every other 'service' that ecosystems provide to humanity. The assessment put forward some goals to understand the biological foundations for the functions and services ecosystems provide to humanity. They also looked at metrics and instruments used to evaluate ecosystem services including economic models and decision-making tools. Negotiation and implementation of ecosystem services requires a combination of incentives and cooperation at multiple scales.

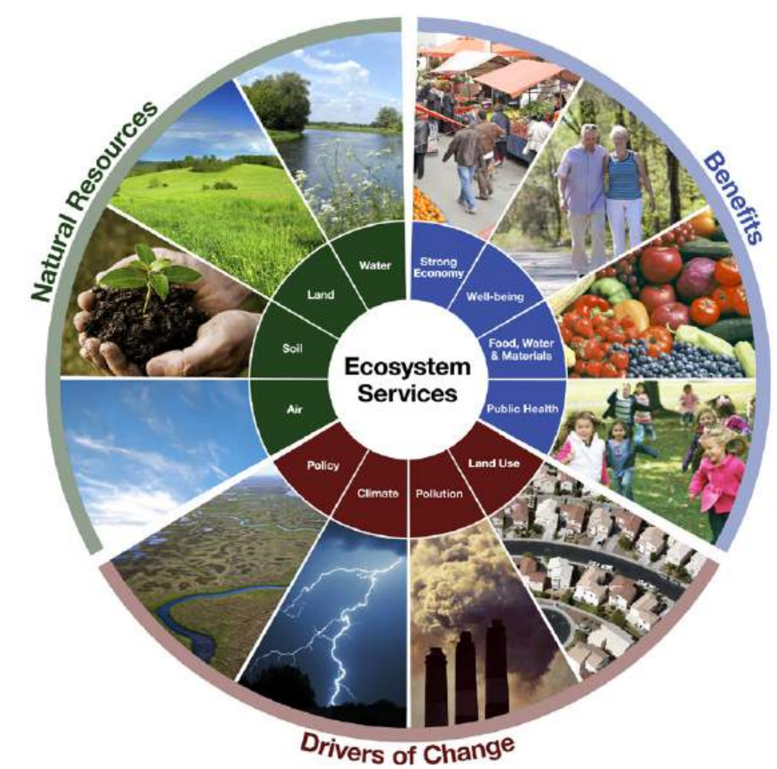
There are four categories of ecosystem services: supporting, provisioning, regulating, and cultural services. Supporting services can maintain material stocks and fluxes in ecosystems, including resource capture, productivity, decomposition, and nutrient cycling. Provisioning services are services that control the production of renewable resources, including production of food, freshwater, wood, fiber, and fuel. Services that reduce environmental variation are regulating services. Climate regulation, water purification, flood regulation, and disease regulation belong to this category. Cultural services consist of non-material benefits, which provide aesthetic, spiritual, educational, and recreational value.

Climate change has significant effects on ecosystems and ecosystem services, such as altering the communities that live there and exacerbating drought.

15. Millennium Ecosystem Assessment (2005).



Designing for increased ecosystem services is one of most powerful adaptations in the face of society's environmental predicaments. For example, forests sequester carbon, improve air and water quality, and mitigate the heat-island effect in urban environments.[16] However, ecosystem services are also influenced by climate change. Ecosystem services are threatened by the impacts of climate change on water supplies, species distributions, phenology and ecosystem integrity. Climate change causes ecosystem degradation, which reduces the capacity of ecosystems to buffer against extreme events. Ecosystem degradation reduces carbon sequestration in ecosystems and may turn carbon sinks into carbon sources. Drinking water provisioning, hydropower production, and erosion control are expected to decrease significantly in the face of climate change, increasing cost for dredging reservoirs as well as treating drinking water. Degraded ecosystems will further exacerbate climate change effects, forming a vicious and unpredictable cycle.[17] The vulnerability of ecosystem services calls for scientific and practical management. However, many conventional management practices not only fail to protect ecosystem services but also potentially harm them. For example, forest thinning, a common management practice, raises the risk for drought impacts.[18] To protect ecosystem services and mitigate climate change, research on different scales in ecology, biology, environmental sciences, economics and politics are required. Cooperation across countries is critical because climate change is global. Because agriculture is such a prominent feature of the modern global landscape, management of agricultural lands is therefore a highly valuable leverage point for maintaining and augmenting the ecosystem services provided by a landscape.



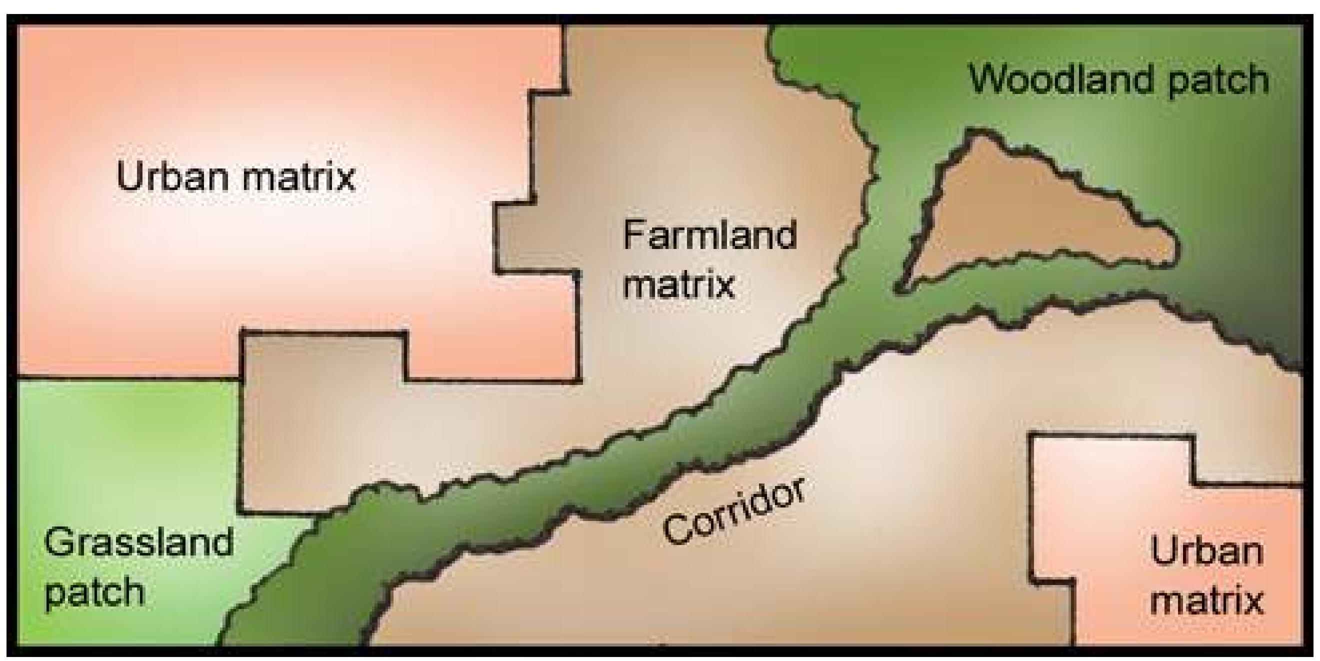

Various ecosystem services, image provided by the EPA.

Baró et al. (2014).
Munang et al. (2013).
Grimm et al. (2016).

# LANDSCAPE ECOLOGY

Landscape ecology is a growing field intersecting ecological processes and principles with spatial patterns and context. A few ideas within the field are especially applicable to our masters project:

The patch-corridor-matrix model states that there are three main features that when combined create our surrounding landscape.[19,20] Patches are areas of a discrete spatial pattern distinct from the surrounding land uses. Often, patches are described in terms of habitat value. Patch dynamics are complex, but in general larger, simpler, and closer together patches with minimal edges create the best habitat and highest ecological value.[21,22] Corridors refer to linear patches that usually function as connectors between different or similar patches. The matrix is the rest of the landscape, and can be thought of as the context that the patches and corridors sit in and interact with. A heterogeneous matrix usually supports more ecological diversity.[23] The patch-corridor-matrix model allows us to think about landscape structure and function, which can be useful in ecological analyses and design.



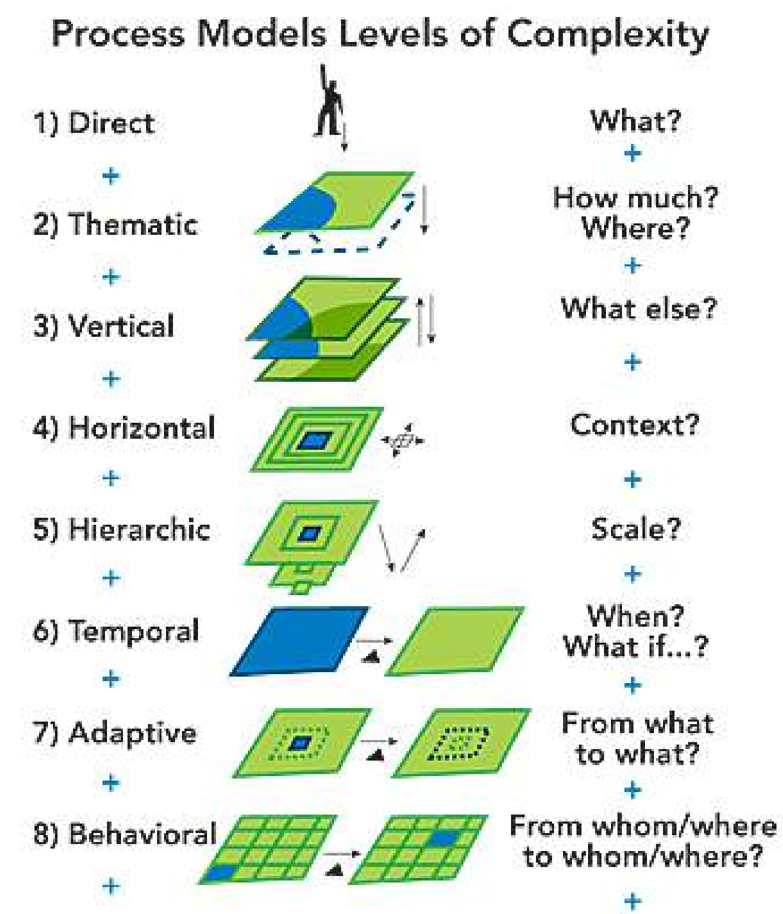

A depiction of the patch corridor matrix model. Patch, corrdior, and matrix size and type all have implications for connectivity and community composition. Originally published in Conservation Buffers: Design Guidelines for Buffers, Corridors, and Greenways.

19. Forman. (1995).
20. Forman. (2014).
21. Pickett & White. (1985).
22. Opdam & Steingrover. (2008).
23. Tscharntke et al. (2005).



The importance of spatial context: This idea sets out that when looking within a specific boundary for any design, it is important to broaden the analytical scale by looking at surrounding land use, patches, corridors, and matrix types.[24] These adjacencies could have a large impact on a design area because ecology does not function in isolation. Outside forces impact site ecology, and most human and ecological forces flow across arbitrary site boundaries.

Ecosystem flows: Related to looking at outside context, it is important to realize that ecosystem processes act and change across space and time. For example, water does not flow linearly unless it had been channelized by human intervention, and it does not flow constantly at the same rate. It is generally more difficult to portray flows graphically while designing but by incorporating them into our analysis, our designs can become much more robust and meaningful. As another example, habitat succession is difficult to draw on a map that shows a specific place in a specific time. Different time scales must be considered, as certain processes proceed at different rates and different patterns may emerge at different scales.[25]




An example of different forms of context and scale to consider when analyzing a landscape. From Steinitz, 2008.

24. Steinitz. (2008).
25. Turner, Gardner, & O'Neill. (2001).

# ECOLOGICAL MANAGEMENT

Our clients are interested, in addition to creating a productive and profitable farm, in conserving and improving the habitat quality on their property. The northwest portion of the property contains a woodland that was never tilled for agriculture, and as our surveys revealed, possesses a high plant diversity, high quality soils, and amphibian diversity. Moreover, many of the fields that have been conventionally farmed for decades stand to see an improvement in soil quality and plant diversity as perennial polycultures and water management systems are implemented. These data provide reference conditions and potential management goals for our site. Further, monitoring floral and faunal changes over time would make excellent future projects to track the impacts of agroforestry and restoration agriculture in temperate climates. Fortunately, the sciences of conservation ecology and restoration ecology provide a wide array of lessons that can be drawn upon to create landscapes that both conserve and improve habitat quality.

As is, there are several landscape features that bode well for conservation and restoration. The site contains three primary habitat types: mesic woodland, a wooded swamp, and open fields. Diversity of habitat types is key to sustaining biodiversity over time, and using different agroecological systems across the site could increase the heterogeneity of vegetative composition and structure. Further, the rolling topography of the site provides opportunities to create microclimates that can host different species of plants and animals. There are a number of existing vernal pools that host a suite of amphibians, and the creation of ponds and swales on the site could increase habitat value as well. Lastly, there are a series of hedgerows across the property that connect the woodland areas across the field.

Invasive species, such as garlic mustard, present a threat to local populations of native vegetation. Controlling the spread of invasive exotics will preserve the floristic quality of the site, and provides an opportunity for education and volunteer collaboration.



Lindenmayer et al. provide a useful framework to craft ecological management plans.[26] Among the most important criteria for successful management is the establishment of quantifiable and realistic goals. Our management goals are to improve soil quality, increase plant diversity, increase net primary productivity of the site, and increase the flow and diversity of organisms across the site. While this project has laid out these goals, and how to quantify them, future projects could work with the client to refine and quantitatively track the farm's progress toward them.

Further, it is important to manage the entire site, not just the high quality patches. Related to this is identifying the important species and processes across the site. We suspect that insects and birds currently are and will continue to be key actors. Insects are the primary pollinators and agricultural pests in the region, and several bird species are frugivores, potentially functioning as crop pests and as dispersers of wanted and unwanted plants alike. However, encouraging predator species like hawks and foxes may be important to prevent, say, rodent outbreaks.

Finally, Lindenmayer et al. suggest that management must be flexible. A defining characteristic of a resilient ecosystem is the ability to function properly in the face of changes, and evolve in the face of transformative changes in climate and species composition.[27] Our clients could, therefore, adopt strategies such as planting varieties of crops that are suited to slightly different ecological conditions, for example.

Conserving and improving ecosystem processes requires intentional and well-thought out management plans.

26. Lindenmayer et al. (2008).
27. Lindenmayer et al. (2008).

# ALTERNATIVE AGRICULTURAL MODELS

## AGROFORESTRY/INTERCROPPING

Agroforestry is a land use management system that combines shrubs and trees with agricultural and forestry technologies to create more diverse, productive, healthy and sustainable landscapes. The multiple cropping practice combining crops, trees and/or shrubs is a kind of intercropping, with the goal to produce a greater yield on a given piece of land by making use of resources or ecological processes that would otherwise be utilized by a single crop.

Agroforestry systems can provide a number of ecosystem services and environmental benefits. Carbon sequestration is one of the most attractive services. By incorporating trees or shrubs, agroforestry systems can sequester more carbon than a monoculture field of crop plants or pasture.[28] In addition to the increased total sequestration amount, forests also hold more underground carbon, which renews the soil carbon pool. Enhancing and maintaining long-term soil productivity and sustainability is an additional benefit. Trees enhance soil productivity either by directly fixing nitrogen or by accelerating nutrient cycling. This hypothesis is based primarily upon observations of higher crop yields near trees or where trees were previously grown. Tree pruning is one major way to provide nutrients to meet crop demands.[29] Another direct effect of agroforestry is increased biodiversity. Agroforestry increases biodiversity by providing habitat for species, preserving germplasm, and making ecosystems more robust and interconnected.[30]

Silvoarable agroforestry experiment with poplar and barley in Bedfordshire, 2002.

28. Kirby & Potvin. (2007).
29. Palm. (1995).
30. Jose. (2009).



Because agroforestry has been developed to ameliorate ecological as well as social consequences of industrial agricultural, scholars and practitioners emphasize a combination of ecological and social concepts. Among the chief ecological features of agroecological systems are management of competition and complexity. Social features include profitability and sustainability. Competition existing between trees and crops for light, water and nutrients is one of the research focuses. Management of competition to a farmer's benefit can be a determinant of successful agroforestry systems. A major distinction within agroforestry systems is simultaneous and sequential systems. In simultaneous systems, multiple woody crops are planted together, while in sequential systems one crop is planted and harvested before the next is grown. Simultaneous agroforestry systems are more susceptible to competition than sequential ones, probably because of increased competition among species for living space. Complexity in social, economical and ecological aspects is typical of agroforestry systems, which makes complexity another key principle. Effective agroforestry research requires participatory, analytical and multidisciplinary studies at different spatial scales. Research about complexity should be combined with profitability, another objective of agroforestry science. Diverse products and services from these systems should be manipulated in a way that puts money in farmers' pockets. Domestication of indigenous trees with high-value products enhances profitability, particularly those that can be marketed as ingredients of multiple finished products. Policy research interventions are often necessary to help farmers during the initial years before trees become productive and exert their positive ecological functions. Profitable agroforestry systems are potentially sustainable, they control erosion, enhance biodiversity, and conserve carbon; provided nutrient offtake is balanced by nutrient returns via litter and the strategic use of fertilizers, particularly phosphorus.[31]

Some challenges to managing agroforestry systems include the fact that competition between different species may harm total productivity of ecosystems. With difficult trade-offs between conservation and production in mind, agroforestry entails hard and sometimes controversial management decisions, which can discourage farmers from adopting agroforestry systems. Partly for this reason, until recently, agroforestry and intercropping have been poorly integrated.[32]

Agroforestry intercropping system in the UK.

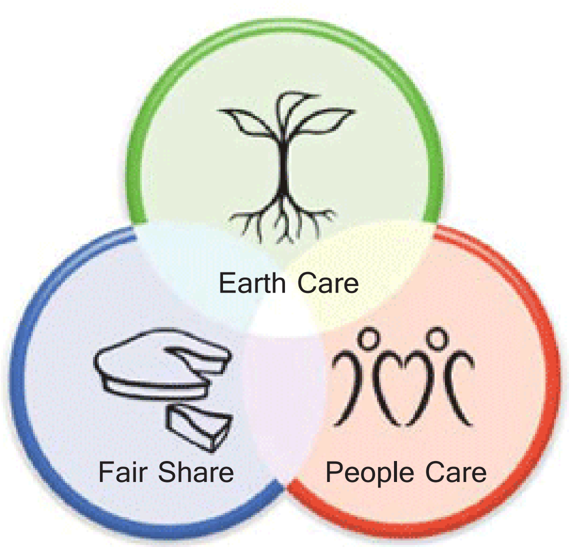
31. Sanchez. (1995).
32. Wezel et al. (2014).

# PERMACULTURE

Permaculture, an agriculture system centered on perennial agriculture and natural ecosystem processes, was developed in the late 1970's by Bill Mollison, a scientist, and David Holmgren, a designer. Permaculture focuses on how perennial agricultural systems can imitate natural ecosystems and still be productive and economically viable. Permaculture is an umbrella term that contains many of the other practices outlined here, so this section will contain a brief overview and a look into permaculture theory.

One of the tenets of permaculture is farming with perennial crops. Diverse perennial agriculture has quantifiable benefits for pest management, soil management, water quality, pollination, production of a diversity of food crops, resilience to climate change, and creating more social amenities.[33,34,35,36] In one study, levels of nitrate leaching into subsurface water were significantly lower in perennial agricultural systems compared with conventional row crops.[38] In another study, trees with perennial grass planting strips (what the authors call agroforestry) reduced nutrient runoff and nonpoint-source pollution compared with a conventional corn-soybean rotation.[39]

Permaculture also contains a social philosophy that includes people and community in the agricultural setting. One of the core tenets of permaculture is caring for people through providing resources and livelihoods and building strong communities rooted in their cultural and productive landscapes.




Three main principles of permaculture

33. Gurr, Wratten, & Luna. (2003).
34. Asbjornsen et al. (2014).
35. Pimentel et al. (1997).
36. Smith et al. (2013).
37. Pimentel et al. (2012).
38. Randall et al. (1997).
39. Udawatta et al. (2002).



One theory in permaculture that is specific to spatial design is the idea of a layered productive structure. A permaculture design is composed of seven or eight layers:


1. The canopy layer: the largest and tallest trees that provide shade. Can produce edible products such as nuts or be used as a fuel resource.
2. The understory layer: shorter trees that grow in the partly shaded area beneath canopy trees. Producers of nuts and fruit.
3. The shrub layer: Shorter still woody perennials such as berry bushes.
4. The herbaceous layer: consist of perennial and annual non-woody plants that produce a wide array of fruits, medicinals, fibers, herbs, and spices.
5. The groundcover layer: plants that work as cover crops and green manures or low to the ground, trailing plants such as strawberry.
6. The underground layer: the root layer underground that contains root crops such as tubers.
7. The vertical layer: vining plants that climb up the other layers. Consists of beans, grapes, and other lianas.
8. The fungal layer: above and belowground mushrooms and hyphal networks. Includes edible mushrooms.

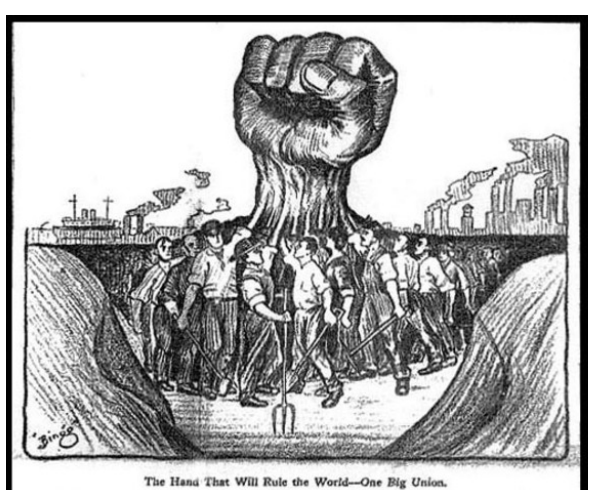
For additional information, Hathaway does a good job of outlining permaculture practices and principles as well as its benefits compared to conventional agriculture.[40]

40. Hathaway. (2016).

# SOCIAL SCIENCES

## BOTTOM-UP MOVEMENT

Far from being an exclusively ecological matter, food system reform has a critical social component. Because reform of the food system is inherently social, we placed a high premium on opportunities to incorporate social engagement in our design, and so it is helpful to understand the social aspects of food systems reform. A myriad of social organizations have emerged, with the intent of incorporating social and economic justice into the food system. La Via Campesina is a multinational grassroots coalition that is actively trying to change the dominant global food system. Slow Food is another global movement promoting food sovereignty goals and raising public awareness. The new peasantry movement is a grassroots effort aimed at addressing the concentration of corporations, primarily by disrupting and reshaping the food system. Academically, the writing of Jan Douwe van der Ploeg is a social-science approach to understanding the new peasantry movement as a resistance to large agri-business food empires. The scholar defines peasant agriculture as a type of farm that relies primarily on agroecology instead of synthetic inputs and is typically engaged in mostly local commerce with small or medium sized businesses. His writing suggests that peasant agriculture is a resilient method of farming that offers a more sustainable form of economic growth than the current industrial system. The new peasantry movement is combating corporate concentration indirectly through engagement in agroecological farming methods, as well as directly through protests against corporations in the streets and government buildings throughout the world.




The Hand That Will Rule the World by Ralph Chaplin, 1917. Published in Solidarity.



# FARMER TO FARMER NETWORKS

Wisconsin has become a hub for farmer-to-farmer networks.[41,42] These organizations are defined by a non-hierarchical leadership between different farmers, where each member is expected to contribute whatever resources and expertise they may have. The original intention of these networks was to create a flexible community of farmers that could learn from and support one another. Through partnerships, they are able to experiment with management practices and business models. This has created a space in the Wisconsin food scene for relatively widespread adoption of ecologically sound practices such as intensive rotational grazing. In addition to internal resource and idea sharing, farmer-to-farmer networks engage their community through activities such as field walks. Not only does this strengthen the relationship between farmers and community members, but it also provides a platform of advocacy for alternative agricultural systems.

Farmer to Farmer Networks support farmers and food citizens with ongoing hands-on, peer-to-peer learning and networking opportunities.

UW-Extension. (2012).
Center for Integrated Agricultural Systems. (1996).

# HOMESTEADING

Our clients see the transition to their farm as a shift in lifestyle. With the intent of providing more for themselves and earning a living through agriculture, they are pursuing, at least in part, a homesteading lifestyle. This lifestyle is a form of "living-off-the-land" that often centers around the production and consumption of food.[43] Home gardens or family farmsteads are fixtures in many traditional cultures, but the meaning of the word "homesteading" has changed in recent times.

The American concept of homesteading often traces back to the Homestead Act of 1862, in which the U.S. government granted ownership of western U.S. (formerly Native American) land to any adult willing to relocate and settle on their given 160 acre parcel. The legislation was not only a contentious social justice issue, but many of these homesteads became defunct during environmental and economic catastrophes in the 20th century, such as the simultaneous Great Plains Dust Bowl and Great Depression.[44] The original Homestead Act was officially discontinued during the 1970's and 1980's, when national policy shifted toward federal management of Western lands.[45]

Today and over the past few decades, modern homesteading has mostly been about increasing self-reliance within one's living space, especially as it relates to health and energy. Participants in the hippie movement embraced some principles of homesteading as a form of resistance against powerful industrial and corporate interests.[46] Simple homesteading now may involve an herb garden in an urban apartment window with some low-tech preservation capability; an extreme homestead may be completely "off-the-grid," capable of supporting a family through any significant disruption in the availability of provisions within the market (sometimes called "doomsday prepping"). An established popular culture associated with homesteading has emerged with considerable amounts of instructional material available online, on television, and in-print.[47]

The culture of homesteaders has elicited some philosophical and sociological study. Gould makes comparisons between religion and the practices of homesteading, particularly in the ritualization of behavior and the desire for immortality or transcendence.[48] The author notes the irony of homesteading being counter-cultural to standard religious behavior, while at the same time recreating tendencies of some religious cultures. To give an example of this irony, homesteaders may cultivate crops and prepare meals every day as a ritual instead of going to an organized place of worship; at the same time, homesteaders may seek immortality through their interaction with the land, perpetuating the theme of afterlife found in many religions.

43. Smith. (2015).
44. Hansen & Libecap. (2001).
45. "The Last Homesteader."
46. Smith. (2015).
47. Smith. (2015).
48. Gould. (1997).



One of the explanations for why homesteading intrigues some philosophers may be sociological; there is a fascinating group-learning component to the movement being perpetuated by increases in technology and changes in means of communication. The factors underlying the increasing popularity of homesteading are complex, but mainly they relate to people's environmental concerns, discontent with establishment economics, and desire to change U.S. work culture to allow for increasing time spent at home. In many cases, urban homesteading is conducted by women participating in a "community of practice," often bringing together diverse ideologies, ethnicities, and social classes. As Smith points out, a common interest among homesteaders is the need to be educated. An individual with an extensive formal education today may lack many of the domestic skills taught through homesteading networks; these well-educated people often learn domestic skills informally, receiving support from social groups online or in-person. The informality of online homesteading resources provides an alternative to the more scientific agroecological approach and the more politically organized social movements described previously.[49] Understanding the homesteading culture in which our clients are immersed provided us insight as to the types of community and cultural resources that could potentially be served and augmented by our design.

Riverside Farmstead by Mikhail Konstantinovich Klodt, 1858. Oil on canvas.

49. Smith. (2015).

# METHODS AND RESULTS

One of the most important first steps for beginning an ecologically restorative agricultural system is having a firm understanding of the site on which one is working. To that end, we spent time performing a myriad of ecological surveys to help clarify the existing conditions and needs of the property as they relate to our client's goals. Over the course of the spring, summer and fall of 2016, we conducted a soil survey, three avian surveys, two botanical surveys, an invertebrate survey, and a herpetological survey with the assistance of Herpetological Resource and Management, LLC. The methods and results from each survey are described in turn. We combined methods and results sections to make the report easier to read and provide a more complete picture of each survey.



# SOIL HEALTH

Soil health is a fundamental characteristic of productive systems due to its direct impact on yield and overall ecosystem function and health.[50] There are many different interacting components that make up a healthy soil, broadly categorized into chemical, physical, and biological properties. For our preliminary soil tests, we focused on some basic chemical factors such as pH, micronutrients, and macronutrient levels, which have a direct impact on crop resources and growth. However, the majority of our analyses focused on biological measures of soil organic matter content and quality. Higher organic matter levels typically correspond with greater nutrient availability for plants (as reflected in the cation exchange capacity [CEC]), more variability in soil structure through the formation of aggregates (which allows better water and gas exchange), and a higher diversity and/or activity of soil microorganisms, which carry out many nutrient cycling processes in soil.

In this study, we considered three different pools of soil organic matter: total organic matter, a pool which changes very slowly, and two different fractions of organic matter that are known to respond to changes in management on year to decadal time-scales, and which can provide useful guideposts for farm management.[51,52] Free particulate organic matter (fPOM) contains organic matter that is relatively recently derived from plant residues or other organic matter inputs and which is readily accessible to soil microorganisms. Occluded particulate organic matter (oPOM) consists of organic matter particles that are physically protected in clay particles and soil aggregates and so are not immediately available for decomposition by organisms. However, the organic matter in the oPOM pool is slowly made accessible to organisms over time, so the C and N content of the oPOM pool is an indicator of changes in organic matter due to different management systems. A large fPOM pool, and high N content of the oPOM pool are indicators of a high quality soil for agricultural purposes.

Another measure of soil fertility status is potentially mineralizable carbon (PMC), which tends to reflect the quality of an organic matter pool similar to the fPOM, but is a flux measurement that is an indicator of the size of the easily decomposable carbon pool.[53] This metric thus reflects soil nutrient cycling capacity and the potential for microbial activity to supply plant nutrients. Soil aggregate size is directly related to PMC, where larger aggregates correspond with larger PMC values.[54] As such, PMC - and other measures of organic matter - are often related to the soil clay content because clay particles promote smaller aggregate formation.

50. Doran & Zeiss. (2000).
51. Wander. (2004).
52. Marriott & Wander. (2006).
53. Hurisso et al. (2016).
54. Franzluebbers & Arshad. (1997).

# SOIL FIELD TESTING

Working closely with our clients, we divided the existing farm fields into smaller sections based on management techniques and crop rotations. We did this because our clients would like to learn as much as possible about fine scale variation in each field and the differences in perennial versus annual vegetation.[55] We located sixteen samples points across the property, including samples across the fields and unmanaged natural areas. On May 21, 2016, we collected soil samples at the sixteen points. Following the collection procedure outlined by the University of Massachusetts soil lab, soil was collected at twelve subsample points in each field section that have similar soil texture, slope, and drainage. Subsample points were separated by at least 5 meters. For each sample, we cleared away any litter and debris on top of the soil and dug a six inch deep by four inch wide hole. Then, we scraped off a slice of the side of the hole as our subsample. This procedure was repeated eleven more times in the section and all of the subsamples were combined into one container to act as our section sample. Large clumps were broken down and any roots or large debris were removed. A few cups of the sample were separated and spread into an aluminum foil tray to air-dry in the Nature and Nurture seed drying area for one week. We sent soil samples to the University of Massachusetts Amherst Soil & Plant Nutrient Testing Laboratory for their routine soil analysis (metrics are: pH; exchangeable acidity; lime deficit; extractable phosphorus, potassium, calcium, iron, manganese, zinc, copper, boron, sulfur, lead, aluminum, and magnesium; cation exchange capacity; and percent base saturation).[56]

The full results of the soil surveys returned from the UMass laboratory can be found in Appendix A and B of this report. In the analysis of the data, we categorized the records of the report by land use: there were four samples taken in forested areas, four samples taken in the fallow fields on the Levine parent's land, six samples taken in the large field crop areas, and two samples taken inside the more intensively farmed fenced area. For all of the soil characteristics mentioned above, we computed basic descriptive statistics including mean, range, and standard deviation. For a full summary of the results, see the data table on page 29. We made density plots of each parameter to assess the normality of the data and look for outliers. We assessed the correlations between metrics by looking at Pearson correlation coefficients.

Collecting soil across the farm

55. Levine, M. (2016). Personal Communication. March 15.
56. Services, n.d.



| Land Use | Acres | Percent | Habitat / Vegetation* |
|---|---|---|---|
| Total Site | 122 | 100.0 | - |
| Forested | 36 | 29.5 | Mesic Oak-Hickory, Silver Maple Swamp |
| Field Crops | 31 | 25.4 | Alfalfa |
| Fallow | 42 | 34.4 | *Solidago* |
| Fenced, Production | 3 | 2.5 | Fruit trees, produce and seed crops, cover crops |
| Pond/Wetland | 2.5 | 2.0 | *Phragmites* |
| Homestead / Other | 7.5 | 6.1 | Grass, herb garden, conifers |

* See Burhop 2015 Forest Management Plan for more detailed description and site history.

To analyze soil difference between different landscape, we classified our sample points into several categories. The categories are shown as follows:


Map of the 16 soil sample points across the property and their soil type category

| Land-Use | ID | Soil_Type | Slope | Soil pH | CEC | Soil Organic Carbon | Soil Nitrogen |
|---|---|---|---|---|---|---|---|
| | | | Percent | | meq/100g soil | Percent | Percent |
| Forest | 1 | Miami Loam | 12-18% | 6.1 | 14.3 | 3.06 ± 0.09 | 0.19 ± 0.01 |
| | 2 | Conover-Brookston Loam | 0-2% | 5.5 | 17.6 | 2.95 ± 0.05 | 0.17 ± 0.00 |
| | 3 | Miami Loam | 6-12% | 7 | 26.2 | 1.99 ± 0.03 | 0.08 ± 0.00 |
| | 4 | Houghton Muck, Disintegration Moraine | 0-2% | 6.3 | 36.9 | 7.16 ± 0.30 | 0.49 ± 0.01 |
| Fallow | 5 | Miami Loam | 2-6% | 6.4 | 11.5 | 2.19 ± 0.05 | 0.13 ± 0.00 |
| | 6 | Miami Loam | 2-6% | 5.9 | 8.2 | 1.28 ± 0.07 | 0.07 ± 0.01 |
| | 7 | Miami Loam | 2-6% | 6.2 | 8.4 | 1.00 ± 0.00 | 0.06 ± 0.01 |
| | 8 | Miami Loam | 2-6% | 6.9 | 10 | 1.51 ± 0.01 | 0.10 ± 0.00 |
| Field | 9 | Spinks Loamy Sand | 0-6% | 6.7 | 7.1 | 1.08 ± 0.01 | 0.07 ± 0.00 |
| | 10 | Miami Loam | 2-6% | 6 | 7.7 | 0.99 ± 0.11 | 0.06 ± 0.01 |
| | 11 | Miami Loam | 2-6% | 5.9 | 7.8 | 1.09 ± 0.01 | 0.07 ± 0.00 |
| | 12 | Miami Loam | 6-12% | 5.8 | 9.1 | 0.89 ± 0.06 | 0.05 ± 0.00 |
| | 13 | Miami Loam | 6-12% | 5.5 | 8.3 | 0.97 ± 0.01 | 0.06 ± 0.00 |
| | 14 | Miami Loam | 2-6% | 5.2 | 9.3 | 1.08 ± 0.00 | 0.07 ± 0.00 |
| Fenced | 15 | Miami Loam | 2-6% | 7.4 | 16.2 | 1.48 ± 0.01 | 0.08 ± 0.00 |
| | 16 | Miami Loam | 2-6% | 4.8 | 7.6 | 0.70 ± 0.04 | 0.03 ± 0.01 |
| | | | **Mean ± SD** | **Soil_pH** | **CEC** | **% C** | **% N** |
| | | | **Forest** | 6.23 ± 0.6 | 23.75 ± 10.1 | 3.79 ± 2.30 | 0.23 ± 0.18 |
| | | | **Fallow** | 6.25 ± 0.4 | 9.53 ± 1.5 | 1.49 ± 0.51 | 0.09 ± 0.03 |
| | | | **Field** | 5.85 ± 0.5 | 8.22 ± 0.9 | 1.01 ± 0.08 | 0.06 ± 0.01 |
| | | | **Fenced** | 6.10 ± 1.8 | 11.9 ± 6.1 | 1.09 ± 0.55 | 0.06 ± 0.04 |

A subset of the UMass laboratory results. For additional results see Appendix A and B.



# CATION EXCHANGE CAPACITY

The various metrics in our baseline soil tests showed that soil composition differed by land use type. The soil cation exchange capacity (CEC) gives an indication of the potential for the soil to supply nutrients critical to plant growth. Large CEC values reflect high levels of clay and/or organic matter, while sandy or silty soils typically have low CEC values. The value of CEC is very well correlated with the concentration of some micronutrients, including sulfur [Figure 2]. The soil we collected in the forested areas matched the expected value in the literature, but the CEC was typically on the low end or below the expected range for nearly all of the farmed or fallow Miami loam soil [Figure 1].[58] The notable outlier of the farmed area was the one intensively managed area that had been recently fertilized and cover cropped.

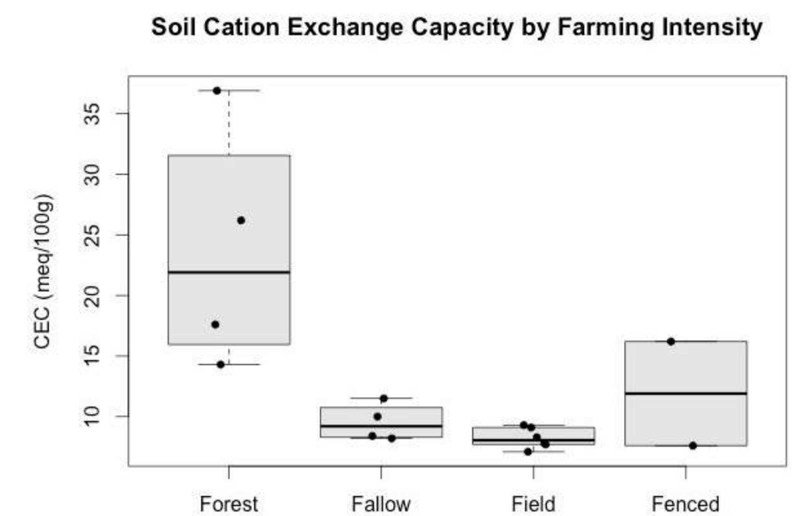



Figure 1: Cation Exchange Capacity (meq/100g) by Sampling Location Land Use. Points show the results for all 16 sampling location, boxes show median (dark bar), middle 50% of the data (gray box), and range (whiskers) of each category.

The northwest forest had significantly higher CEC compared to other land-use types. Fallow and field were similar, with fallow being slightly higher. The two sampling points within the fenced area show the variation in soil composition within the crop production area.

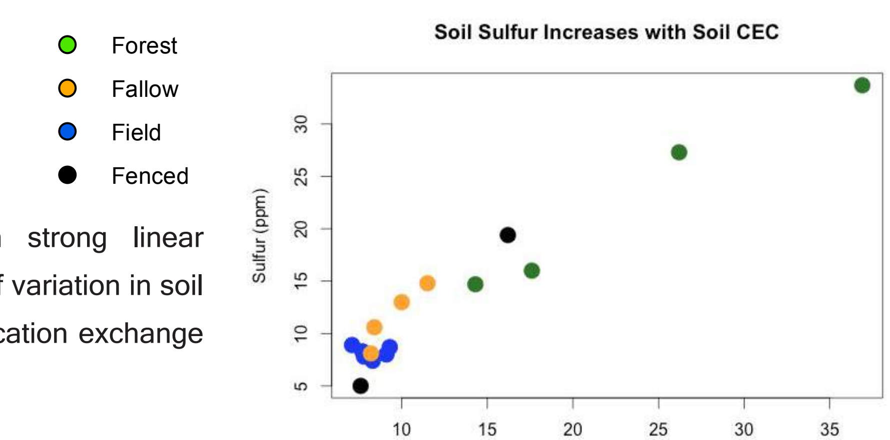



Figure 2: There is a strong linear relationship, with 94% of variation in soil sulfur explained by soil cation exchange capacity.

58. Mengel, n.d.

# SOIL LABORATORY TESTING

For each of the sixteen soil samples, percent carbon and percent nitrogen were determined via a dry combustion method using a LECO TruMac CN® determinator. Subsamples were finely ground, and run in duplicate.

To assess the quantity and composition of soil organic matter, we determined free and occluded particulate organic matter (POM) pools, as well as potentially mineralizable carbon (PMC) for four of the soil samples. These four samples were chosen based on their location throughout the property and their ability to stand in as proxies for long-term land use/management history. The sample from the northwest forest was included as a baseline; indicating the high quality forest ecosystem that covered the entire property before it was brought into conventional agricultural production. We also included a sample from one of the fields currently in alfalfa production to compare to one of the currently fallow fields, formerly farmed, on the clients' parents' property. The last of the four samples was taken from the highly managed organic annual vegetable and seed field to explore any soil health impacts from the myriad of practices our clients are applying (composting, perennial crops, living aisles).

To determine PMC, we followed the Blesh laboratory protocol using a method modified from Franzleubbers et al.[59] To begin, we sieved soil to 2 mm and weighed 10g of air-dried soil into 50 mL centrifuge tubes (three replicates) with lids fitted with airtight, rubber septa. Deionized water was added to each tube to bring the samples to approximately 50% water-filled pore space. The CO2 concentration was measured with an infrared gas analyzer (LI-820) at the time of initial wetting, and again 24 hours later after being incubated in the dark at 25ºC. The difference in CO2- C between time zero and after 24 hours was used to calculate the PMC flux.

Particulate organic matter (POM) was determined following the Blesh laboratory protocols after Marriott and Wander[60], measuring both free and occluded POM pools. For each sample, the material was dried and chunks greater than 4 cm wide were crushed. Forty grams of material were placed in a bottle and 75 ml of Sodium Polytungstate solution was added. The bottles were then placed in an orbital shaker at 100 rpm for one hour. The solutions were transferred to beakers and rinsed with more Sodium Polytungstate, such that a total of 100-125 ml was added. The samples were then covered in tin foil and left to rest for 24 hours at room temperature.

59. Franzluebbers et al. (2000).
60. Marriott & Wander. (2006).



To recover the free light fraction (fPOM),we attached a micron mesh to a filtration funnel, and removed the large clumps of POM with tweezers and then captured the rest using aspiration. Then, we rinsed our samples from the funnel onto the fabric and dried the sample in an oven, 60° C for 48 hours. Samples were then weighed and analyzed for C and N on a LECO TruMac CN® analyzer.

To recover the occluded POM fraction (oPOM), we put the remaining portion of our samples in a nalgene bottle covered with a cored lid, with 53 micron mesh fabric and placed this into a larger nalgene bottle. We added water and rinsed the remaining Sodium Polytungstate from the soil and then added 150 mL of Na HMP and let them settle overnight. The next day we placed the samples on a shaker for one hour at 250 rpm. We then discarded the Na HMP and filled the bottle with 150 mL of tap water and shook the bottles at high speed for 15 minutes.This process was repeated 6 to 8 times or until the tap water after shaking was clear. Our samples consisted of oPOM and sand at this point, and since the oPOM is less dense than the sand, we were able to recover the occluded POM fraction by decanting. After the samples were thoroughly dried, we weighed the oPOM fraction and ran it on a LECO TruMac CN® analyzer to determine % C and N.

Preparing soil samples to analyze via the LECO determinator.

Sifted and ground soil samples from across the property.

## TOTAL ORGANIC MATTER

Results showed that soils sampled from the forest area contained significantly more nitrogen and carbon than all other categories.

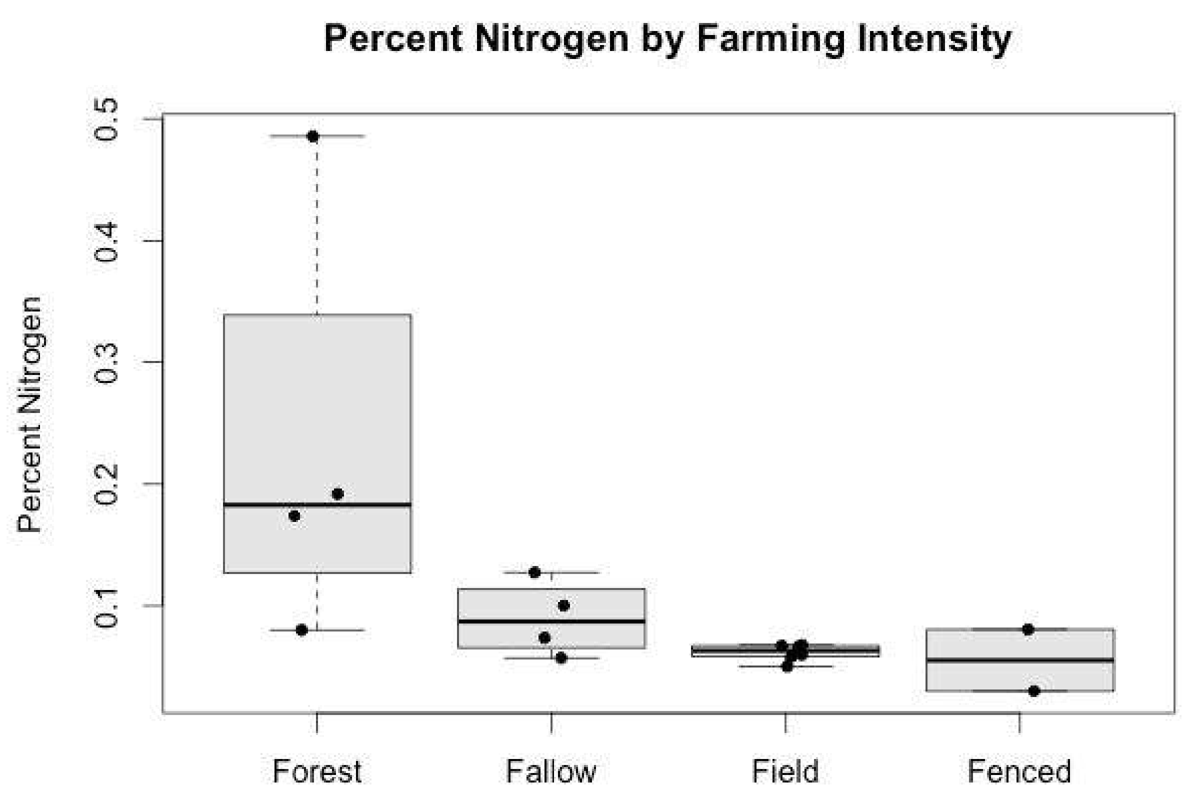



Figure 3: Percent Nitrogen by Sampling Location Land Use. Points show the average of duplicate measures for all 16 sampling location, boxes show median (dark bar), middle 50% of the data (gray box), and range (whiskers) of each category.

The forest had significantly greater overall nitrogen content (0.233% ± 0.152%), with fallow fields coming in a distant second (0.09% ± 0.027%). Fallow fields were slightly more nitrogen rich than fields and row cropped areas, the latter two being almost identical in total nitrogen content.

A similar pattern holds for total carbon content.

The fenced area had the highest total C:N ratio, followed by fallow, field, then forest. But the differences don't appear to be statistically significant.

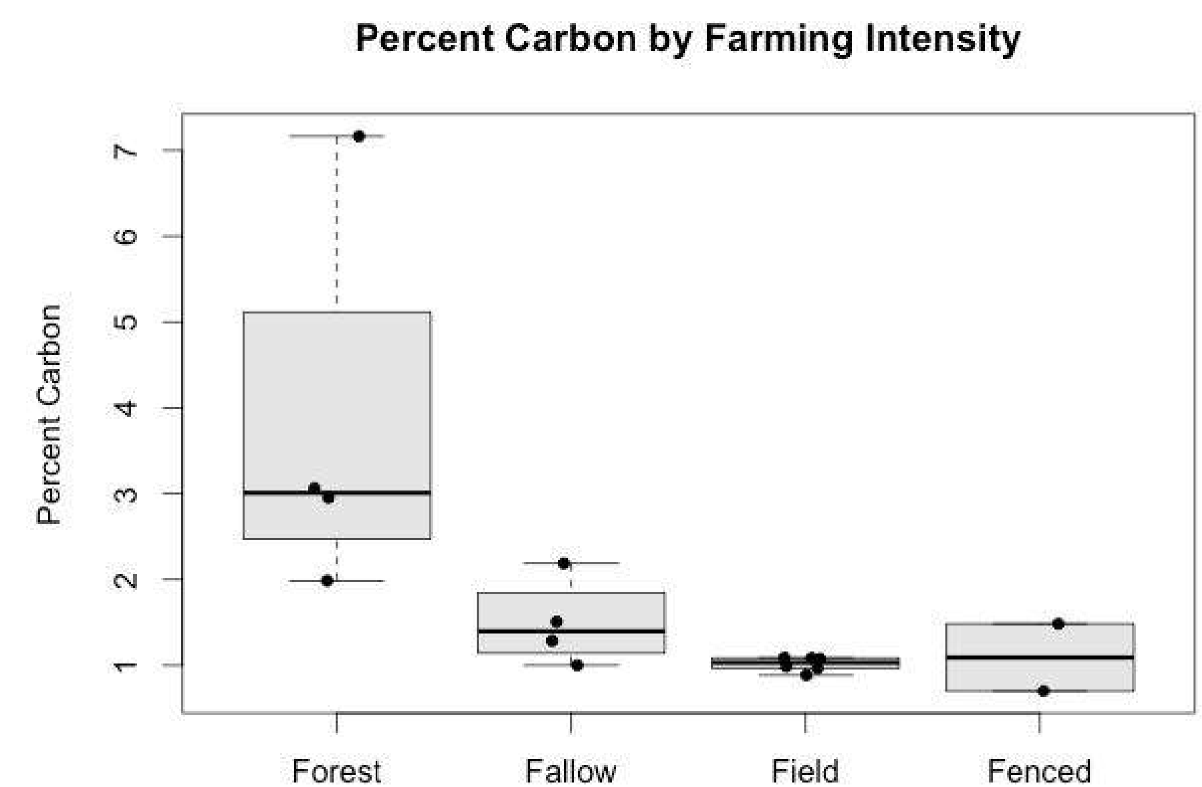
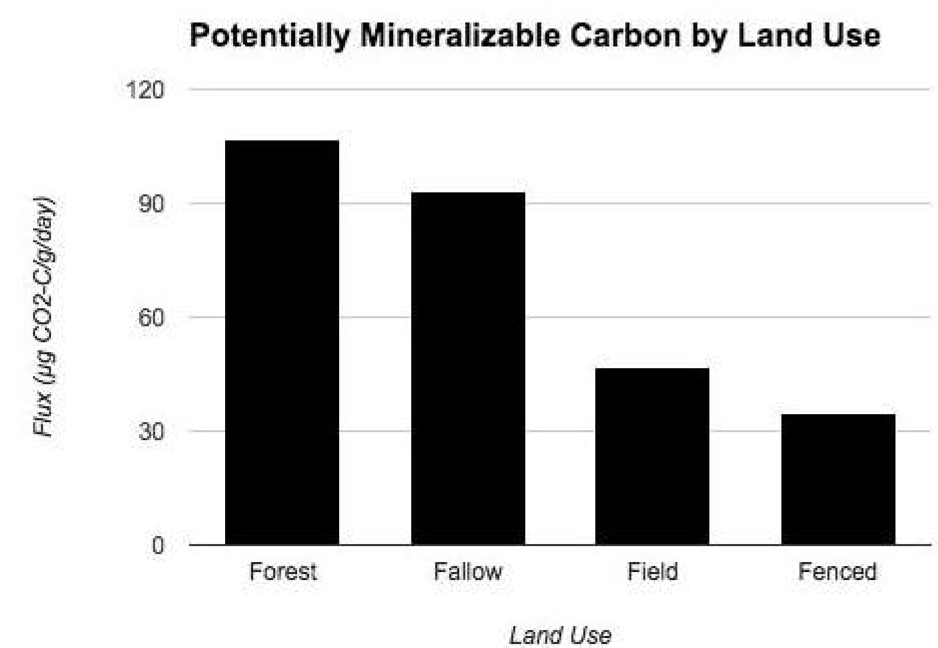



Figure 4: Percent soil Carbon by Sampling Location Land Use. Points show the average of duplicate measures for all 16 sampling location, boxes show median (dark bar), middle 50% of the data (gray box), and range (whiskers) of each category.

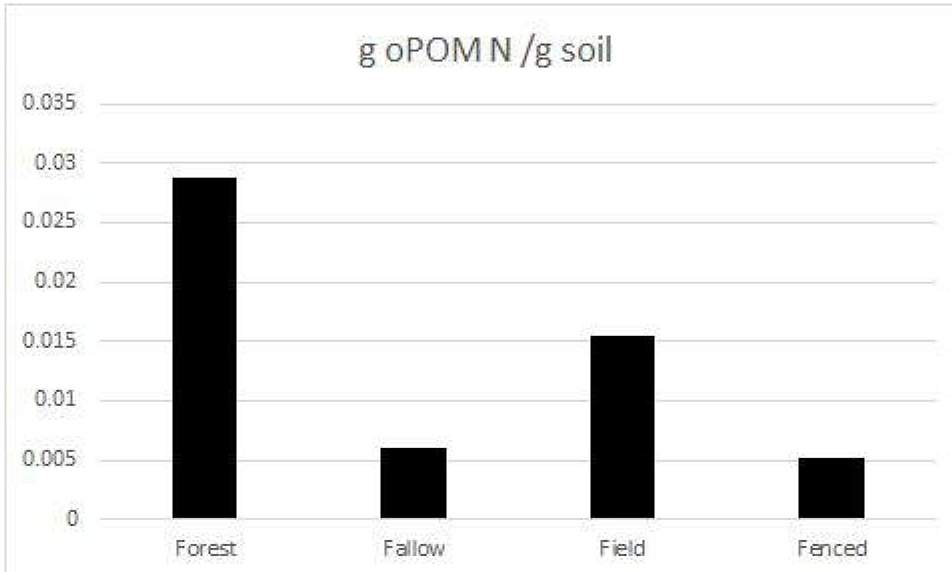
# POTENTIALLY MINERALIZABLE CARBON

Among all sample points, the forest had the highest CO2 daily efflux. This makes sense and is coincident with our LECO result because it contains the most organic matter (see POM data on next page). It was followed by fallow, field and fenced. This reflects the higher quality organic matter in the forest and fallow areas compared to the more degraded annual fields and highly managed areas. The forest and long-term fallow area PMC values also indicate a higher nutrient capacity in the soil.

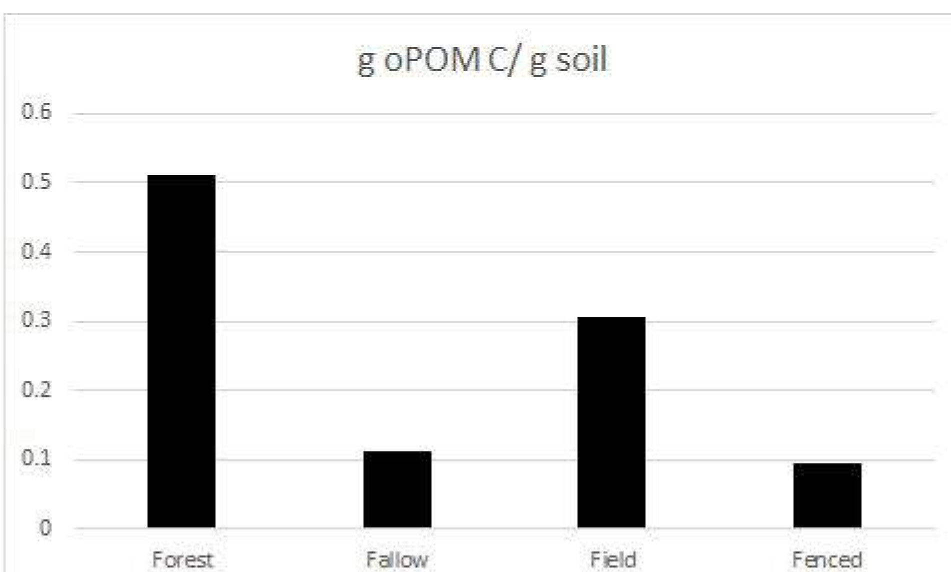


# PARTICULATE ORGANIC MATTER

## oPOM:

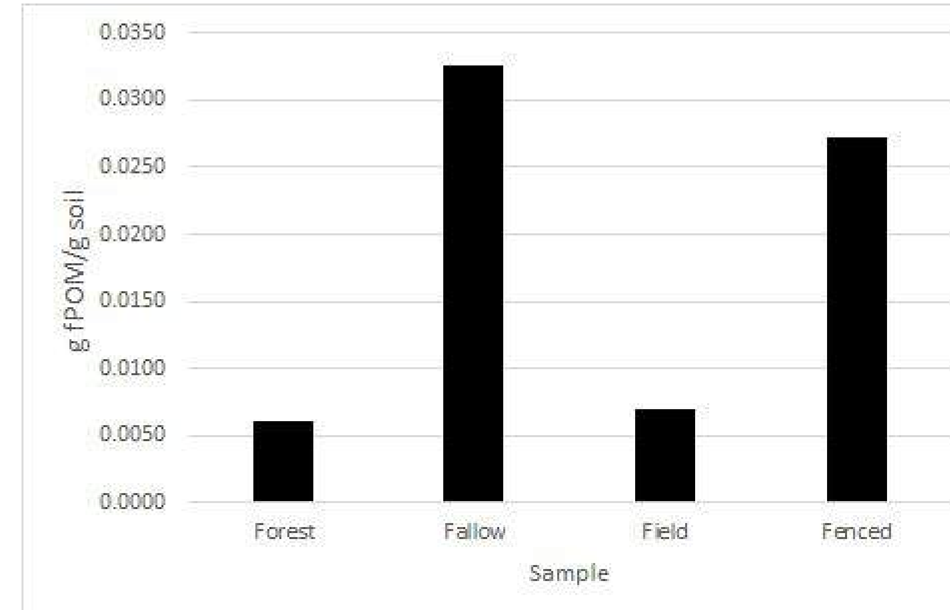



Nitrogen content: The forest contained the highest fraction of nitrogen in the oPOM pool, followed by the agricultural fields. The fallow and fenced areas showed the lowest fraction of nitrogen, and the difference between them was minimal.




Carbon Content: oPOM carbon content is similar to the Nitrogen results. Forest oPOM fraction had the highest carbon content. Carbon content was lowest in the oPOM in the fenced area and fields.

## fPOM:




Fraction of fPOM mass in soil by management.

The higher fPOM in the fallow and fenced areas can be attributed to carbon inputs of grass litter and fine root decomposition, whereas the higher oPOM in the forest and fields likely reflects long-term build up of fertility, though for different reasons. The forest has enjoyed a long-term buildup of soil fertility, where the agricultural fields have been managed for fertility via cover-cropping and application of compost. This would imply that the fallow and fenced areas might be slightly more degraded in terms of potential internal nutrient cycling capacity.

Taken together, these metrics of soil fertility are consistent with long-term and recent management. The forest represents historical baselines, prior to agricultural disturbance by Europeans. The decreased quality of the agricultural and fallow fields is what one would expect given long-term annual agriculture. It is interesting to speculate how quickly one could detect changes in these metrics as the transition to perennial agriculture and restoration projects intensifies. Tracking these changes would make a valuable future project.

# AVIAN SURVEYS

We conducted three avian surveys in order to capture preliminary data on how the composition of species alters through the course of a year. Because birds can be relatively easy to see and identify, and serve important ecological functions including insect control and dispersal of desired/undesired plants, we thought that a formal look into the bird communities was worthwhile.[60,61] The respective dates and times of these surveys were June 4,2016 between 7:50 am-9:40 am and July 23, 2016 between 10:00 am-11:00 am to observe summer resident species, and October 18, 2016 between 9:00 am-11:00 am to observe the end of fall migration. We performed a meandering survey, loosely based on the fixed-radius point count method outlined by Hutto et al.[62] At five points on the route we did a fixed point count, recording the different species and the number of individuals from these species that we identified (by sight or sound) within sight and earshot. We then traveled to the next point, identifying species and numbers of individuals while walking between the point locations. We started our surveys near the main house, and surveyed all the fields and natural areas, moving in a clockwise direction through the property. The June 4th and October 18th surveys followed similar routes and fixed points, while the July 23rd survey focused on the area of the property in and around the main fenced production area (see route map). Although sampling at decided points and along trails can result in biased species composition, it should serve our purposes of understanding general diversity and species present on the property.[63]

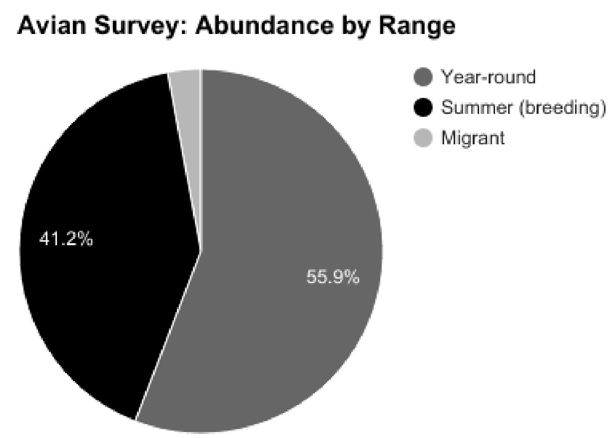
Over the course of three surveys, 36 species of birds were identified, although a few species of sparrow and swallow were undistinguished. We detected the most birds on our first survey; 29 species were observed. Our second survey was scaled back in scope compared to our first and third surveys. We only went out for half the time dedicated to the other surveys, we stayed in a close geographical area for the entire survey, and we conducted the survey at the same time as our invertebrate survey. Also, the second survey was conducted on a hot (90F) sunny day, which would decrease the number of observable birds out in the open. 20 species were observed in our final survey, including seven species that had not been detected in our first survey. A complete list of the species seen can be found in Appendix C.

60. Sekercioglu. (2006).
61. Whelan, Wenny, & Marquis. (2008).
62. Hutto, Pletschet, & Hendricks. (1986).
63. Thompson. (2002).



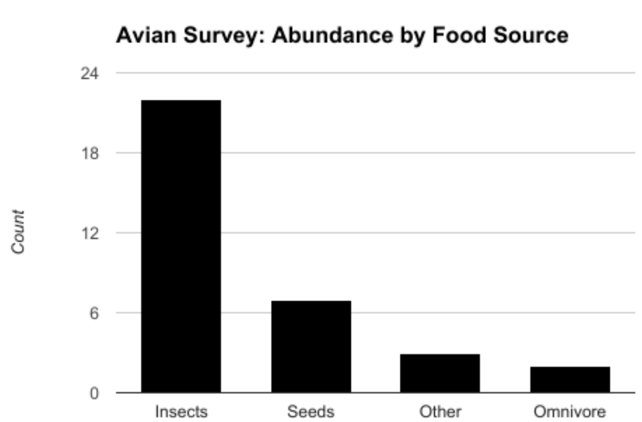

1st survey 6/4/16
3rd survey 10/18/16
2nd survey 7/23/16
Both 1st and 3rd surveys

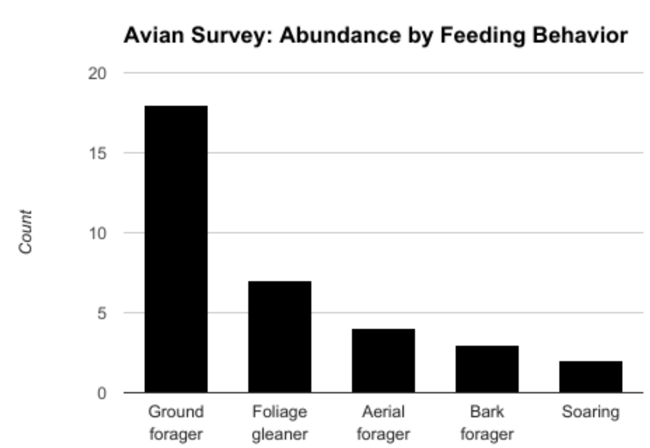
1. House
2. Compost
3. N Woods
4. Meadow
5. Parent's Property
6. Front Pond
7. Permaculture Field




As shown in the above chart, bird sightings were reasonably split between year-round species and breeding species. Only one migrant species was seen, the white-crowned sparrow, but our avian surveys did not cover the spring migration period, where we may have seen a better representation of species passing through the property.

Our surveys also indicated the diversity of food sources that the species we found rely on. A majority of the species were insect-eaters, which has pest management implications for the property. Depending on the type of insects these birds eat, they could serve as natural predators to common agricultural pests. By providing quality habitat for these bird species, our clients can promote ecological regulation of their food system. From observation, we saw that swallows, an important insect predator, were very common predating on the insects above and in the fenced area near the hoop house. As shown below, most of the bird species (including seed-eaters and insect-eaters) are considered ground foragers. Establishing areas of cover for these species will support their feeding behavior.



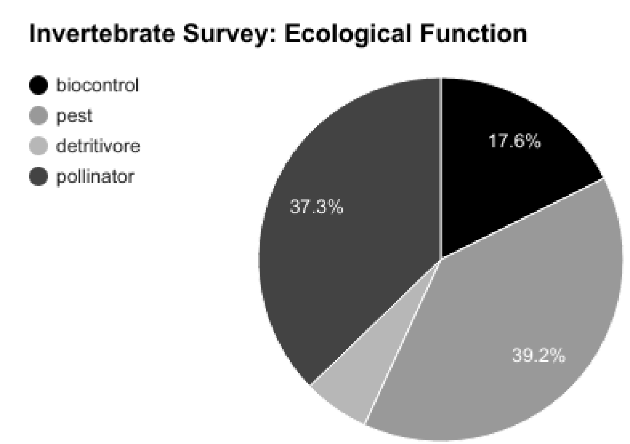



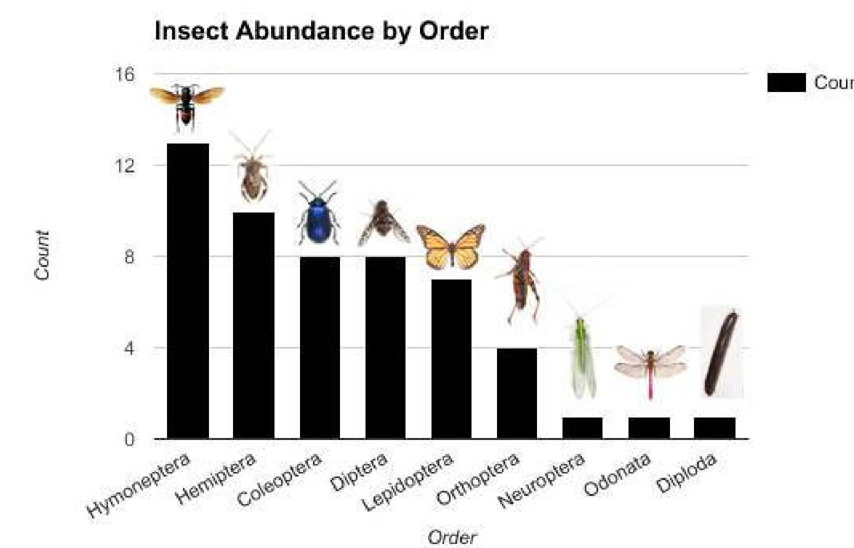



# INVERTEBRATE SURVEYS

On the morning of July 23, 2016 we conducted a survey of invertebrates with the assistance of Beth Weiler, an employee at Nature and Nurture with insect identification skills. The weather was sunny and approximately 90ºF. We used a sweep net and an aerial net as we walked throughout the production field (inside the fence), the alfalfa field to the east, and the surrounding maple swamp edge habitat, identifying every organism we could find for about 2 hours. Organisms were identified to the lowest taxonomic unit possible using field guides.

We identified a total of thirty-nine different invertebrates representing eight orders and thirty-one different families. There were a variety of pollinator species, some of which were found on native plants intercropped with annual food plants. There was a balance of invertebrates considered to be pests and those that predate on other invertebrates. We also spotted a gorgone checkerspot, which is considered a species of special concern in Michigan.




We found that bees, true bugs, beetles, flies, and butterflies/moths were among the most commonly represented order found at our site. While about 1/3 of the insects found had the potential to be a pest species, the species we saw rarely become a major problem (for example the locust species we found). We found a number of pollinators and insects associated with biocontrol, suggesting that the existing entomological community is serving a number of ecosystem services including pollination, keeping pest species down, and decomposing detritus on the site. Our complete invertebrate dataset is available in Appendix D.

# VEGETATIVE SURVEYS

We inventoried herbaceous and woody plants at 20 points across the 120 acres. The points were selected systematically using the "cartwheel approach," which is a recommended method for surveying plants across a landscape.[64] We picked a location in the northwest forest, and surveyed 10-1$m^2$ quadrats around that point. In each 1$m^2$ quadrat, we recorded all vascular plants (excluding trees with trunk diameter at breast height greater than 10cm, and excluding plants with heights smaller than 2 cm) to the lowest taxonomic level that we could identify. We did this because the northwest woodland is the least disturbed area on the site and is the best indication of pre-agricultural plant communities. A comprehensive survey of this area, then, is valuable to serve as comparisons to the plant communities across the site. Further, since this woodland is the most likely candidate for conservation, since it is the highest quality habitat currently, it is important to document what plants are currently there, so that future impacts of conservation management can be compared with baseline data.

We also chose a location near the center of the farm, and sampled from 10 more points spread across the site. This was so we could capture a coarse-grained picture of how plant communities differ across the site. This is helpful to document consequences of previous management on plant composition, and also to gather baseline data so that changes in plant communities can be documented in the future.


Using keys to identify an unknown plant


1m x 1m survey plot

64. Loos et al. (2015).



Map of 20 vegetative survey plots across the property

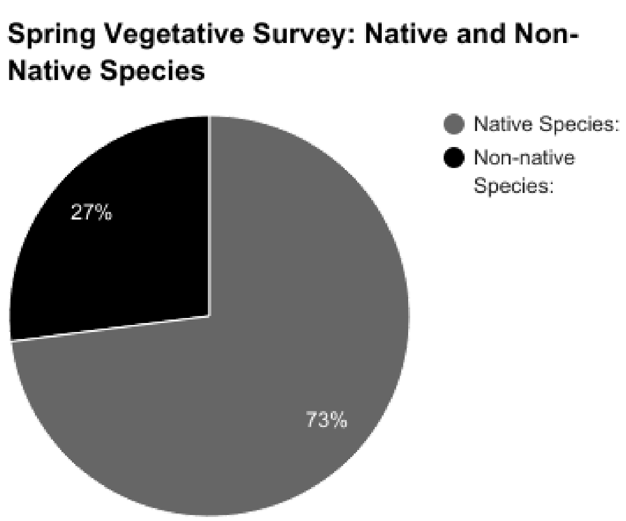
Plant surveys were done in the spring and summer. Using an online calculator, we were able to distill the results of our surveys to show a number of metrics, specifically: floristic quality index (FQI), a commonly used metric of habitat quality, native FQI, adjusted FQI, total richness, native richness, and non-native richness. The reason for distinguishing between total and adjusted FQI is to account for the presence of non-native exotic species. In sum: “To reduce sensitivity to species richness and include the contribution of non-native species when assessing sites with high levels of human disturbance, the Adjusted FQI was developed.”[65] A higher FQI score corresponds with a higher quality habitat.

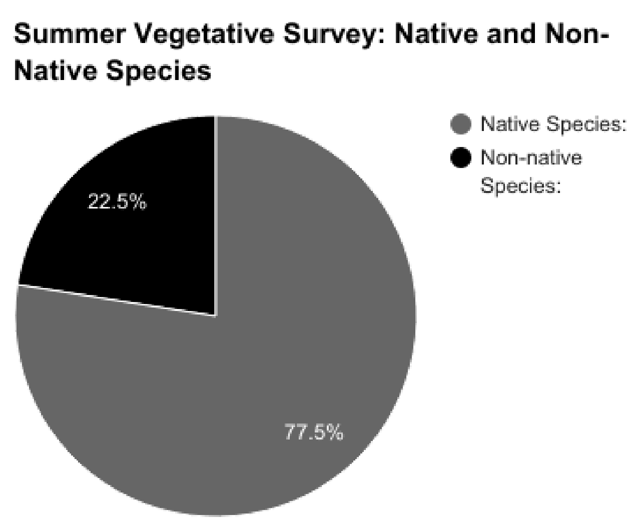
*Spring Results:*

| Total FQI | Native FQI | Adjusted FQI | Total Richness | Native Richness | Non-native Richness |
|---|---|---|---|---|---|
| 16.6 | 19.2 | 31.6 | 37 | 27 | 10 |

*Summer Results:*

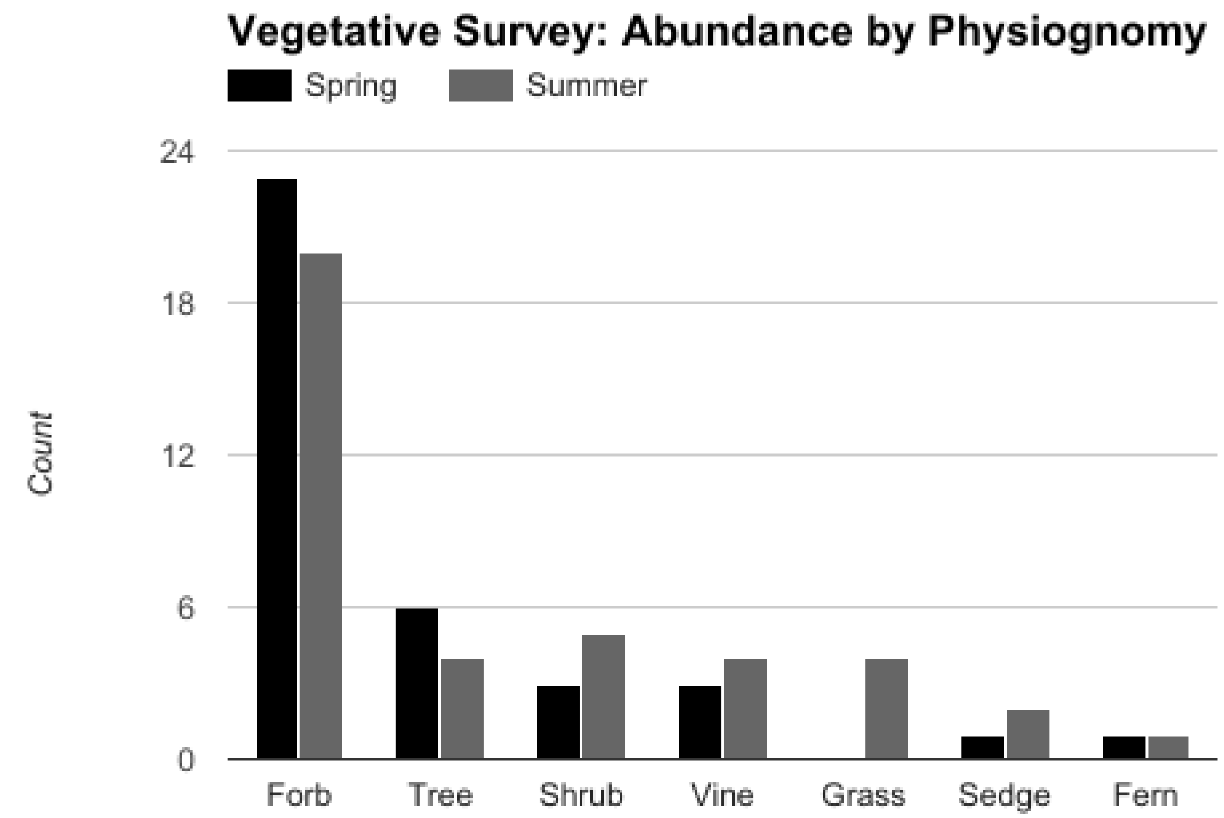
| Total FQI | Native FQI | Adjusted FQI | Total Richness | Native Richness | Non-native Richness |
|---|---|---|---|---|---|
| 16.4 | 19.2 | 31.6 | 37 | 27 | 10 |




65. Freyman, Masters, & Packard. (2016).






In both surveys, the ratio of native to non-native plants was about 75% native, 25% non-native. Observed richness went down in the summer survey, likely because many quadrats in the fallow fields were dominated by a single species (usually Solidago).

Considering that the adjusted FQI of most lands in Michigan where conservation is deemed appropriate is 35, we conclude that our site does indeed have a relatively high quality population of native vegetation, though not as high as a designated protected area.[66] However, because of the large difference between total and adjusted FQI, we suspect that the presence of aggressive exotic plants could pose significant challenges conserving the native plant communities.[67] Our complete botanical dataset is available in Appendix E.

66. Walters, n.d.
67. Corteau (2016), personal communication

# HERPETOLOGICAL SURVEYS

Amphibians and reptiles are recognized as key bioindicators (gauges of environmental health), due in part to their high sensitivity to environmental and habitat disturbances. The abundance and species richness of herpetofauna within an area can reveal much about the health of the ecosystem and can point to habitat quality concerns that may not be detected by other assessment methods.[68,69,70] Overall amphibian and reptile presence, represented age classes, spatial distribution, and relative abundance can be important tools in identifying the need for and success of habitat improvement projects.[71]

Our group enlisted the help of David Mifsud and Herpetological Resource and Management, LLC to carry out two herpetological surveys on the Nature Nurture property. Our team was present at the first survey and were able to observe the protocol.

The two surveys were conducted in May and August of 2016 by biologists trained in the sampling and identification of herpetofauna. Survey techniques including visual observation, aural identification of species calling, identification of potential nesting and basking spots, turning over cover materials, and dip-netting were incorporated to optimize detection success and better depict species richness and spatial distribution. Each positively identified amphibian and reptile was recorded and observation locations were recorded using a Juno SB GPS Unit, which records the location to U.S. Environmental Protection Agency (EPA) Tier II National Geospatial Data Spatial Standards, and mapped using ArcMap 9.3.1®.[72]


Wood Frog


Blue-spotted Salamander

68. Guthrey et al. (1988).
69. Welsh & Droege. (2001).
70. Micacchion. (2004).
71. Herpetological Resource and Management, LLC. (2016).
72. Herpetological Resource and Management, LLC. (2016).



A total of 13 species of amphibians and reptiles were identified on the farm.

| **Levine Farm Observed Herpetofauna** | |
|---|---|
| **Common Name** | **Scientific Name** |
| Bullfrog | *Rana catesbeiana* |
| Eastern American Toad | *Bufo (Anaxyrus) americanus americanus* |
| Gray Treefrog | *Hyla versicolor/chrysocelis* |
| Green Frog | *Rana clamitans melanota* |
| Northern Spring Peeper | *Pseudacris crucifer crucifer* |
| Western Chorus Frog | *Pseudacris triseriata* |
| Wood Frog | *Rana sylvatica* |
| Blue-spotted Salamander | *Ambystoma laterale* |
| Spotted Salamander | *Ambystoma maculatum* |
| Unisexual Salamander | *Ambystoma spp.* |
| Eastern Garter Snake | *Thamnophis sirtalis sirtalis* |
| Northern red-bellied Snake | *Storeria occipitomaculata occipitomaculata* |
| Midland Painted Turtle | *Chrysemys picta marginata* |

Other species known to occur based on communication with property owners, but not observed during our surveys were Northern Leopard Frog (Rana pipiens) and Eastern Tiger Salamander (Ambystoma tigrinum).

Based on the available habitat and current conditions, an additional twelve species not observed by HRM may occur on the site (See Appendix F).


Eastern Garter Snake


Northern red-bellied Snake

# SUITABLE FOREST HABITAT ANALYSIS

To meet our client's landscape management goals, we did an analysis to find the most favorable areas for forest restoration. The study area was the combined 120 acres. We downloaded a satellite photo from eWashtenaw and digitized it to get a binomial shapefile which contained only forest and non-forest cover. To get rid of too many data points, we rasterized and resampled the property to the cell size of 41.91 meters (about 137.5 feet). 192 cells were presented in the final raster layer on the original parcel, 83 of which were classified as forest. 102 cells are presented in the final raster layer on the parents' property, 8 of which were classified as forest. The satellite photo was taken in 2015.

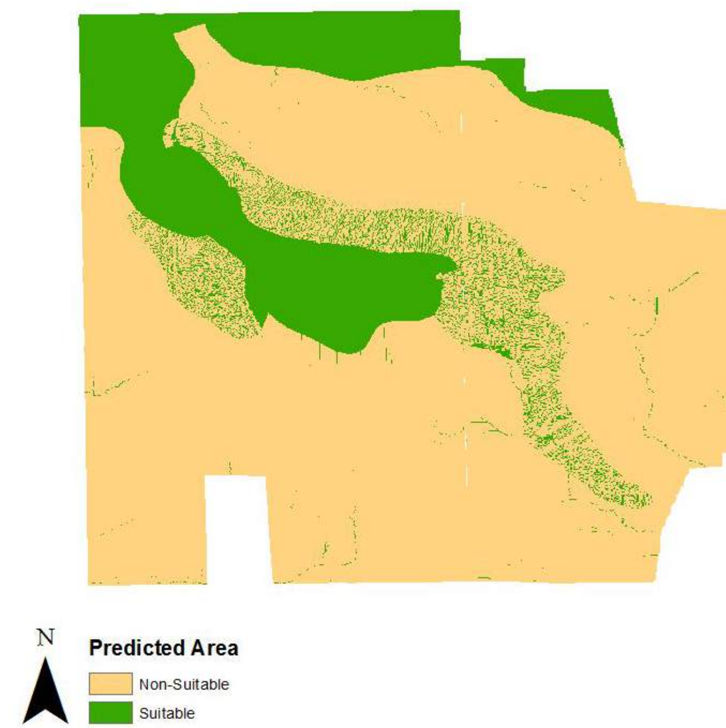
We selected and gathered environmental variables of potential ecological relevance for the distribution of forest. Temperature has comprehensive effects on plant growth, both at the individual level and the community level. It can affect physiological processes of both trees and other competing species.

Temperature also alters frequency, intensity, duration and timing of fire and drought, which is a community or landscape effect.[73] Precipitation provides direct water sources for plant growth. Slope affects how much water is received by one individual plant and can also influence seed dispersal, which is important for forest community composition. High-albedo reflects more energy, which decreases temperature in microhabitats.[74] Available water table measures how much water can be held in soil and topographic wetness index (TWI) indicates how much water one grid can receive due to its topography features. Biodiversity is important especially in seed dispersal, which can be measured by Shannon's diversity index. Elevation is another influential factor that should be involved.

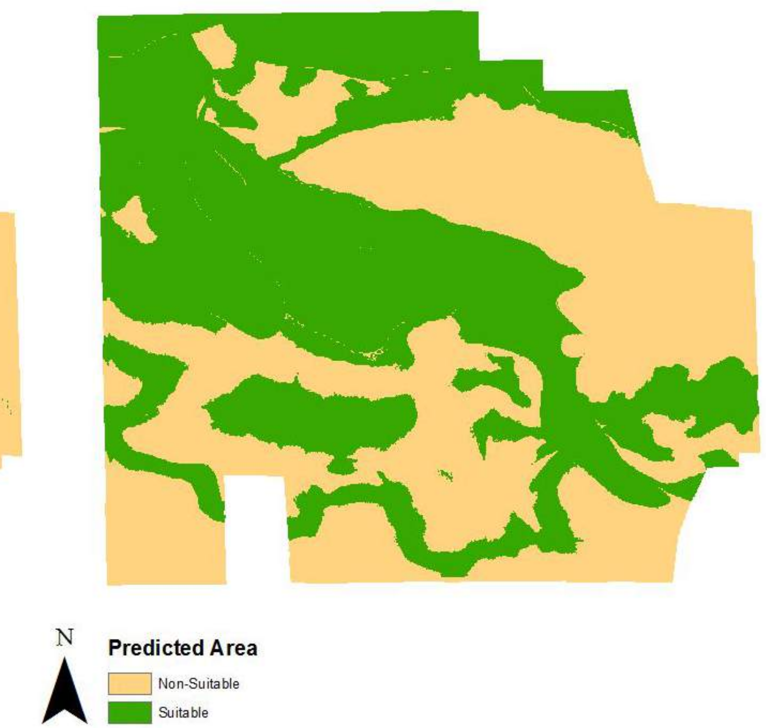
Elevation data was obtained from Clark Data Geospatial Data Server. Then using ArcGIS, we derived TWI data according to elevation. Albedo, slope and available water data came from the USGS soil survey in 2013. Precipitation and temperature data were from the Geospatial Data Gateway in USDA. Biodiversity data was calculated from the survey data we collected over the summer. Resolution of the elevation layer was about 1.92 meter, which was set for all other environmental factors except Shannon's Index. Because we only have 16 points surveyed in the farm for biodiversity, biodiversity data was not able to be incorporated into the final models. We built both a generalized linear model (GLM) and a MaxEnt model. We excluded temperature and precipitation from models because they are homogenized across a larger scale than the farm and differences are not captured by the resolution in our dataset. The generalized linear model was built in RStudio. Maximum Entropy models were built with MaxEnt Software (version 3.3.3k).

73. Dale et al. (2001).
74. Akbari, Pomerantz, & Taha. (2001).






Suitable forest habitat predicted by the GLM model




Suitable forest habitat predicted by MaxEnt

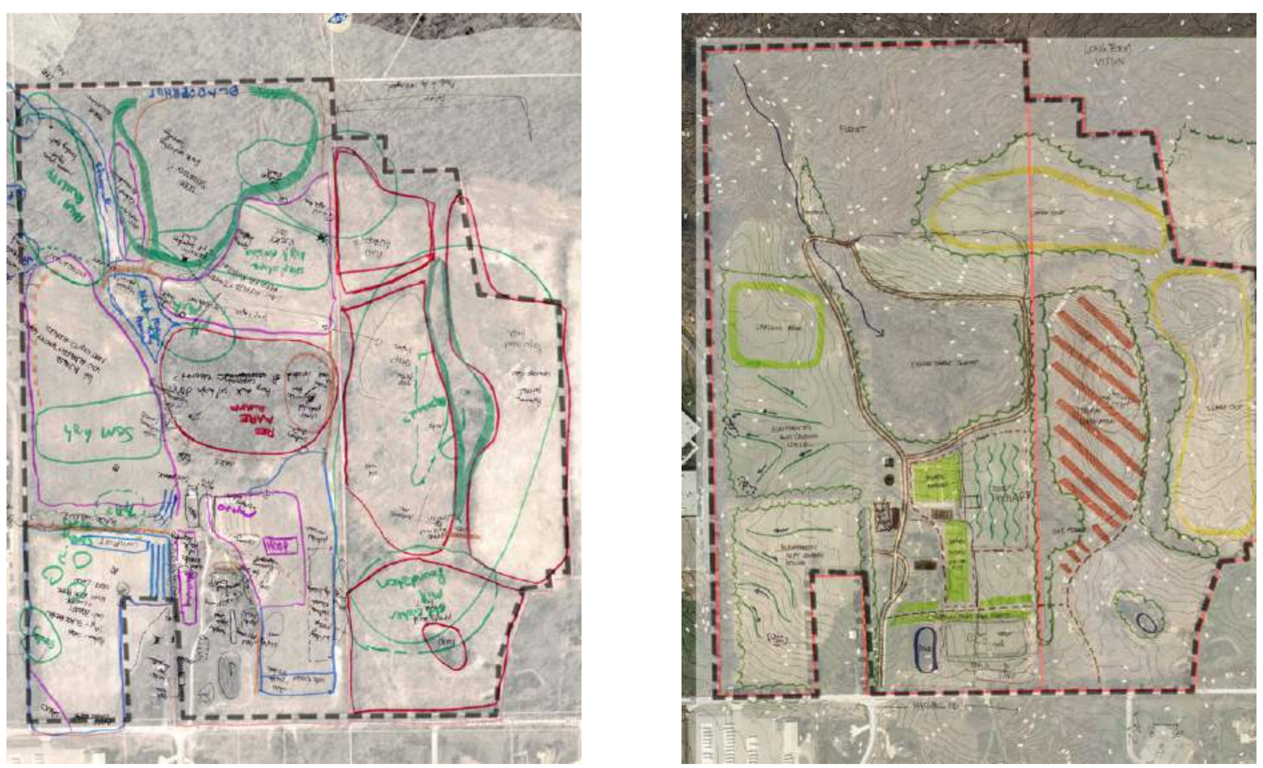
Analysis of variance showed that slope and albedo were significant, TWI was significant to some extent (p-value around 0.1). Removal of other predictors made intercept in the final model significant and decreased AIC scores, which corresponds to better fitness. So we only included slope, albedo and TWI in the final GLM model.

For the MaxEnt model, we included slope, albedo and DEM because it had the highest classification accuracy among all combinations of those environmental factors.

# INTERVIEWS WITH CLIENTS

Naturally, data alone cannot inform design decisions, and must be supplemented with knowledge of our clients' goals. To that end, we relied heavily on participatory design methodology: including our clients and welcoming their feedback at nearly every stage of design development. This was accomplished initially through a series of interviews to clarify their short-term and long-term goals, especially with regards to the nature of their business and their lifestyles. These initial interviews were extremely informative in gathering information on the site's history, as well as current management practices. We also went on several site tours with our clients in order to gain familiarity with the site, but also to interpret how they themselves perceive the landscape and opportunities they see for future growth.

As the project matured, we held a series of design charrettes with our clients, Mr. Levine's parents, and a handful of farm interns. These were open ended brainstorming sessions aimed at identifying existing usage of the site and opportunities to improve the workflow of the site. It also gave us the first ideas at how the space would look in the short and long term given our client's goals. These initial design ideas were refined and critiqued by our team and faculty in the University of Michigan Landscape Architecture program. We then presented these refinements to our clients, and begun a new cycle of design charrettes, critiques and refinement. This process continued for several months, leading up to our final design in the spring of 2017.



Results of design charrettes in September 2016 and March 2017



# CASE STUDIES

During the first few months of our project, we searched for precedent farms and extracted as much information as we could through internet searches. From these efforts, we created a short list of farms that we were interested in touring and talking with the owners. The farms we selected as case studies had a similar climate and/or a commitment to utilizing the practices of agroecology. Moreover, we selected a variety of farms at different levels of development, in order to capture how strategies change over time, and how that can be transferred to our client. We present four in-depth case studies in this report, based on our research and personal conversations.

Between June 16-19, 2016, our team took a trip out to Wisconsin to visit our four case study sites. We toured the farms and properties and conducted interviews with their owners concerning best practices, tradeoffs, problems they have encountered, and possibilities of integrating various site elements. Prior to visiting the farm, we created a semi-structured qualitative interview guide.[75] A semi-structured interview begins with a set of open-ended guiding questions, but allows for flexibility and natural flow of the conversation. We conducted four interviews and tours lasting about 1.5-3 hours each with Mark Shepherd of New Forest Farm, Peter Allen of Mastodon Valley Farm, Eli Utne and Drew Slevin of Lily Springs Farm, and Dennis Fiser of Regenerative Roots. The tour at New Forest Farm was open to the public with around 20 other attendees, while the other farms offered us private tours.

Our interview guide was based on the following questions. First, how does the owner/farmer manage their farm? What was the design process that led to the current landscape and farm enterprises? What does the owner/farmer think "sustainability" means in the context of their farm? What experience or advice could they offer to educate us prior to the final landscape design in our project? How can we use design to best increase our chances for success and long-term sustainability?

Our experiences during our interviews and case studies helped us to partially answer some of our research questions. For example, when looking at restoration agriculture precedents we considered how other farms prioritize competing land uses such as community outreach, food production, and ecological restoration. We assessed how they strike a balance between economic profit and environmental concerns This assisted us in recommending ways for Mike Levine and Erica Kempter to structure their land to make the best use of it in the variety of ventures they wish to pursue.

*Note: The statements expressed in this section are based on the authors' experiences and opinions, notes from the field, and information published by the case study subjects on their business websites.

75. Patton. (2002).

# LILY SPRINGS FARM

**Date Established:** 2015; land owned for more than 30 years

**Owners/Farmers:** The land is owned by Utne family, business operated by Eli Utne, with farm operations managed by Drew Slevin.

**Location:** Osceola, WI

**Size:** 100 acres

### Economic Model and Market

There is a farmhouse and other spaces on the farm that are rented out throughout the summer. Nearly all of the income at this moment is coming from the rental space, through reservations made on AirBNB and Hipcamp. Many of the renters are from the Twin Cities metro area or know the farm owners personally, and have become regular visitors. There is a centrally located 40 acre spring fed lake that the rest of the property is based around. There is about 10 acres of red pine forest containing recreation biking and hiking trails. They do not yet have a market for crops or food because they have not started harvesting regularly. In the future, some income will likely be derived from 3 acres of u-pick berries and harvesting the 7 acres of hazelnuts. Labor is low, with a single employee working full-time plus a few large-crew volunteer workdays. There is currently personal money and credit being invested into the company. The land has been owned by the Utne family for more than 30 years, but only recently has the family invested money to restore the property and fuel the business.

### Ecological Practices

Lily Springs wants to heavily prioritize perennials as their main agricultural crops. Hybrid hazelnuts, Aronia, currants, asparagus, raspberries, wheatgrass from the Land Institute, and wine cap mushrooms are some of the primary species being included in the management plan. In 2015, Lily Springs Farm tilled and turned the soil for the first time in over 30 years of ownership; they spread many tons of manure from a local dairy and set up their hazelnut field. In 2016, they pressed rows of perennial wheat grass cover crop to create a mulch to plant the asparagus.

Eight male goats are used as land managers in the red pine forest. The Boy Band, as they've been called, are helping to control the invasive growth of Buckthorn (R. cathartica) and Poison Ivy (T. radicans). They are moved around every few days in temporary paddocks, then kept in a permanent area during the winter. The goats are protected by Aldo, an Anatolian Shepherd/Maremma. Their full-time employee, Drew, lives on the farm and watches over the goats all year.

Lily Springs attempts to model a full spring-fed lake ecosystem. In their plans, they promote perches for predatory birds such as hawks. They are attempting to manage the land to mimic an oak savannah on the portion of their property currently established with red pine, even if it means reduction in farmland area. There is a colony of bees on the farm, in partnership with a group called Pollinate Minnesota.



### Outreach and Education

Lily Springs Farm's mission statement reflects their goals related to outreach and education, "We are partnering to build an education and demonstration farm using permaculture design to restore habitats to health and build a perennial-based food system that integrates land and people." Eli Utne travels frequently as a means of promoting the business and fostering educational opportunities. Lily Spring Farm hosts an annual festival in collaboration with Eat for Equity, a non-profit that raises money for charitable causes. Lily Spring has also worked with the Minnesota Science Museum youth employment program, and hopes to host educational camps for marginalized populations. The permaculture designer for Lily Springs has taught PDC's in the past. They offer tours to all sorts of groups to share their work and progress on the property. Our group was happy to be one of the first groups to receive an official tour of Lily Springs Farm on the "people mover," a trailer towed behind the tractor with wooden bench seating.

### Farm Design

Lily Springs worked with Lindsay Rebhan of Ecological Designs, formerly Ecological Gardens. The owners promote the principles in One Straw Revolution, in the sense that they look to nature to find solutions to their problems. They summarize their use of permaculture as a means to "maximize hammock time."

### Take-aways for Nature and Nurture

Alternative forms of income, through rentals in the case of Lily Springs, can help support long-term investment in perennial agriculture. There can be a large value in brand-building and promotions. Spaces for public gatherings and events build community around the land. The "people mover" attached to the back of the tractor is a fun way to give group tours. The time-lapse camera overlooking the perennial wheatgrass is a unique visual tool. Due to Lily Spring's unique familial investments in the land and their lack of debt, it is difficult to make business plan comparisons with our clients' farm.

Lily Springs has a long-term master plan for their farm area and a detailed keyline plan.

Visitors camp and celebrate community at the annual Wild Springs Fest.

# MASTODON VALLEY

**Date Established:** 2012

**Owners/Farmers:** Peter and Maureen Allen

**Location:** Viola, WI

**Size:** 100 acres

### Economic Model and Market

Meat is the major product they provide for sale. Meat can be bought in different ways, e.g. raw meat or manufactured products like sausage and beef jerky, either online, at a local farmer's market, or through a CSA. Other foods like bone broths, summer sausage, jerky, lard, poultry, eggs, mushrooms, vegetables, fruits, nuts, and honey are also available.

Another source of income is design and consulting services for local property owners. They also teach a Permaculture Design Course every summer. Mr. and Mrs. Allen avoid debt by purchasing items on zero-interest or low-interest credit cards and then paying off the balance when they have more funds (such as after market days). They have developed a five year positive cash flow plan with profits coming after 3 years and are on track with their model.

### Ecological Practices

Mr. Allen is interested in restoring the existing second growth forests to their historical vegetation type: savannas – scattered groves of fruit and nut trees and shrubs among continuous grasslands that are rotationally grazed. The farm provides habitat for many wildlife and endangered species. In addition to grassland species, perennials such as oaks, pines, aronia, asparagus, chestnuts, hickory, mulberries, apples, cherries and hazelnuts also grow on the farm. Rapid grazing followed by long rests allow the grasses, flowers, shrubs, and trees to continually and sustainably regenerate soils with organic matter. The Allens use a no-till system in order to sequester carbon below-ground. By maintaining continuous perennial grassland, they allow all the rainwater to percolate through soils, into groundwater reserves, thus reducing the flooding waters that often originate on upland crop fields.

Through these management practices, ecosystem services provided by Mastodon Valley include: carbon sequestration, biodiversity, purified water, habitat and enhanced soil fertility/quality.



### Outreach and Education

One of Mr. and Mrs. Allen's primary means of providing education is through the Mastodon Valley Permaculture Design Course. The farm owners also assist with land assessment and farm design as a form of outreach, encouraging perennial agriculture and development of grazing plans for other sites. The Allens are renovating a barn on their property to serve as a classroom and educational space.

### Farm Design

The farm is not "designed" per se, but is very flexible in order to accommodate animal rotations. The Allens live in a small home built by Mr. Allen on their property. They are "off-the-grid" and get their water from the spring on their farm. They have plans for re-purposing an existing farm building into an education center with internet and electricity to house their permaculture design courses. They faced zoning challenges on their land (need to be compliant with living quarter size and septic equipment) but worked around them by purchasing a camper.

### Take-aways for Nature and Nurture

The farm provides different options of purchasing meat, like bundles, which makes it more convenient for customers. This should be helpful to facilitate meat sales. Their cooperation with Mark Shepard strengthens their local influence on farms. Their website is concise but has sufficient information for both customers and visitors. Careful timing of every step in their rotation is critical for operating the farm. Educational and consulting services also build their reputation, which is helpful for sustaining their business. Tight connection with the community stores is another advantage for cash flows. Providing peripherals can be attractive for younger customers. Like other farms, they have several sources of income and strive for collaboration with other local farms.

The farm includes rollings hills, a spring, and meadows.

Peter explains his rotating paddock system and diversity of animals.

# NEW FOREST FARM

**Date Established:** 1994

**Owners/Farmers:** Mark and Jen Shepard

**Location:** Viola, WI

**Size:** 106 acres

### Economic Model and Market

New Forest Farm enjoys an extremely diverse cash flow, though it relies heavily on debt and savvy business dealings. Early on, Mr. Shepard made his income through wholesale vegetable sales, selling row crops and annual vegetables (~15 acres of cultivated land), raising cows and pigs for meat, and also took on several part-time jobs. As the farm grew, Shepard decreased the amount of annual vegetable production, and shifted toward selling perennial crops, nursery stocks, and focusing more on developing his farm for selling meat and produce. The Shepherds' income is also supplemented by Jen Shepard's massage therapy business. As Mr. Shepard began to gain notoriety, selling vegetables and nuts became a smaller part of the business, and his income relied more on teaching/consulting, pigs, book sales, tours, and nursery stock. The main crops from the farm are still annual vegetables, especially asparagus, which are sold to local CSAs. The Shepards have acquired a lot of financial debt, but that does not seem to perturb them. They essentially buy up land, redevelop it into an agroforestry system and sell it with the Shepard brand. They use the profit to buy another piece of land and repeat the cycle. Mark has developed an interesting partnership to grow and sell woody plants. He collects hazelnuts from his farm and gives them to a greenhouse at no charge, which the greenhouse will then propagate at a very low rate. The catch is, Mr. Shepard guarantees that he will buy back every single rootstock, albeit well-below the market rate (since it is still profitable for the greenhouse, too). Then, he resells the the hazelnut rootstock at market value, generating a handsome profit.  He also belongs to an energy CSA to offset operating costs.

### Ecological Practices

Shepard is famous for his hazelnut production, along with chestnuts, pinenuts, elderberry, Aronia, Seaberry, and a number of other fruiting shrubs. These are mostly sold through the nursery wing of his business: New Forest Enterprises. Mark also runs a design/build firm, Restoration Agriculture Enterprises.

Shepard relies on selling beef cows, pigs, and chickens. These animals eat extra nuts and fruits on the farm, and as part of a grazing system (rotating between pasture fields, between alleys of perennials). Animals are put in paddocks but left to their own devices, and then fed regularly with supplemental feed - perhaps by Shepard or by others. The cows are cared for by enterprise partners.



### Outreach and Education

Mark Shepard has gained a reputation for broad scale perennial food production, and because of this image is able to give several group tours on the farm, speak at conferences, and teach at classes given across the country. He quite literally wrote the book on restoration agriculture: "Restoration Agriculture: Real world permaculture for farmers" which is widely read and is the magnet drawing people in for tours and classes. Unlike many farms, he does not rely on interns or apprentices. Instead he rents out land and equipment to people interested in developing their own enterprise. Further, he hires seasonal employees, especially for vegetable production.

### Farm Design

The layout of the farm was first determined by strategic placement of low grade swales (~1%) to transfer water where Mr. Shepard wants it to go. He then set up alleys along the swales and ponds of woody crops. He employs his STUN method of sheer, total, utter neglect. Basically, this minimal approach to plant care ensures that crops are well-suited for his site. Today, he presides over a diverse suite of crops ranging from fruiting shrubs to conifers, to large chestnut and oak trees, with a mix of animals including chickens, cows, and pigs.  Among the ecosystem services provided by this management are: carbon sequestration, biodiversity, pollination, habitat/refugia, and enhanced soil fertility/quality.

### Take-aways for Nature and Nurture

Mr. Shepard, arguably, is not primarily a farmer.  He is a consultant, teacher, and land developer above that. He sells a lot of vegetables and pigs, to be sure, but he doesn't sell the nuts and acorns on his farm nearly to the degree that he suggests. The Shepards are okay with being in debt, but have a reliable brand. Mr. Shepard bought life insurance to get rid of the debt upon his death, and now his kids all have great farmsteads across the country. Our study of New Forest Farm suggests that having a diversity of income sources is key. Fortunately, Nature and Nurture already has several such enterprises, and should work to keep them viable or expand them as needed. Collaborating with other businesses and cultivating relationships is also important. Of further interest is the Shepard strategy of letting entrepreneurs use land and equipment to set up their own business in a way that is mutually beneficial. Nature and Nurture currently has a farm internship program, but exploring other means of involving people with the farm could be useful.

Mark Shepard explains his farm design and business to a paying tour group.

New Forest Farm nested within a landscape of conventional agriculture.

# REGENERATIVE ROOTS, LLC

**Date Established:** Moved to current property in 2013.

**Owners/Farmers:** Regenerative Roots is a limited liability company (LLC) owned by seven people, three of which live at the farm. The organic vegetable production is overseen by Dennis Fiser and Anne Drehfal.

**Location:** Jefferson, WI

**Size:** 30 acres

### Economic Model and Market

The LLC is composed of people with a variety of farming-related interests that came together with their own enterprises. They are particularly interested in promoting good quality of life, holistic management, and community education. 70% of gross income for the LLC comes from the 2-acre certified-organic vegetable farm. Direct to customer and wholesale meat rabbits (on 6-acres of pasture) and a small seed business also provide income. Income distribution and benefits were laid out in the original creation of the LLC, and each original partner contributed differentially to the founding of the company. The farm is economically profitable due to their low overhead costs, which they minimize by using human labor, creating partnerships with other local farmers (using manure as fertilizer, etc), using passive solar heat in their greenhouse by using large drums of water as a heat sink, and limiting the size of their farm. Regenerative Roots has a 20 week (+ 2 fall delivery dates) certified organic CSA which composes about 1/3 of their business. They also sell at local farmers markets (1/10 of business) and wholesale to a co-op in Madison (½ of business). The meat rabbits are sold direct to customers and also wholesale to restaurants.

### Outreach and Education

Regenerative Roots is interested in partnering with and incubating other farmers and creating a larger farming community. They interact with their CSA members through monthly or bi-monthly workdays and farm dinners. They also offer permaculture design services and courses as well as farm tours.

### Farm Design

No overall design masterplan is present. They have been implementing things as they go based on management concerns. Overall the farmers are flexible and keep their options open.



### Ecological Practices

The 1.5-acre berry orchard is currently unmanaged but they hope to garner interest from other farmers to take it on. Perennial fruit bearing trees and shrubs like Aronia and hazelnuts are located in the orchard and near the house. There are also perennial pastures throughout the property and oak trees were planted but have not been very successful due to plant spacing and management. The 2-acre organic vegetable fields contain living aisles of cover crops such as clover. These aisles provide nitrogen to crops, attract pollinators, cool the soil, and act as windbreaks during storms. Meat rabbits are bred and sold on the farm. They also are very efficient foragers and eat thistle and other weedy plants. When we visited, Regenerative Roots had a partnership with a nearby sheep owner. The sheep were kept on their property in the summer where they grazed the pasture and provided manure. The vegetable field is certified organic and there are no chemical fertilizer or pesticide inputs. The farmers also supplement the soil with cow manure. The only heavy machinery they use on their property is a two-wheeled walk behind tractor, so the soils are not heavily compacted. After a few years farming the vegetable fields, the farmers plan on returning that area of the property to pasture and rotating the location of their vegetable crops.

### Take-aways for Nature and Nurture

Their business set-up and collaboration with other local farmers has really diversified their business and allows them to create a more holistic enterprise. The animals on the farm are cared for by people other than Dennis and Anne, although it seems they take some sort of responsibility for rotating them or training them to eat certain weeds. Partnering with more local businesses and co-ops could make up the majority of produce markets if a CSA is not desirable. One of Regenerative Roots' main philosophies - not expanding beyond their means and remaining small spatially, may not be applicable to Nature Nurture in the spatial sense, but could apply when thinking about working on and perfecting current enterprises before diversifying too much. Their living aisle system seems to be productive and manageable for them, in addition to providing a myriad of ecosystem services, and is a design strategy to consider for our client's property.

Annual vegetables are inercropped with nitrogen fixing plants.

Partnerships with other farmers brings animals to the farm.

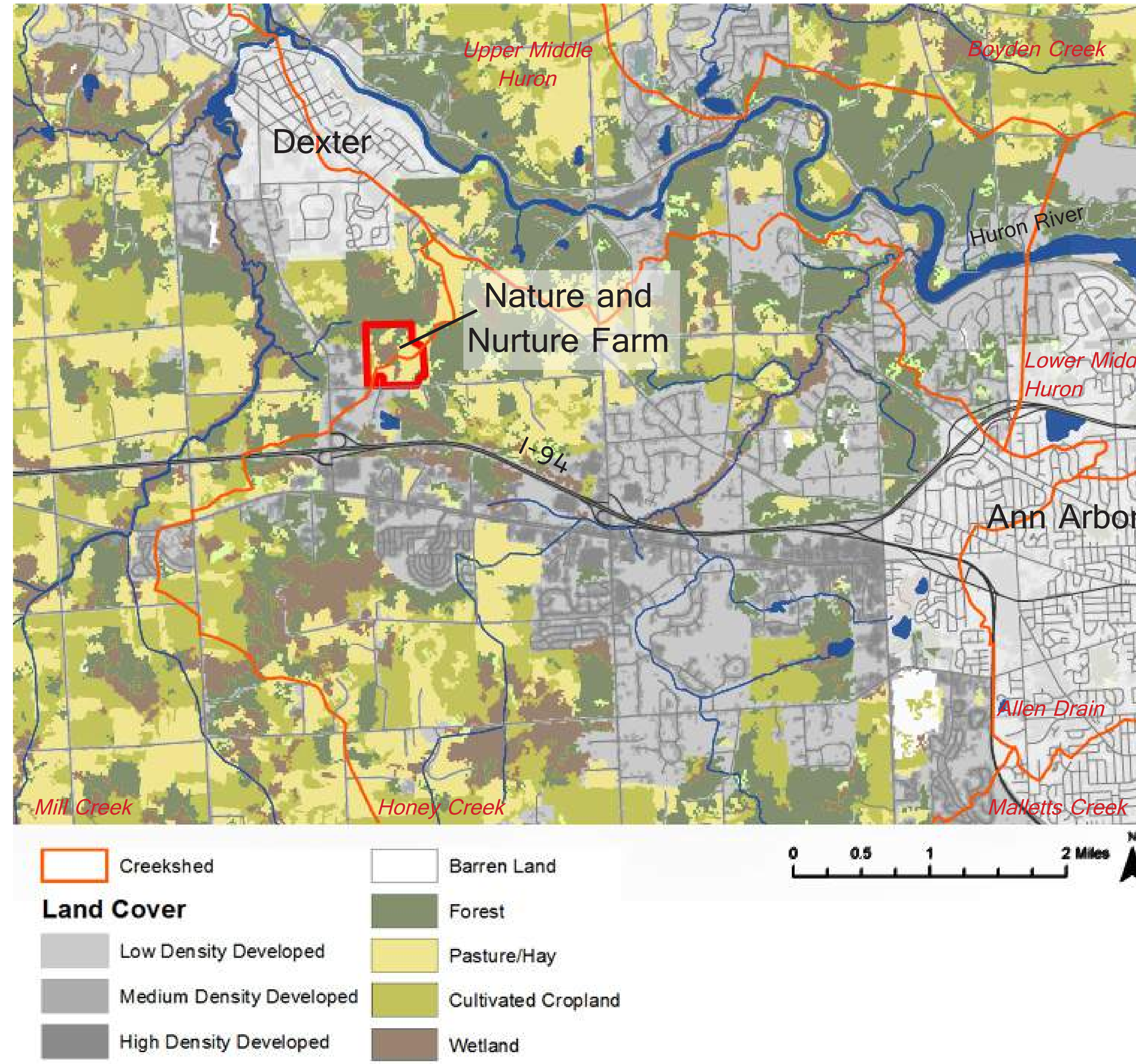
# CASE STUDY ANALYSIS

One common theme among our case studies is that they sell produce via CSA and direct-sale markets. Moreover, the four farms all had a diversity of income sources, including educational outreach. Costs were cut in a number of ways, from communal ownership of land (Regenerative Roots) to using local biofuels to lower the cost of farm operations (New Forest).  Labor was varied across our farms, but none of them relied on the typical intern and stipend arrangement.  The closest approximation to that was Mr. Shepard's farm, which employs seasonal interns, but prefers to form co-enterprises with people and rent equipment and land. Regenerative Roots insists on paying a living wage to their workers, but cannot employ people year round. However they hope to increase their employee count as they bring their berry orchard into production. They also host volunteer workdays. Another common theme was the use of livestock for management, all of the farms used animals as part of their overall soil and ecological management, and two of the farms actually sold animal products to derive income (Mastodon Valley and New Forest Farm).  All of the farms were actively engaged with other farmers to form partnerships.

In terms of finance, the farms we visited ran the gamut from being very fiscally conservative, and insisting on staying out of debt (Mastodon Valley and Regenerative Roots), to those comfortable with using debt as a means to keep their business afloat (New Forest Farm).

# SITE CONTEXT

Nature and Nurture Farm is located five minutes south of Dexter and ten minutes west of Ann Arbor in Scio Township. It is surrounded by a variety of land uses, predominantly other agriculture. The property itself is located within two creeksheds of the Huron River.



# EXISTING CONDITIONS

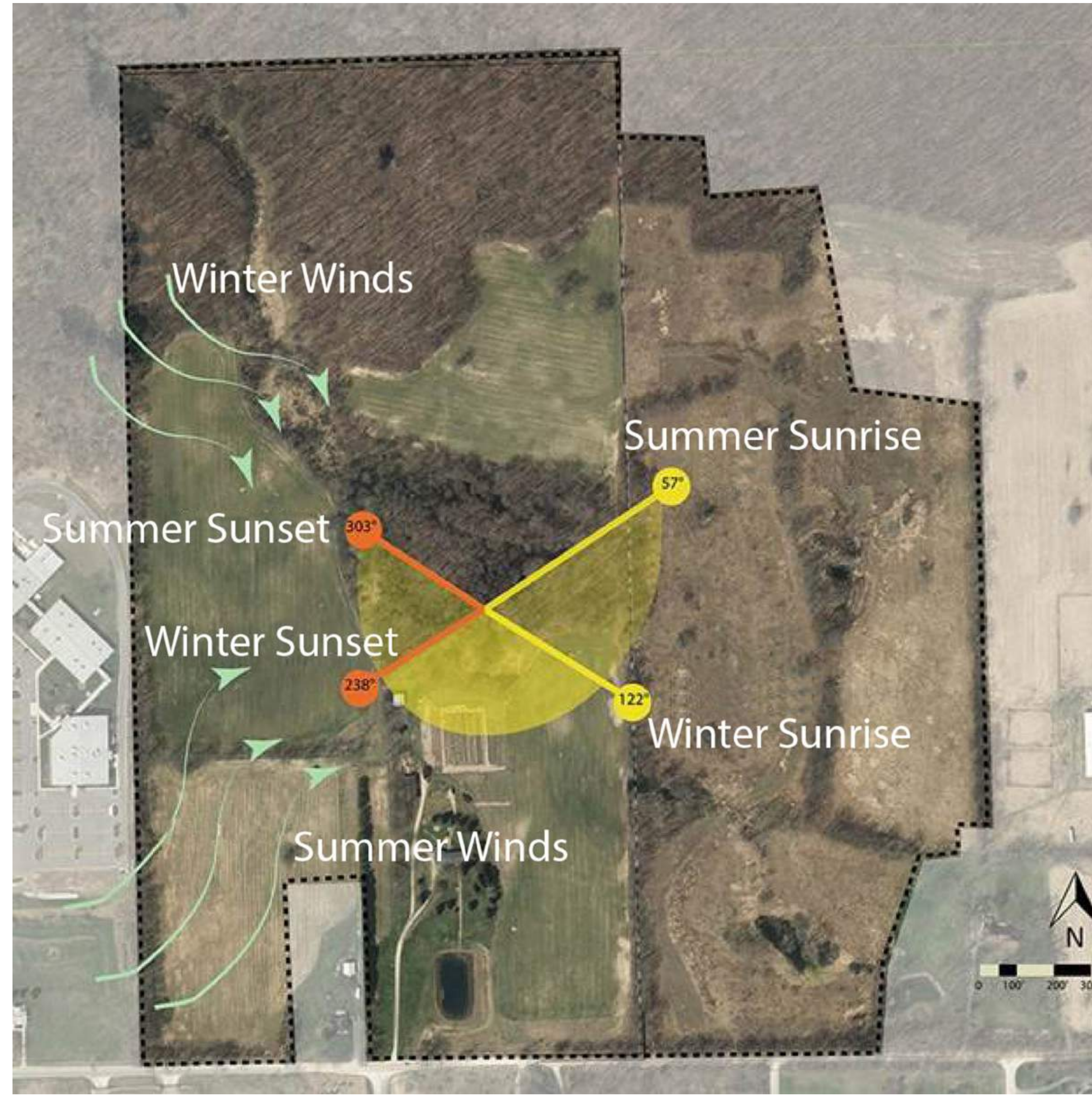
Mr. Levine and Ms. Kempter co-own a lot that is 80 acres, with 60 of those acres put under an agricultural easement. There is a 40 acre parcel of property adjacent to the east which, fortuitously, was purchased by Mr. Levine's parents. Our clients have essentially free reign over the parents' land, and in fact wish to connect the properties with a road. As such, we treated the site as a whole, totaling 120 acres. Aerial imagery shows that the site has had a very consistent landscape since at least the 1950's. The fields that exist there now have been conventionally farmed since then, and the forests and swamps on site have not been disturbed or drastically altered. In the early 2000's the parents' parcel was slated for the development of condominiums. The project was abandoned because of the 2008 recession, though the initial grading for the driveway is visible on site.

# SITE ANALYSIS

Any landscape design must begin with a thorough understanding of the land, and our project is no different. In addition to the ecological surveys, we conducted a site analysis typical to the practice of landscape architecture. This was done in part with conservations with our clients as well as independent research of general climatic trends.

# CLIMATE

Prevailing winds are from the west, oscillating between northwesterly winds in the winter, and southwesterly winds in the summer. Certain areas of the farm are more exposed than others, and our clients specifically mentioned how harsh the northwest winds in winter can be. A few windbreaks have already been planted, however additional hedgerows and forested areas could help buffer production areas and community areas from harsh gusts. A temperate climate site, the farm experiences yearly temperatures of 20°-90° F. June, July, and August are typically the hottest and wettest months.

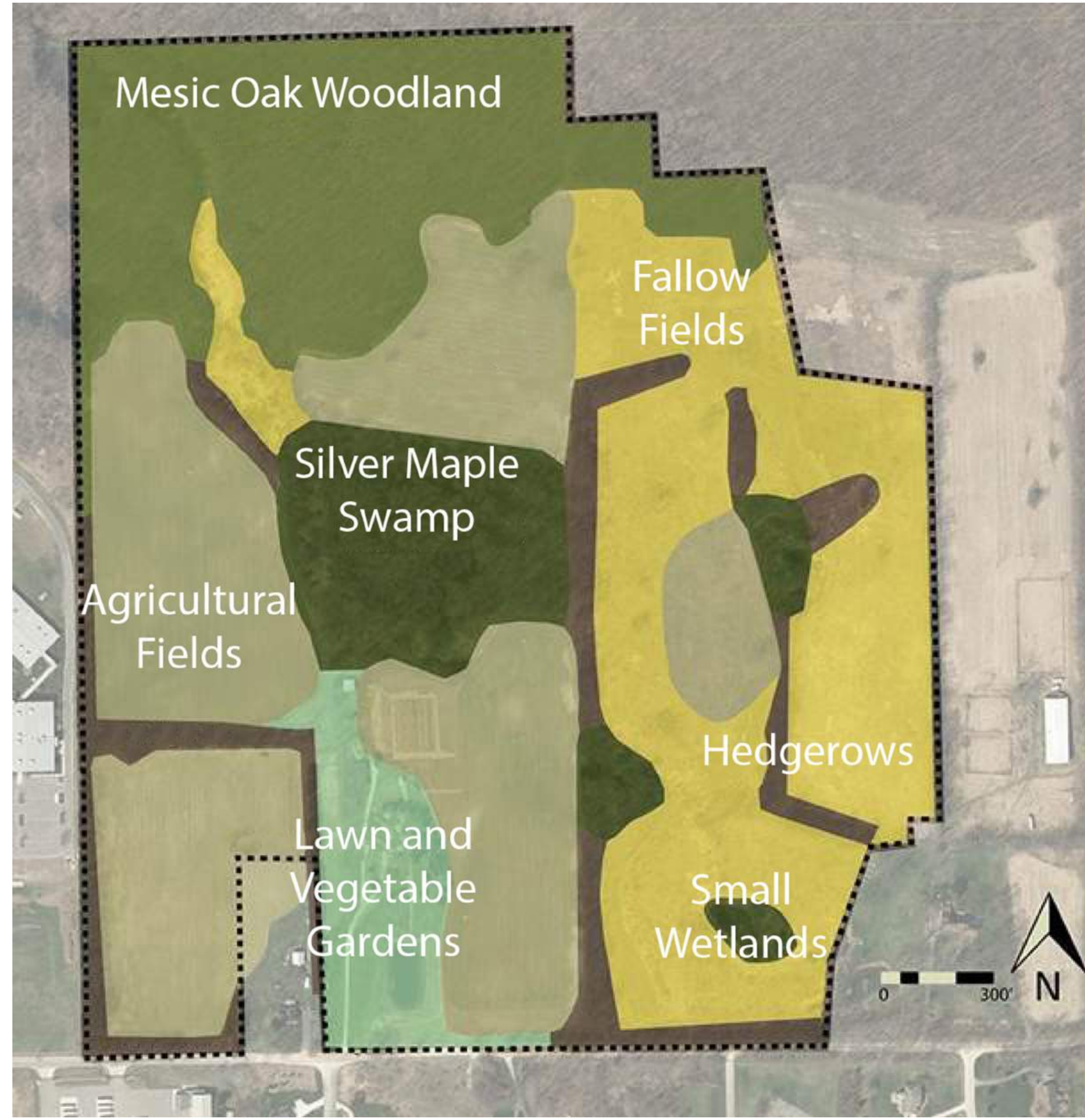


# HYDROLOGY

The property is topographically complex and contains multiple low areas where water collects. Ecologically, this makes for ideal conditions for patches of wetlands and several vernal pools which are dotted across the landscape. The swamps in the northwestern woodlands are present all year round and host a suite of wetland vegetation, especially Buttonbush (Cephalanthus occidentalis). However, in some steep areas, rainwater runs off relatively quickly and erosion is a problem.  This is especially true in the agricultural fields where soils have been compressed through tractor usage. There are a few sites, especially around the house where the soils are not particularly well draining, and spring melts can cause minor flooding and conditions that do not allow for tractors and other vehicles to pass through.

# HABITAT

There are a multitude of habitat types present on the farm that support a diversity of flora and fauna, as demonstrated through our inventory data. The mesic oak woodland in the northwest is particularly high quality, having the highest floristic quality index on the entire site, and the least disturbance since at least the 1950's. Our clients wish to manage this forest as a source of oak logs for shiitake production. In the center of the site is a large silver maple swamp, which has soils with the highest organic matter on the site. This swamp has also been present since at least the 1950's, and has only been lightly used during our clients' tenure on the property. It is currently used as a small space for a children's nature academy. A smattering of small wetland areas are present in the southern and eastern portions of the site. In general, habitat connectivity is good, with windbreaks and hedgerows serving as habitat corridors between the northwest forest, the central swamp, and the small wetlands. Obviously, the large agricultural fields are the dominant land use on the site, though the great majority of the land on the parents' property is fallow fields.



# VEHICULAR CIRCULATION

The property has a gravel drive connecting the Mr. Levine's and Ms. Kempter's house and main production area to Marshall Road to the south. There is also a mown loop around the central swamp that connects the current fields. This is used by the tractor and other equipment. On the parents' property is a remnant of past development. Developers cut the start of a road into the landscape which, after the development was scrapped, is now a sort of ditch running through the property, which is experiencing some erosion. Our clients have expressed an interest in increasing the connectivity between the two parcels via a road. Further, because they sometimes have large deliveries and customers coming to their farm, it is important that vehicles can enter and exit the property smoothly. Lastly, any proposed change in circulation needs to efficient from a production standpoint, allowing workers to quickly access the production areas and buildings, with little chance of congestion.

# DESIGN AND JUSTIFICATION

Our design is a response to the existing conditions of the site, as discovered through our client interviews and ecological surveys, and it is a means to achieve the ecological and business goals outlined at the beginning of the report. Herein, we discuss the justification for the various features of our design, beginning with the large scale view of the property, then zooming in to the landscape immediately around the house.


Buttonbush Swamp
Managed Woodland Oak-Hickory Forest
Creek
Nature & Nurture
Stream
Vernal Pools
Fallow Meadow
Organic Crops
New Canopy Trees Planted
New Canopy Trees Planted
Agroforestry Keyline with Perennial Natives
Perennial Grazing
Silver Maple Swamp
Nature Learning Community Engagement
Agroforestry Keyline with Perennial Alley Cropping
Fenced Intensive Management Area
Prairie Restoration / Seed-bank
Organic Crops
Compost
Wet Prairie
House
Building Envelope - Offices, Classroom
Parents' House
Fallow Grazing Area
Agroforestry Keyline with Perennial Alley Cropping
Wooded Pond
Homestead Area
Perennial Grazing / Oak Forest
Potential Future Development
New Road
Marshall Road
1:1,200
0' 100' 200' 300'
N

# LONG-TERM PLAN

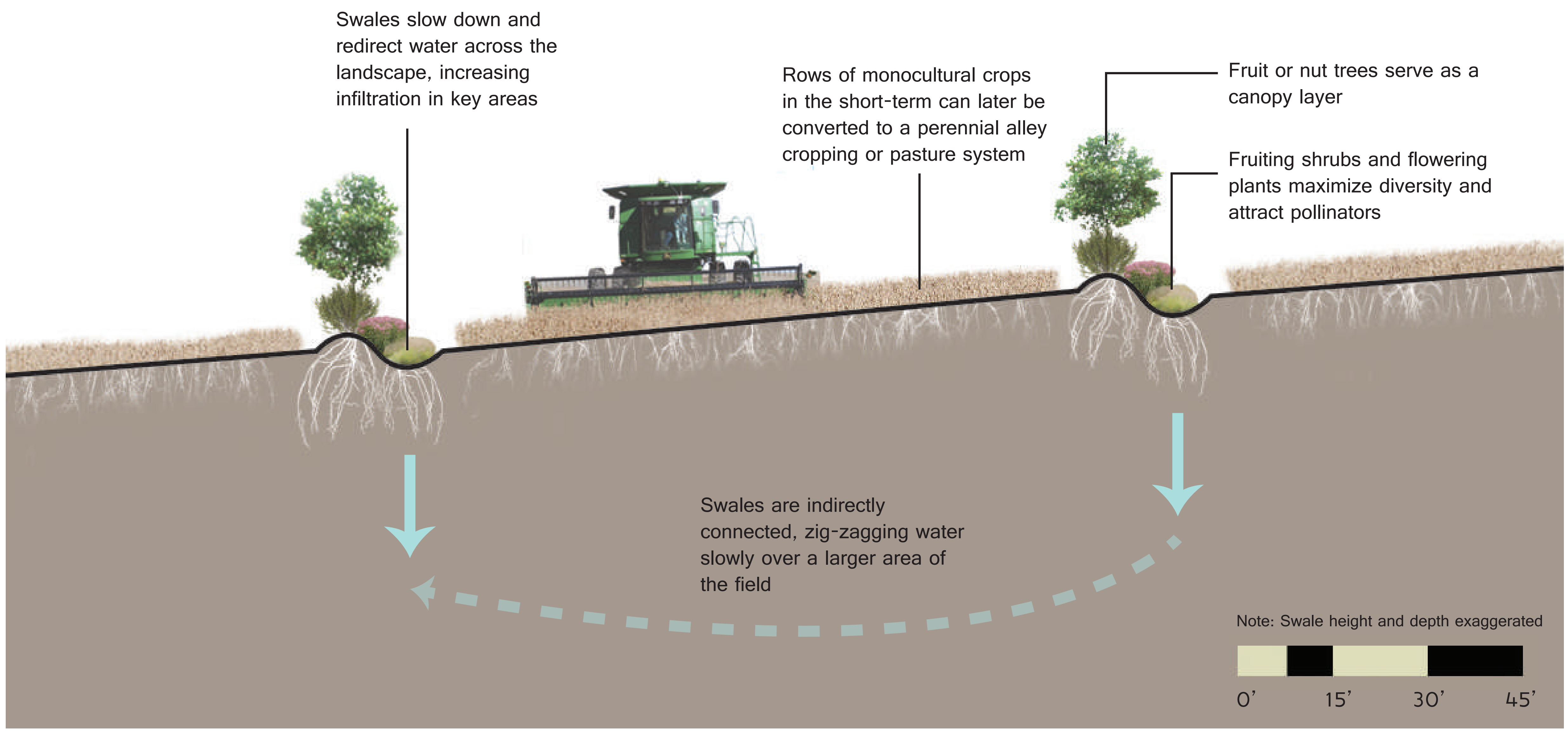



# SHORT-TERM PLAN

# PERENNIAL AGROFORESTRY KEYLINE

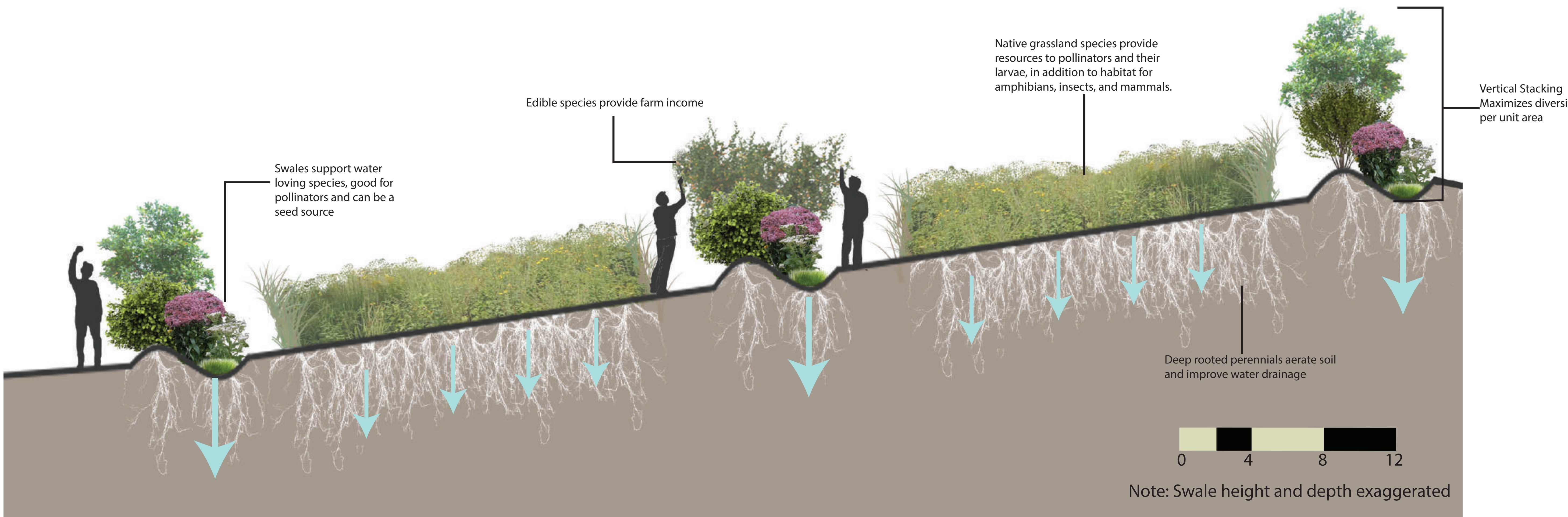
The western-most fields are currently under annual production, oscillating between hay production and leguminous cover crops. The southernmost part of the the southwest field, adjacent to Marshall Road, is buildable land, and our clients hope to one day have a roadside business and educational space there, so we did not engage with that portion of the property. However, the western fields are where we have designed for a transition over to a perennial-based silvicultural system. The swales as we have designed them serve as the backbone for this system, and are designed at a one percent grade to retain stormwater. They are spaced far enough apart such that a tractor can pass easily through the alleys, allowing the current annual production of hay to continue in the short and medium term. However, as the canopy fills in, annuals may become shaded. Therefore, what grasses and plants do remain between the alleys can be grazed as needed. This would provide a spatial opportunity for our clients to collaborate with other farmers in the area.

Moreover, as the space is transitioned from hay production to grazing, the land would no longer require tilling, reducing fossil fuel use, and improving soil biology. The emphasis on woody perennials also entails that atmospheric carbon will be sequestered and organic matter should increase over time. By retaining stormwater in swales, less erosion will occur and the fields will support patches of wet micro-habitats. Also, our design for these systems takes advantage of several vertical layers of vegetation (canopy, shrub, ground layer), implying a greater diversity of crops per unit area. Plant selection by our clients can take advantage of the moisture gradients in the swales, and be catered to maximizing resources to wildlife or income generation, or a judicious combination of the two. In the northern portions of the western field, we propose a large-scale grazing pasture. We wanted to keep this area relatively open, since our clients expressed an interested in potentially using that space for larger public events.



# PRAIRIE KEYLINE

A similar swale system is proposed in the field just east of the silver maple swamp. The slopes here are steep enough to cause erosion and make operating a tractor difficult. Therefore, we have placed the swales much closer together, and the plantings are based on smaller shrubs and trees that would typically be found in the mid to late successional stages of a grassland. As before, the alleys can be planted with native grasses and forbes, and used for seed production or grazing.



# PRAIRIE RESTORATION

To the south of the prairie keyline, we have proposed a large-scale prairie restoration project. A prairie restoration of this scale could be the site of university collaboration, educational classes, and act as a native seed source. Moreover, because this field connects with a large swamp patch and multiple hedgerows across the southern and eastern portions of the property, including many smaller wetlands, having such a large area that is neither tilled nor mown could greatly improve the ability of myriad fauna to traverse different habitat types. Currently, this field is fallow and dominated by goldenrod (Solidago), so diversifying the vegetation would increase the timespan and variety of resources available to wildlife. In the fields to the north and the east of the central prairie field, we propose continued rotational annual crops. These fields are the hardest to access and to manage, and so by leaving them under the care of a partner farmer reduces the time and resource strain on our clients.

Prescribed burn at Lily Springs Farm. Burns can serve as a valuable tool for grassland and forest restoration.



# NORTHERN WOODS

Turning to the woodland in the northern-most portion of the property, our clients have already drafted a management plan with a local forester. The aim of these woodlands is to sustainably harvest oak logs for mushroom cultivation, in addition to conserving the existing vegetation and wildlife there. Our only other recommendation is to manage for invasive species as able, since the high quality herbaceous vegetation would become highly degraded if invasive vegetation is left unchecked. This is an especially interesting part of the site; having escaped cultivation, it offers a glimpse of the baseline conditions of the site, and hence approximates targets for long-term restoration of the site. The central silver maple swamp was similarly part of the forest management plan. Our clients intend to also selectively harvest timber from this site, as well as continue using it as a platform for educational programs.

Select harvesting of oak trees to serve as shiitake logs is one suggestion in the larger Forest Management Plan


Existing Shed
and Corncrib
Existing Windbreak
Intensive Annual and Perennial Agriculture
Mushroom House
Existing Barn
Existing Hoophouse
Proposed
Hoophouse
Existing Windbreak
and Raspberry Patch
Proposed Wash station
Proposed Kiwi
Orchard
Expanded
agriculture
plots
Medicinal and Kitchen
Garden
Existing Nursery
2 acre buildable
land left open for
future building
Native Plantings,
keep open for future
road
Proposed Road
Seed gardens and
annual vegetable
Native Vegetation
and Grazing
Wetland Plantings
U-pick Food forest
Expanded Oak
and Pecan Grove
Proposed Farmstand
and Additional
Parking
0
50′
150′
N

# HOMESTEAD AREA

## ENTRANCE

The area immediately surrounding the house is where much of our clients' productive land is located, and we have built upon the existing usage patterns of this area. But it is also the area with the most interaction with the public as well. Therefore, it is important for our design to meet the ecological and business goals, but also for it to meet the aesthetic expectations of our clients and visitors of the site. With this in mind, we propose a small raingarden at the entrance of the property. A raingarden here can improve the entry to the property, and if our clients are able to restore the vegetation of the pond, using similar vegetation would add a sense of rhythm and harmony to this part of the landscape. Here is where we also propose an entry farmstand and a U-pick fruit and vegetable garden. This would be a unique addition to the Ann Arbor food scene, reduce mowed and tilled area, provide resources for pollinators, sequester carbon, and build up soil organic matter. Further, the existing nursery stock can be used as the first trees to be planted there. South and east of the pond, we have proposed an expansion of the already planted pecan and oak grove, in addition to another grazing area. It is important to keep the area around the buildable land relatively open, so as not to obstruct any future construction projects.


The new entry is a welcoming first look at the Nature and Nurture Farm. A new farmstand and U-pick orchard diversify business practices and build community engagement.



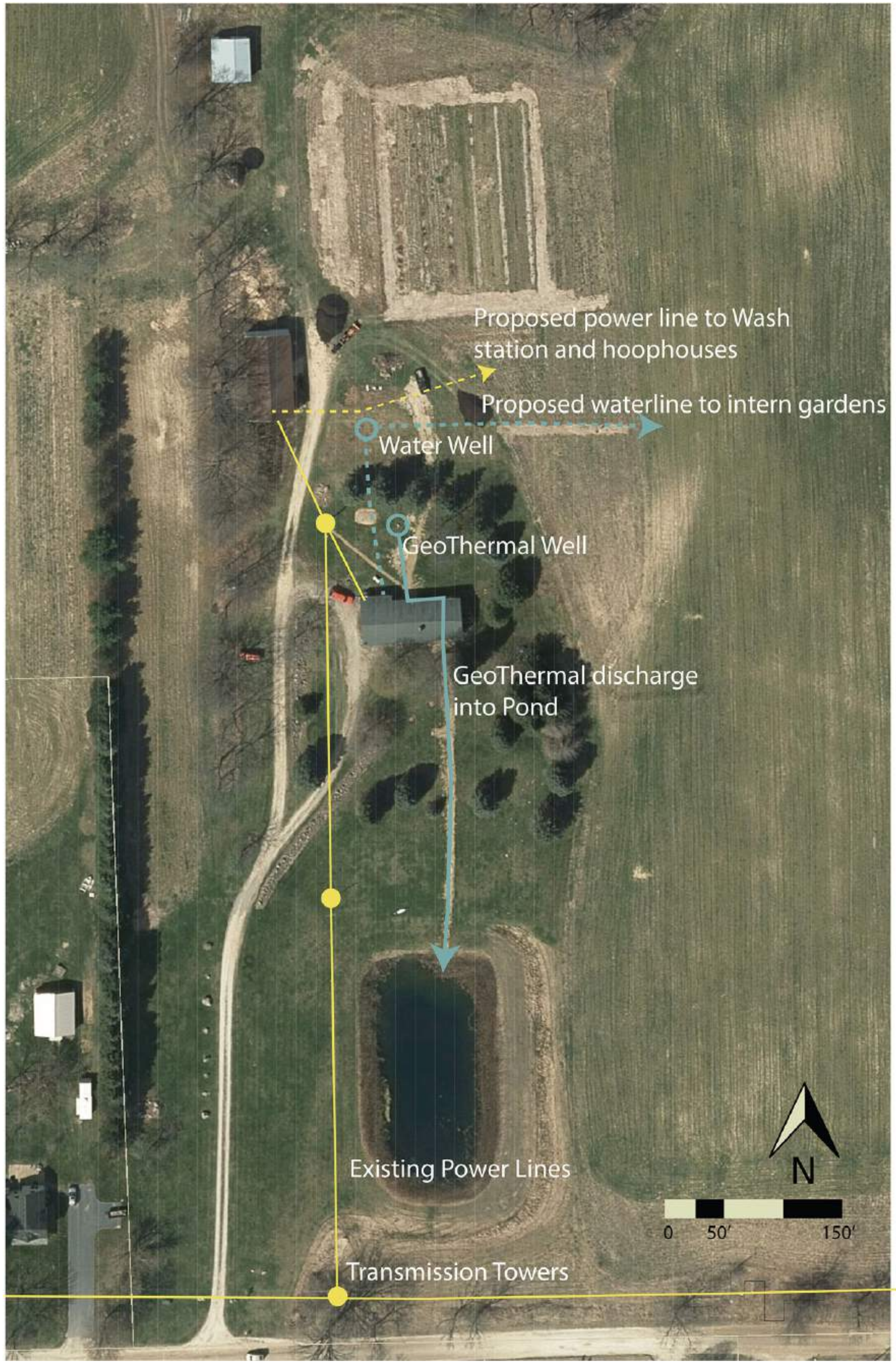
# KIWI ORCHARD

We have also proposed an east-west road that connects the main drive of Nature and Nurture to Mike's parents' property to the east. Not only does this improve circulation and allow trucks and visitors to enter and exit the property without turning around, it provides a backbone for vegetable and seed gardens that would be easily accessible by vehicle. To the east of the house, we have proposed a large expansion of the existing fenced-in area. This would be dedicated to annual and perennial agriculture, primarily for farm employees and Mike and Erica.

Just east of the existing hoophouse, we have proposed two additional hoophouses. One will be used as a shiitake log storage space and mushroom cultivation area, while the other can be used as a much needed expansion for crops that require season extension. We conducted sunshade analyses to confirm that the placement we have suggested would not cause prohibitive shading on the existing gardens and hoophouse. We have also proposed a layout for an orchard of hardy kiwis (Actinidia arguta), a fruit for which our clients wish to become known. The site we have located this orchard on is very sunny and has well-draining soils, both requirements of the hardy kiwi. Additionally, this site is united with the rest of the productive area by an intertwined, yet legible, circulation pattern that allows minimal stops and distance between the productive areas and the wash station that we have proposed.

The new hoophouse and mushroom structure provide additional production space. Together with the kiwi orchard, they define a central hub in the fenced area.

# UTILITIES






# DESIGN ANALYSIS

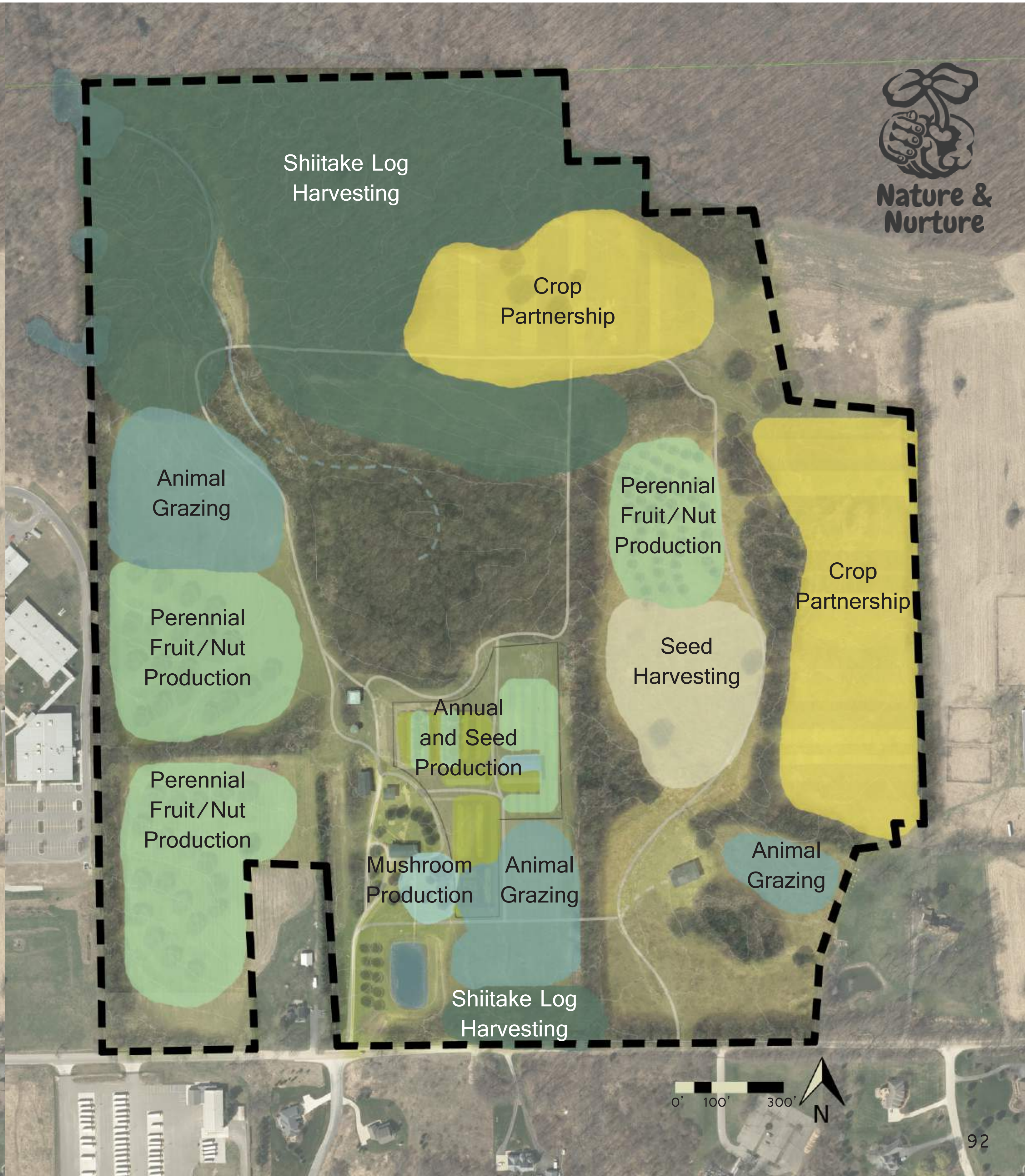
We believe that the increase in edge habitats, the reduction in mowed areas, and connecting the woodlands and swamps to existing hedgerows will improve the ability of populations to traverse the site, especially amphibians and small mammals. By restoring and conserving the existing microhabitats on the site, our plan creates spatial and temporal patchiness, and a relatively undisturbed matrix through which different species can migrate. Moreover, we have laid out the productive areas such that they are separated by either grazing, a hedgerow, or habitat patch, which can slow the spread of pests and diseases across the landscape. Our keyline system will greatly retain the amount of stormwater that infiltrates the site's aquifers, making the site far more resilient to drought. Our proposed prairie restoration and the transition to grazed perennial systems entails a dramatic reduction in the areas of land that are tilled. The prairie restoration could potentially represent the restoration of a highly endangered community, boost the habitat quality of the site and improve soil conditions. This of course means less disturbance to soil ecosystems, less fossil fuel inputs, and less compaction of the soil. The incorporation of animals and prescribed burns (especially in the prairie) supplements the nutrient cycling practices that are already practiced, e.g. composting and use of nitrogen fixers.

These benefits are realized despite the fact that the entire landscape has some sort of income generating feature. Across the entire landscape, nearly every area can be considered to have some agricultural value. Crop partnership continues in the farthest fields, and new areas are opened up to grazing, providing opportunities for renting land, trade or other arrangement. The transition to perennial crops, including kiwis and the vegetation grown in the swale microhabitats will greatly increase the diversity of crops available for sale,making the business more resilient. Even the alleys between the swales and the restored prairie could be harvested as a seed source and sold at native plant sales.

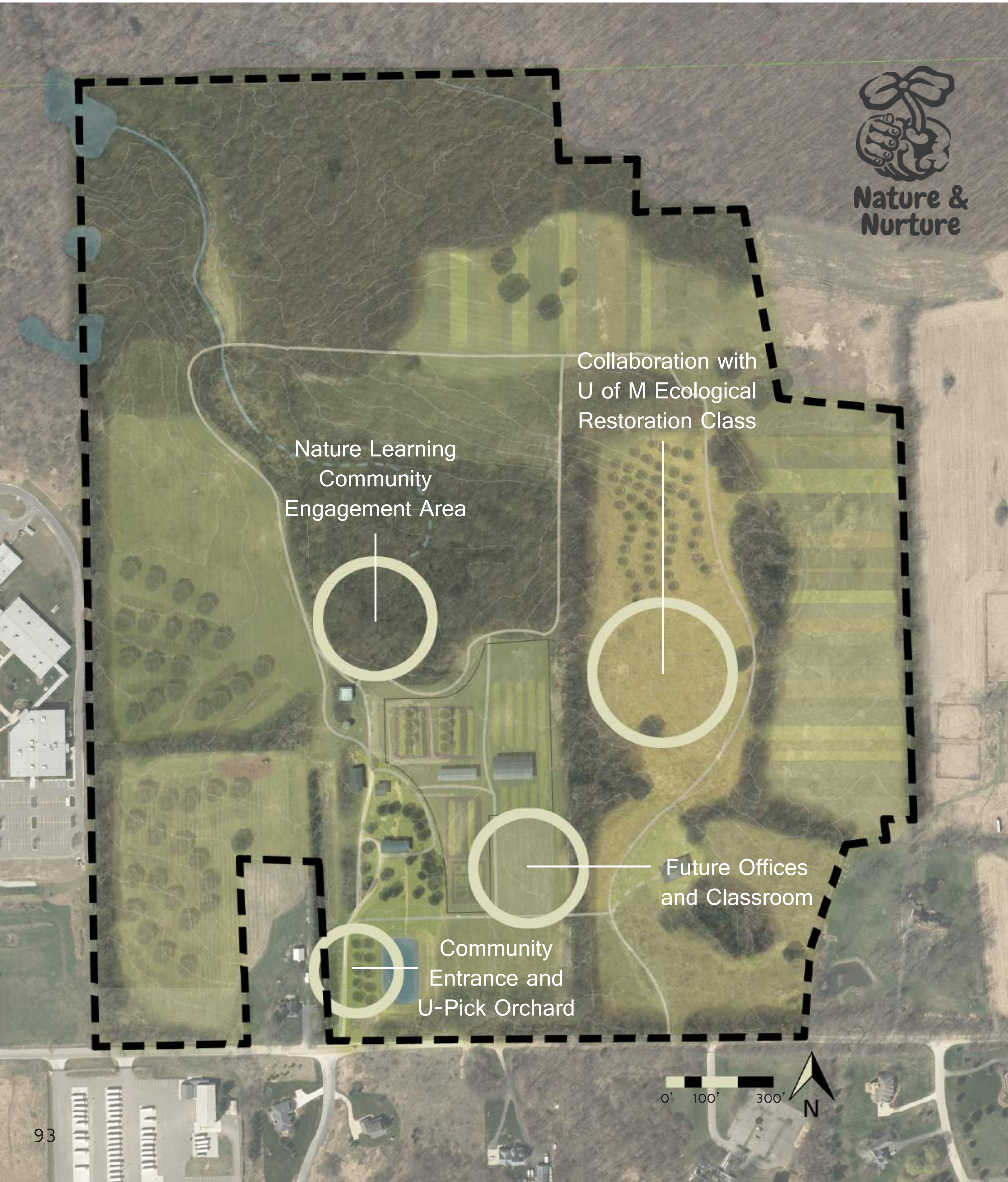
Lastly, opportunities for education, public engagement, and university partnerships are also increased. The practices we have recommended, and importantly, their integration into a single system, is still relatively rare on a broad scale in the area, and so there is plenty of opportunity to hold workshops and classes as these practices become more and more relevant to the food scene. As our clients solidify their visions and needs for a built classroom space, the potential for large groups and extended events becomes a real possibility, even in inclement weather. The entry U-pick food forest would be a unique addition to the local food scene, and with the kiwi orchard would go to great lengths to making Nature and Nurture one of the most distinctive agricultural experiences in the area. Our proposed restoration of the prairie is an excellent opportunity to reach out to the University of Michigan's Ecological Restoration class, or an individual researcher could easily set up plots to monitor the effects of restoration over time. This is true more generally, since much of our work resulted in a set of baseline ecological data. Future students could add and draw upon these data. It would be a fascinating project to see the response of the site to agroforestry.

# HABITAT CONNECTIVITY


# INCOME DIVERSITY



# COMMUNITY ENGAGEMENT






# CONCLUSIONS

The property supports a range of habitat community types including beech maple forest, oak-hickory forest, maple swamp, buttonbush swamp, reed canary marsh, vernal pools, hedgerows, old fields/meadows, and active agriculture. The overall habitat quality throughout the site is good with several areas supporting high quality natural communities. A majority of these communities are present in the northern forest portion.

Soil conditions in the forest are healthier than in other parts of the landscapes. Soil cation exchange capacity, C content, N content and PMC are all highest in the forest. These results show that forest soils contain more organic matter as well as nutrients required for plant growth. These values descended roughly in the order of forest, fallow and field area. The results support the assumption that less human disturbance would improve the soil quality. One exception is the fenced area. These criteria will be affected directly by management activity like applying fertilizer and ploughing. We also found that the fenced area had high POM results, and this is probably because we surveyed right after fertilizer application.

Because we only sampled one replicate for each type of soil, PMC and POM results may not be entirely representative of the farm. Further research may start with our results as preliminary data and explore whether there are deep relationships between PMC, POM and land-use/management practices.

According to the soil results, we encourage our clients' to manage agricultural activities in the fenced area and let semi-disturbed area like the fallow fields recover naturally. Educational activities can be arranged on the border of the forest and other land-uses to explore the differences in communities and quality across land uses. The fPOM results are different from what we expected and reflect the vegetation inputs. This is explained by the fine root litter inputs from perennial grass cover in the fallow and fenced areas. The results showed higher oPOM in the forest and field, reflecting long-term build up of fertility. This confirms the forest as the benchmark ecosystem on the farm with high soil quality and organic matter levels. High oPOM in the field is due to manure, compost, or other amendments it has received. The comparison between fPOM results and oPOM suggest that fallow and fenced areas might be slightly more degraded in terms of potential internal nutrient cycling capacity.

Our avian surveys tracked avian community composition changes from May to October. Though only one migrant species was observed during the three surveys, the composition changes between our first survey and our last survey. This suggests a diversity of avian species using the site. In the second survey, we did not observe many species probably because the high temperature and a relatively late surveying time during the day. The majority of our observed bird species are insect-eaters, thus birds can be a potential management method to control pest communities. Since most observed bird species were mainly ground foragers, it is important to build cover for birds to prey on pests without disturbance.

The abundance and diversity of the invertebrate community is high, which also contributes to an overall healthy farm. The invertebrate community can also have profound ecological consequences by acting as pests, pollinators, predators on other invertebrates, and decomposers. It is important also to consider the interplay between invertebrate, amphibian and avian surveys. For example, most observed birds were insect-eaters, and in order to estimate the effects on the invertebrate community more information about the specific relationships between each bird species and invertebrate species is required. If birds feed mainly on pests, then improving the habitat quality for birds can be beneficial for agricultural activities. However, if the birds feed mainly on those beneficial insects who conduct pollination or decomposition, then the management decisions should consider the priority of conflicting goals, like improvement of ecological quality and increasing agricultural production. In general, we think it prudent to encourage both avian and invertebrate communities on the farm.

We used the floristic quality index (FQI) as a metric for habitat quality. We found an adjusted FQI value of 31.7 for the farm, while the value for successful conservation is usually set as 35. This indicates that the farm provides a relative high quality habitat for vegetation, which also impacts our avian, insect and soil surveys. However, the presence of invasive species is an obvious and potentially severe problem here. In both surveys the non-native species occupied about 25 percent of all plant species, though the actual fraction could be higher. One example of an observed invasive is garlic mustard (Alliaria petiolata) which is present in the high quality woodland, and threatens to locally extirpate much of the herbaceous vegetation there. One potentially fruitful investigation is whether interactions between different organism communities would provide a better way to deal with the invasive species, thus decreasing significantly the cost of maintaining the farm ecology conditions.



The suitable forest habitat analysis outlined a few areas on the site not currently under forest cover that cold potentially be candidates for reforestation efforts. Most notably, the areas we suggest for planting canopy trees (to the south of the Northwest woods, and to the north of the Silver Maple swamp) are also areas identified as suitable forest habitat in the GIS analysis. Additional outlined areas could serve as future areas for windbreaks or habitat corridors.

Our survey results only cover a small portion of the whole farm scale and should be subject to changes in the future. This farm provides relative high quality habitats for different organism communities like plants, birds, insects and herps. The habitat quality is significantly higher in the north forest, which means both higher biodiversity and more suitable environment factors. The residential area is obviously affected by human activities so we recommend the continued development of agriculture here. More information about management history will be helpful for interpretation of results in the future and should be explored by further research projects.

# QUESTIONS LEFT UNANSWERED

Though our project was thorough in its research and well-considered in its design recommendations, there were a number of questions that could not be answered. Most of these have to do with further exploration of the ecosystem processes on the site and how they relate to management decisions. For example, how does the composition of birds change over the season, and what migrating species traverse the site? What sort of habitat niches can be observed in avian populations? Another important relationship for management is the predation of insects by birds. An important consideration for the conservation of the woodland vegetation is how to control invasive species and pests such as deer. There are many opportunities for volunteerism and income (by having hunters target deer), but the optimal way to implement these strategies are still unknown. Lastly, a thorough economic analysis would be extremely useful for Nature and Nurture. Simply devising potential new markets and farmers to partner with could go a long way in increasing the revenue and community engagement of Nature and Nurture.

# FUTURE MASTER'S PROJECTS

One of our clients' requests was that we consider proposals for subsequent master's projects or collaborations with the University of Michigan. There are diverse opportunities for projects spanning multiple fields of study that would be co-beneficial for students and Nature and Nurture.

The first project idea could be an assessment of the success of our design and management plan in meeting the goals set out by our clients, based off our unanswered questions. For example, future students could sample soil in various parts of the farm, using our soil data as a baseline for comparison following conservation or restoration actions. The other ecological surveys we conducted, including plants and birds, should also be replicated in the future. Business-minded student groups could assess the finances associated with Nature and Nurture's transition from primarily landscaping to farm-based income. We would welcome a case study of the success of this project by future student groups.

In addition to financial sustainability, there are numerous other metrics for assessing the resilience and environmental impact of a food system. Life cycle assessment (LCA) is a commonly used approach. The majority of studies measuring the sustainability of diets uses the LCA approach, with greenhouse gas emissions being the most common metric reported. The reliability of LCA results is entirely dependent on the quality of the data being input to the model. Nature and Nurture farm could potentially be a rich source of LCA data for student groups looking to practice industrial ecology data collection and analysis. Other than LCA, functional dietary diversity is another useful metric for comparing land management efficiency; farms that satisfy more diverse dietary needs are ranked favorably. The Center for Sustainable Systems could use Nature and Nurture as a model organic farm.

Future students studying landscape architecture could be involved with planning the new farm developments we have broadly included in our plan. The construction of residential, agricultural, and commercial buildings should include a landscape plan that fits into the overall site design and does not disrupt current operations. Examples of developments that could be planned with assistance from the University include Mike Levine's parents' house, a secondary barn, and a multi-use building with classroom and office space. Nature and Nurture has proven to be a client that is open to a collaborative design process, which suggests future students could gain project experience on the farm.

Conservation ecology students could be useful in the planning and implementation of the prairie restoration and reforestation efforts in our plan. The farm and the diverse array of habitats could be an outdoor classroom space exposing students to restorative agriculture methods. Agroecology students could work closely with Nature and Nurture Seeds to produce a report detailing the effects of different organic management strategies on the yield and quality of seed crops. Any quantitative assessment of seed yield by row, or ideally yield per individual plant or fruit, would be significantly more useful than the currently available, unreliable estimates of seed yield per acre. A high quality report of seed yield for heirloom, organically grown crops would be valuable not only for Nature and Nurture, but for the artisanal seed industry as a whole.

The opportunities for practicing education on the farm are endless, because people of all ages and background could become involved. There is potential to expand youth programs related to food production and outdoor education. Any student interested in developing organizing and coordination skills could lead volunteer recruitment and management on the farm; there is potential to engage local school or extracurricular groups in volunteer farming and conservation work. For individuals and groups passionate about developing environmental curricula for adults, Nature and Nurture could engage with the course design and potentially host educational experiences.

The development of information technology provides useful tools for conservation planning and estimating. Geographic Information system (GIS) is one of most used conservation tools. With appropriate dataset, GIS could serve for many conservation goals like identifying conservation strategies, tracking endangered species, estimating whether a conservation status has changed with time and participatory decision making.GIS can help assessing conservation strategies by identifying physiographic units, making base map for assessment of different environmental factors like slopes, soil types and elevations, combining multi objects by pinning different layers, calculating values that are related to area and presenting data through maps or other graphic files for users to visualize what is happening in the area of interest. This means that GIS can help to quantify different goals and then help managers to prioritize different conservation objects to design a realistic conservation plan.

# REFERENCES

## IMAGES


### INTRODUCTION

http://www.ediblewow.com/food-for-thought/spring-2016/nature-and-nurture/

### BACKGROUND

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### METHODS AND RESULTS

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### METHODS AND RESULTS CONT

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### DESIGN JUSTIFICATION

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# APPENDIX A

| Metric | Unit | Mean | Standard Deviation | Range |
|---|---|---|---|---|
| Soil pH | - | 6.10 | 0.7 | 4.8 - 7.4 |
| P | ppm | 4.64 | 8.8 | 0.6 - 36.5 |
| K | ppm | 74.56 | 22.6 | 37 - 118 |
| Ca | ppm | 1618.4 | 1493.3 | 140 - 5289 |
| Mg | ppm | 185.4 | 163.5 | 18 - 750 |
| S | ppm | 13.23 | 7.8 | 5.0 - 33.7 |
| B | ppm | 0.31 | 0.3 | 0.1 - 1.2 |
| Mn | ppm | 14.55 | 8.4 | 4.7 - 39.4 |
| Zn | ppm | 0.63 | 0.2 | 0.3 - 1.2 |
| Cu | ppm | 0.15 | 0.1 | 0.1 - 0.2 |
| Fe | ppm | 2.91 | 2.7 | 0.7 - 11.2 |
| Al | ppm | 16.81 | 15.5 | 4 - 59 |
| Pb | ppm | 0.44 | 0.2 | 0.2 - 0.9 |
| CEC | meq/100g | 12.89 | 8.2 | 7.1 -36.9 |
| Exchange Acidity | meq/100g | 3.08 | 2.0 | 0 - 6.6 |
| Ca Base Saturation | % | 56.13 | 20.9 | 9 - 93 |
| Mg Base Saturation | % | 11.38 | 4.3 | 2 - 18 |
| K Base Saturation | % | 1.75 | 0.7 | 1.0 - 3.0 |
| Scoop Density | g/cc | 1.14 | 0.1 | 0.90- 1.39 |

Soil measure values averaged across the farm.



# APPENDIX B

UMass Extension

**Soil and Plant Nutrient Testing Laboratory**
203 Paige Laboratory
161 Holdsworth Way
University of Massachusetts
Amherst, MA 01003
Phone: (413) 545-2311
e-mail: soiltest@umass.edu
website: soiltest.umass.edu

***Soil Test Report***

**Sample Information:**
Sample ID: 1

Order Number: 24651
Lab Number: S160810-206
Area Sampled: 5.1 acres
Received: 8/10/2016
Reported: 8/16/2016

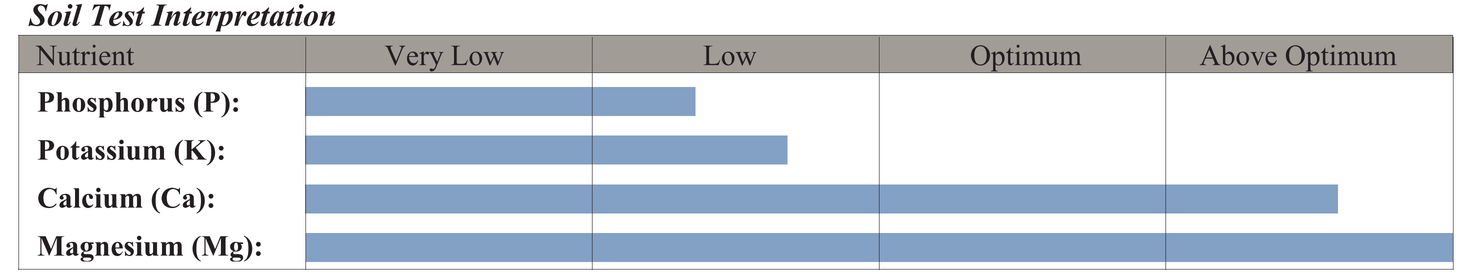
**Results**

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Soil pH (1:1, H2O)** | 6.1 | |
| **Modified Morgan extractable, ppm** | | |
| *Macronutrients* | | |
| Phosphorus (P) | 2.8 | 4-14 |
| Potassium (K) | 83 | 100-160 |
| Calcium (Ca) | 1795 | 1000-1500 |
| Magnesium (Mg) | 223 | 50-120 |
| Sulfur (S) | 14.7 | >10 |
| *Micronutrients* * | | |
| Boron (B) | 0.5 | 0.1-0.5 |
| Manganese (Mn) | 5.7 | 1.1-6.3 |
| Zinc (Zn) | 0.5 | 1.0-7.6 |
| Copper (Cu) | 0.1 | 0.3-0.6 |
| Iron (Fe) | 1.7 | 2.7-9.4 |
| Aluminum (Al) | 11 | <75 |
| Lead (Pb) | 0.4 | <22 |

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Cation Exch. Capacity, meq/100g** | 14.3 | |
| **Exch. Acidity, meq/100g** | 3.3 | |
| **Base Saturation, %** | | |
| Calcium Base Saturation | 63 | 50-80 |
| Magnesium Base Saturation | 13 | 10-30 |
| Potassium Base Saturation | 1 | 2.0-7.0 |
| **Scoop Density, g/cc** | 1.07 | |

* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

***Soil Test Interpretation***



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## *Soil Test Report*

**Sample Information:**
Sample ID: 2

Order Number: 24651
Lab Number: S160810-209
Area Sampled: 15.6 acres
Received: 8/10/2016
Reported: 8/16/2016

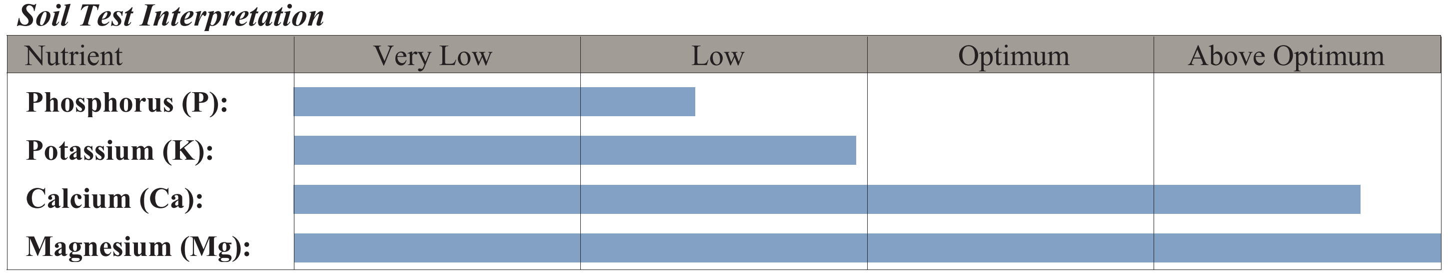
### Results

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Soil pH (1:1, H2O)** | 5.5 | |
| **Modified Morgan extractable, ppm** | | |
| *Macronutrients* | | |
| Phosphorus (P) | 2.8 | 4-14 |
| Potassium (K) | 97 | 100-160 |
| Calcium (Ca) | 1864 | 1000-1500 |
| Magnesium (Mg) | 221 | 50-120 |
| Sulfur (S) | 16.0 | >10 |
| *Micronutrients* * | | |
| Boron (B) | 0.3 | 0.1-0.5 |
| Manganese (Mn) | 24.8 | 1.1-6.3 |
| Zinc (Zn) | 0.9 | 1.0-7.6 |
| Copper (Cu) | 0.2 | 0.3-0.6 |
| Iron (Fe) | 6.4 | 2.7-9.4 |
| Aluminum (Al) | 34 | <75 |
| Lead (Pb) | 0.9 | <22 |

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Cation Exch. Capacity, meq/100g** | 17.6 | |
| **Exch. Acidity, meq/100g** | 6.2 | |
| **Base Saturation, %** | | |
| Calcium Base Saturation | 53 | 50-80 |
| Magnesium Base Saturation | 10 | 10-30 |
| Potassium Base Saturation | 1 | 2.0-7.0 |
| **Scoop Density, g/cc** | 0.97 | |

* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

### *Soil Test Interpretation*



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## *Soil Test Report*

**Sample Information:**
Sample ID: 3

Order Number: 24651
Lab Number: S160810-215
Area Sampled: 10 acres
Received: 8/10/2016
Reported: 8/16/2016

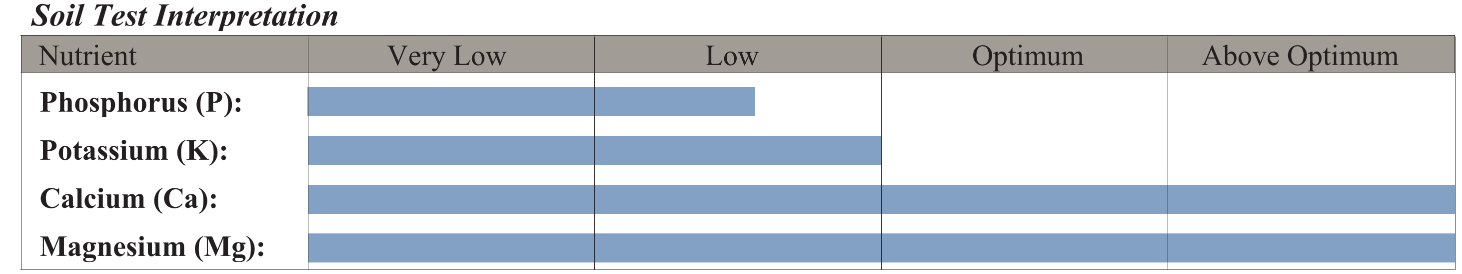
### Results

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Soil pH (1:1, H2O)** | 7.0 | |
| **Modified Morgan extractable, ppm** | | |
| *Macronutrients* | | |
| Phosphorus (P) | 3.1 | 4-14 |
| Potassium (K) | 99 | 100-160 |
| Calcium (Ca) | 4848 | 1000-1500 |
| Magnesium (Mg) | 204 | 50-120 |
| Sulfur (S) | 27.3 | >10 |
| *Micronutrients* * | | |
| Boron (B) | 0.3 | 0.1-0.5 |
| Manganese (Mn) | 16.4 | 1.1-6.3 |
| Zinc (Zn) | 0.6 | 1.0-7.6 |
| Copper (Cu) | 0.2 | 0.3-0.6 |
| Iron (Fe) | 2.0 | 2.7-9.4 |
| Aluminum (Al) | 10 | <75 |
| Lead (Pb) | 0.4 | <22 |

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Cation Exch. Capacity, meq/100g** | 26.2 | |
| **Exch. Acidity, meq/100g** | 0.0 | |
| **Base Saturation, %** | | |
| Calcium Base Saturation | 93 | 50-80 |
| Magnesium Base Saturation | 6 | 10-30 |
| Potassium Base Saturation | 1 | 2.0-7.0 |
| **Scoop Density, g/cc** | 1.15 | |

* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

### *Soil Test Interpretation*



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## *Soil Test Report*

**Sample Information:**
Sample ID: 4

Order Number: 24651
Lab Number: S160810-216
Area Sampled: 10 acres
Received: 8/10/2016
Reported: 8/16/2016

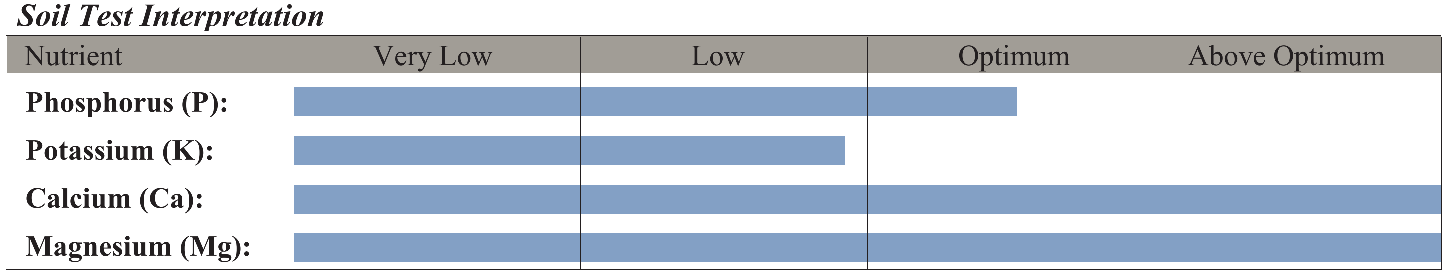
### Results

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Soil pH (1:1, H2O)** | 6.3 | |
| **Modified Morgan extractable, ppm** | | |
| *Macronutrients* | | |
| Phosphorus (P) | 9.1 | 4-14 |
| Potassium (K) | 97 | 100-160 |
| Calcium (Ca) | 5289 | 1000-1500 |
| Magnesium (Mg) | 750 | 50-120 |
| Sulfur (S) | 33.7 | >10 |
| *Micronutrients* * | | |
| Boron (B) | 1.2 | 0.1-0.5 |
| Manganese (Mn) | 4.7 | 1.1-6.3 |
| Zinc (Zn) | 1.2 | 1.0-7.6 |
| Copper (Cu) | 0.2 | 0.3-0.6 |
| Iron (Fe) | 4.6 | 2.7-9.4 |
| Aluminum (Al) | 6 | <75 |
| Lead (Pb) | 0.8 | <22 |

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Cation Exch. Capacity, meq/100g** | 36.9 | |
| **Exch. Acidity, meq/100g** | 4.0 | |
| **Base Saturation, %** | | |
| Calcium Base Saturation | 72 | 50-80 |
| Magnesium Base Saturation | 17 | 10-30 |
| Potassium Base Saturation | 1 | 2.0-7.0 |
| **Scoop Density, g/cc** | 0.90 | |

* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

### *Soil Test Interpretation*



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## *Soil Test Report*

**Sample Information:**
Sample ID: 5

Order Number: 24651
Lab Number: S160810-210
Area Sampled: 4 acres
Received: 8/10/2016
Reported: 8/16/2016

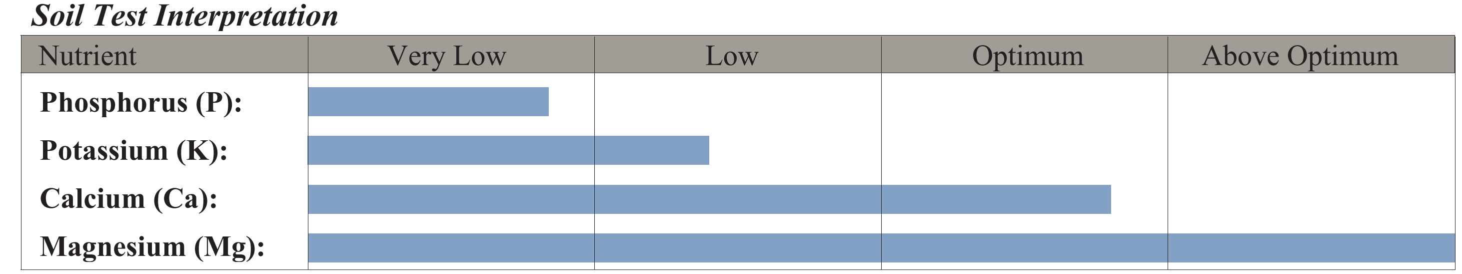
### Results

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Soil pH (1:1, H2O)** | 6.4 | |
| **Modified Morgan extractable, ppm** | | |
| *Macronutrients* | | |
| Phosphorus (P) | 1.7 | 4-14 |
| Potassium (K) | 70 | 100-160 |
| Calcium (Ca) | 1390 | 1000-1500 |
| Magnesium (Mg) | 223 | 50-120 |
| Sulfur (S) | 14.8 | >10 |
| *Micronutrients* * | | |
| Boron (B) | 0.3 | 0.1-0.5 |
| Manganese (Mn) | 6.9 | 1.1-6.3 |
| Zinc (Zn) | 0.4 | 1.0-7.6 |
| Copper (Cu) | 0.1 | 0.3-0.6 |
| Iron (Fe) | 1.8 | 2.7-9.4 |
| Aluminum (Al) | 11 | <75 |
| Lead (Pb) | 0.4 | <22 |

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Cation Exch. Capacity, meq/100g** | 11.5 | |
| **Exch. Acidity, meq/100g** | 2.5 | |
| **Base Saturation, %** | | |
| Calcium Base Saturation | 61 | 50-80 |
| Magnesium Base Saturation | 16 | 10-30 |
| Potassium Base Saturation | 2 | 2.0-7.0 |
| **Scoop Density, g/cc** | 1.02 | |

* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

### *Soil Test Interpretation*



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website: soiltest.umass.edu

## *Soil Test Report*

**Sample Information:**
Sample ID: 6

Order Number: 24651
Lab Number: S160810-211
Area Sampled: 5.75 acres
Received: 8/10/2016
Reported: 8/16/2016

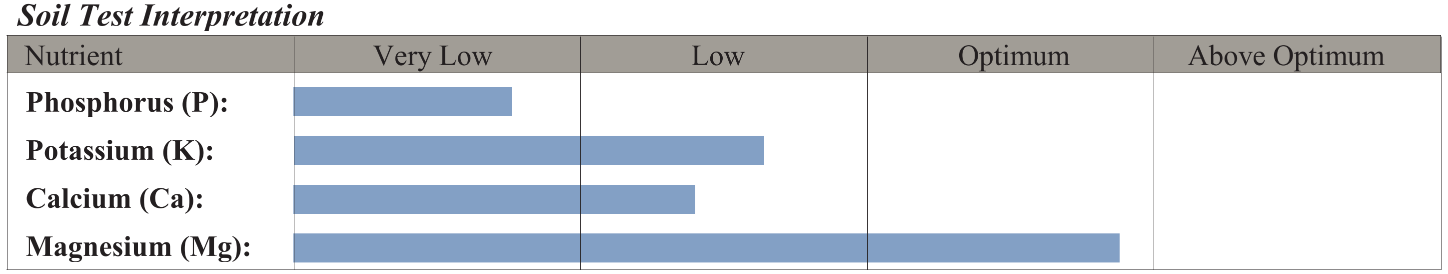
### Results

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Soil pH (1:1, H2O)** | 5.9 | |
| **Modified Morgan extractable, ppm** | | |
| *Macronutrients* | | |
| Phosphorus (P) | 1.6 | 4-14 |
| Potassium (K) | 83 | 100-160 |
| Calcium (Ca) | 701 | 1000-1500 |
| Magnesium (Mg) | 111 | 50-120 |
| Sulfur (S) | 8.1 | >10 |
| *Micronutrients* * | | |
| Boron (B) | 0.1 | 0.1-0.5 |
| Manganese (Mn) | 13.5 | 1.1-6.3 |
| Zinc (Zn) | 0.3 | 1.0-7.6 |
| Copper (Cu) | 0.1 | 0.3-0.6 |
| Iron (Fe) | 1.8 | 2.7-9.4 |
| Aluminum (Al) | 18 | <75 |
| Lead (Pb) | 0.4 | <22 |

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Cation Exch. Capacity, meq/100g** | 8.2 | |
| **Exch. Acidity, meq/100g** | 3.5 | |
| **Base Saturation, %** | | |
| Calcium Base Saturation | 43 | 50-80 |
| Magnesium Base Saturation | 11 | 10-30 |
| Potassium Base Saturation | 3 | 2.0-7.0 |
| **Scoop Density, g/cc** | 1.16 | |

* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

### *Soil Test Interpretation*



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## *Soil Test Report*

**Sample Information:**
Sample ID: 7

Order Number: 24651
Lab Number: S160810-213
Area Sampled: 2 acres
Received: 8/10/2016
Reported: 8/16/2016

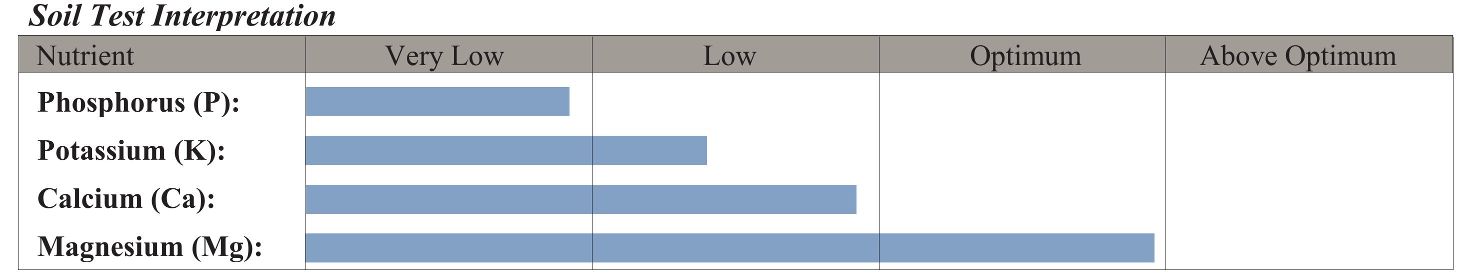
### Results

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Soil pH (1:1, H2O)** | 6.2 | |
| **Modified Morgan extractable, ppm** | | |
| *Macronutrients* | | |
| Phosphorus (P) | 1.9 | 4-14 |
| Potassium (K) | 71 | 100-160 |
| Calcium (Ca) | 969 | 1000-1500 |
| Magnesium (Mg) | 116 | 50-120 |
| Sulfur (S) | 10.6 | >10 |
| *Micronutrients* * | | |
| Boron (B) | 0.2 | 0.1-0.5 |
| Manganese (Mn) | 9.7 | 1.1-6.3 |
| Zinc (Zn) | 0.4 | 1.0-7.6 |
| Copper (Cu) | 0.1 | 0.3-0.6 |
| Iron (Fe) | 1.7 | 2.7-9.4 |
| Aluminum (Al) | 8 | <75 |
| Lead (Pb) | 0.4 | <22 |

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Cation Exch. Capacity, meq/100g** | 8.4 | |
| **Exch. Acidity, meq/100g** | 2.4 | |
| **Base Saturation, %** | | |
| Calcium Base Saturation | 58 | 50-80 |
| Magnesium Base Saturation | 11 | 10-30 |
| Potassium Base Saturation | 2 | 2.0-7.0 |
| **Scoop Density, g/cc** | 1.16 | |

* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

### *Soil Test Interpretation*



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## *Soil Test Report*

**Sample Information:**
Sample ID: 8

Order Number: 24651
Lab Number: S160810-214
Area Sampled: 4.75 acres
Received: 8/10/2016
Reported: 8/16/2016

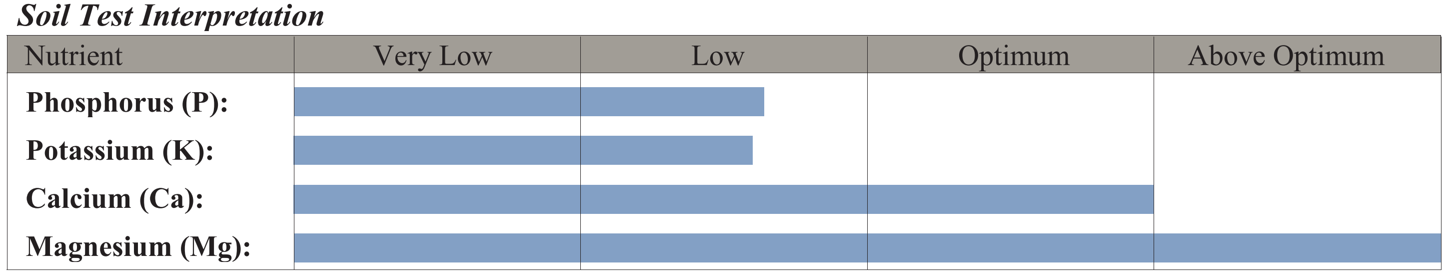
### Results

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Soil pH (1:1, H2O)** | 6.9 | |
| **Modified Morgan extractable, ppm** | | |
| *Macronutrients* | | |
| Phosphorus (P) | 3.3 | 4-14 |
| Potassium (K) | 81 | 100-160 |
| Calcium (Ca) | 1491 | 1000-1500 |
| Magnesium (Mg) | 218 | 50-120 |
| Sulfur (S) | 13.0 | >10 |
| *Micronutrients* * | | |
| Boron (B) | 0.4 | 0.1-0.5 |
| Manganese (Mn) | 9.7 | 1.1-6.3 |
| Zinc (Zn) | 0.3 | 1.0-7.6 |
| Copper (Cu) | 0.2 | 0.3-0.6 |
| Iron (Fe) | 0.9 | 2.7-9.4 |
| Aluminum (Al) | 5 | <75 |
| Lead (Pb) | 0.3 | <22 |

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Cation Exch. Capacity, meq/100g** | 10.0 | |
| **Exch. Acidity, meq/100g** | 0.6 | |
| **Base Saturation, %** | | |
| Calcium Base Saturation | 74 | 50-80 |
| Magnesium Base Saturation | 18 | 10-30 |
| Potassium Base Saturation | 2 | 2.0-7.0 |
| **Scoop Density, g/cc** | 1.14 | |

* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

### *Soil Test Interpretation*



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## *Soil Test Report*

**Sample Information:**
Sample ID: 9

Order Number: 24651
Lab Number: S160810-202
Area Sampled: 0.5 acres
Received: 8/10/2016
Reported: 8/16/2016

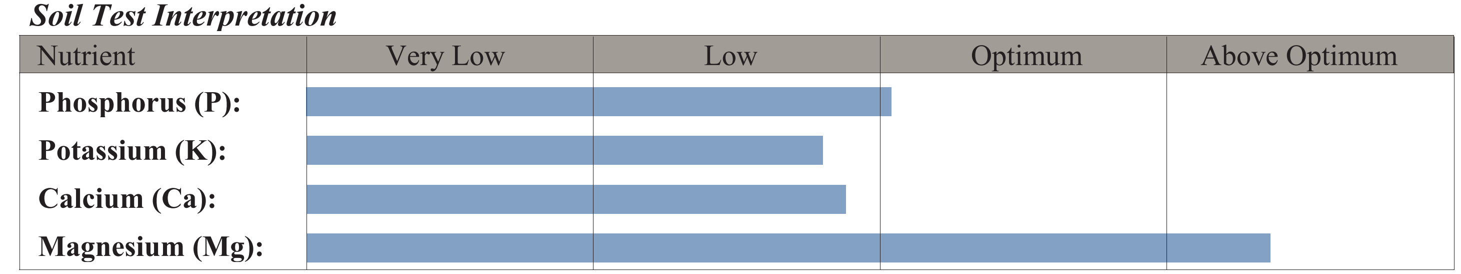
### Results

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Soil pH (1:1, H2O)** | 6.7 | |
| **Modified Morgan extractable, ppm** | | |
| *Macronutrients* | | |
| Phosphorus (P) | 4.4 | 4-14 |
| Potassium (K) | 90 | 100-160 |
| Calcium (Ca) | 936 | 1000-1500 |
| Magnesium (Mg) | 149 | 50-120 |
| Sulfur (S) | 8.9 | >10 |
| *Micronutrients* * | | |
| Boron (B) | 0.3 | 0.1-0.5 |
| Manganese (Mn) | 15.1 | 1.1-6.3 |
| Zinc (Zn) | 0.8 | 1.0-7.6 |
| Copper (Cu) | 0.1 | 0.3-0.6 |
| Iron (Fe) | 0.7 | 2.7-9.4 |
| Aluminum (Al) | 4 | <75 |
| Lead (Pb) | 0.2 | <22 |

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Cation Exch. Capacity, meq/100g** | 7.1 | |
| **Exch. Acidity, meq/100g** | 1.0 | |
| **Base Saturation, %** | | |
| Calcium Base Saturation | 66 | 50-80 |
| Magnesium Base Saturation | 17 | 10-30 |
| Potassium Base Saturation | 3 | 2.0-7.0 |
| **Scoop Density, g/cc** | 1.24 | |

* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

### *Soil Test Interpretation*



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## *Soil Test Report*

**Sample Information:**
Sample ID: 10

Order Number: 24651
Lab Number: S160810-203
Area Sampled: 7.5 acres
Received: 8/10/2016
Reported: 8/16/2016

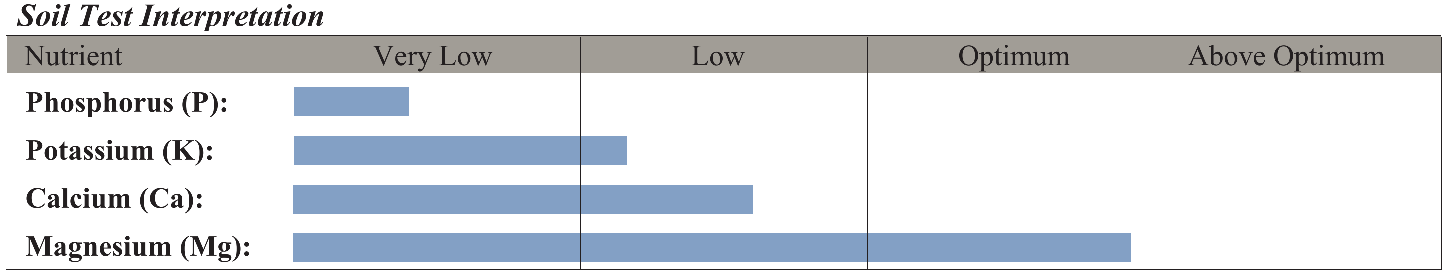
### Results

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Soil pH (1:1, H2O)** | 6.0 | |
| **Modified Morgan extractable, ppm** | | |
| *Macronutrients* | | |
| Phosphorus (P) | 0.8 | 4-14 |
| Potassium (K) | 58 | 100-160 |
| Calcium (Ca) | 795 | 1000-1500 |
| Magnesium (Mg) | 115 | 50-120 |
| Sulfur (S) | 8.3 | >10 |
| *Micronutrients* * | | |
| Boron (B) | 0.1 | 0.1-0.5 |
| Manganese (Mn) | 17.9 | 1.1-6.3 |
| Zinc (Zn) | 0.9 | 1.0-7.6 |
| Copper (Cu) | 0.1 | 0.3-0.6 |
| Iron (Fe) | 1.1 | 2.7-9.4 |
| Aluminum (Al) | 8 | <75 |
| Lead (Pb) | 0.3 | <22 |

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Cation Exch. Capacity, meq/100g** | 7.7 | |
| **Exch. Acidity, meq/100g** | 2.6 | |
| **Base Saturation, %** | | |
| Calcium Base Saturation | 52 | 50-80 |
| Magnesium Base Saturation | 12 | 10-30 |
| Potassium Base Saturation | 2 | 2.0-7.0 |
| **Scoop Density, g/cc** | 1.23 | |

* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

### *Soil Test Interpretation*



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## *Soil Test Report*

**Sample Information:**
Sample ID: 11

Order Number: 24651
Lab Number: S160810-204
Area Sampled: 7.5 acres
Received: 8/10/2016
Reported: 8/16/2016

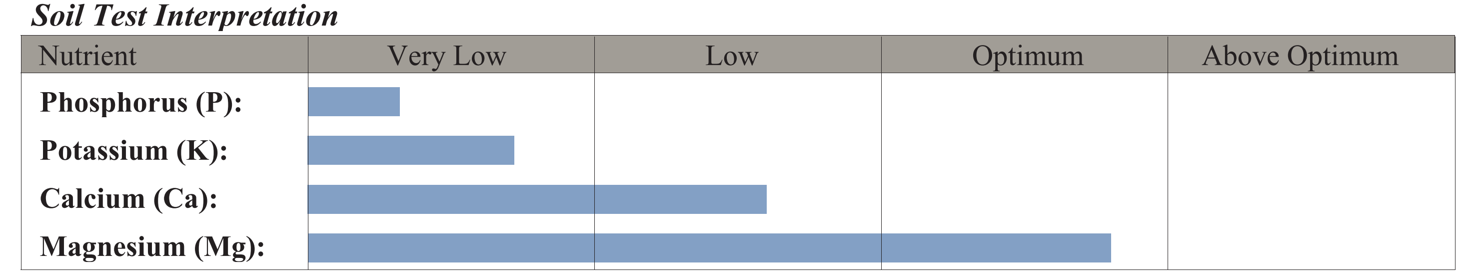
### Results

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Soil pH (1:1, H2O)** | 5.9 | |
| **Modified Morgan extractable, ppm** | | |
| *Macronutrients* | | |
| Phosphorus (P) | 0.7 | 4-14 |
| Potassium (K) | 37 | 100-160 |
| Calcium (Ca) | 791 | 1000-1500 |
| Magnesium (Mg) | 106 | 50-120 |
| Sulfur (S) | 7.8 | >10 |
| *Micronutrients* * | | |
| Boron (B) | 0.1 | 0.1-0.5 |
| Manganese (Mn) | 11.1 | 1.1-6.3 |
| Zinc (Zn) | 0.5 | 1.0-7.6 |
| Copper (Cu) | 0.1 | 0.3-0.6 |
| Iron (Fe) | 1.3 | 2.7-9.4 |
| Aluminum (Al) | 11 | <75 |
| Lead (Pb) | 0.3 | <22 |

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Cation Exch. Capacity, meq/100g** | 7.8 | |
| **Exch. Acidity, meq/100g** | 2.9 | |
| **Base Saturation, %** | | |
| Calcium Base Saturation | 51 | 50-80 |
| Magnesium Base Saturation | 11 | 10-30 |
| Potassium Base Saturation | 1 | 2.0-7.0 |
| **Scoop Density, g/cc** | 1.16 | |

* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

### *Soil Test Interpretation*



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## *Soil Test Report*

**Sample Information:**
Sample ID: 12

Order Number: 24651
Lab Number: S160810-205
Area Sampled: 11.5 acres
Received: 8/10/2016
Reported: 8/16/2016

### Results

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Soil pH (1:1, H2O)** | 5.8 | |
| **Modified Morgan extractable, ppm** | | |
| *Macronutrients* | | |
| Phosphorus (P) | 0.8 | 4-14 |
| Potassium (K) | 47 | 100-160 |
| Calcium (Ca) | 856 | 1000-1500 |
| Magnesium (Mg) | 122 | 50-120 |
| Sulfur (S) | 8.0 | >10 |
| *Micronutrients* * | | |
| Boron (B) | 0.1 | 0.1-0.5 |
| Manganese (Mn) | 11.8 | 1.1-6.3 |
| Zinc (Zn) | 0.6 | 1.0-7.6 |
| Copper (Cu) | 0.2 | 0.3-0.6 |
| Iron (Fe) | 1.9 | 2.7-9.4 |
| Aluminum (Al) | 15 | <75 |
| Lead (Pb) | 0.4 | <22 |

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Cation Exch. Capacity, meq/100g** | 9.1 | |
| **Exch. Acidity, meq/100g** | 3.7 | |
| **Base Saturation, %** | | |
| Calcium Base Saturation | 47 | 50-80 |
| Magnesium Base Saturation | 11 | 10-30 |
| Potassium Base Saturation | 1 | 2.0-7.0 |
| **Scoop Density, g/cc** | 1.16 | |

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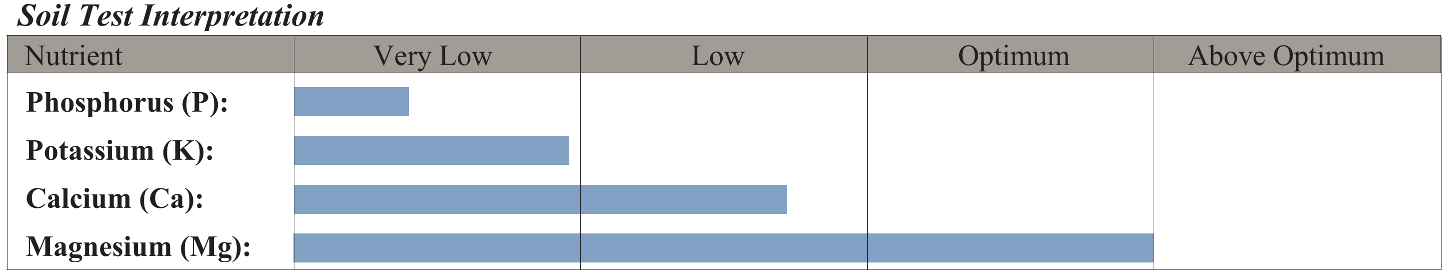
***Soil Test Interpretation***



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## *Soil Test Report*

**Sample Information:**
Sample ID: 13

Order Number: 24651
Lab Number: S160810-207
Area Sampled: 3 acres
Received: 8/10/2016
Reported: 8/16/2016

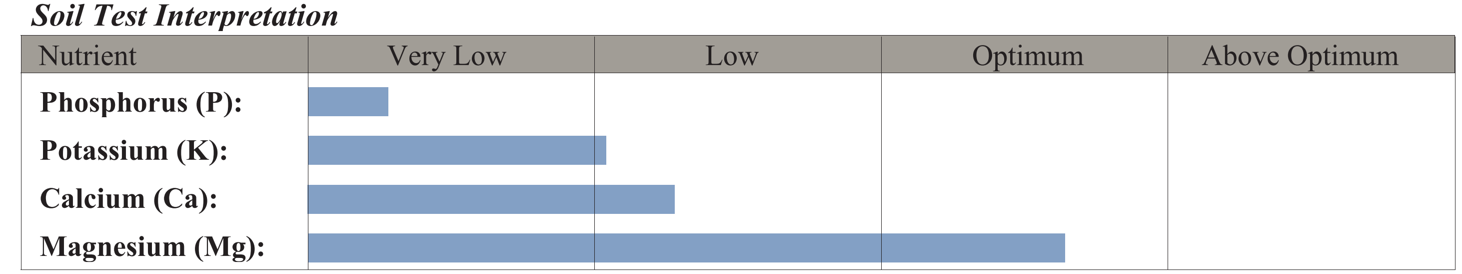
### Results

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Soil pH (1:1, H2O)** | 5.5 | |
| **Modified Morgan extractable, ppm** | | |
| *Macronutrients* | | |
| Phosphorus (P) | 0.6 | 4-14 |
| Potassium (K) | 52 | 100-160 |
| Calcium (Ca) | 644 | 1000-1500 |
| Magnesium (Mg) | 95 | 50-120 |
| Sulfur (S) | 7.4 | >10 |
| *Micronutrients* * | | |
| Boron (B) | 0.1 | 0.1-0.5 |
| Manganese (Mn) | 18.4 | 1.1-6.3 |
| Zinc (Zn) | 0.5 | 1.0-7.6 |
| Copper (Cu) | 0.2 | 0.3-0.6 |
| Iron (Fe) | 3.1 | 2.7-9.4 |
| Aluminum (Al) | 24 | <75 |
| Lead (Pb) | 0.6 | <22 |

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Cation Exch. Capacity, meq/100g** | 8.3 | |
| **Exch. Acidity, meq/100g** | 4.2 | |
| **Base Saturation, %** | | |
| Calcium Base Saturation | 39 | 50-80 |
| Magnesium Base Saturation | 9 | 10-30 |
| Potassium Base Saturation | 2 | 2.0-7.0 |
| **Scoop Density, g/cc** | 1.15 | |

* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

***Soil Test Interpretation***



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## *Soil Test Report*

**Sample Information:**
Sample ID: 14

Order Number: 24651
Lab Number: S160810-208
Area Sampled: 4 acres
Received: 8/10/2016
Reported: 8/16/2016

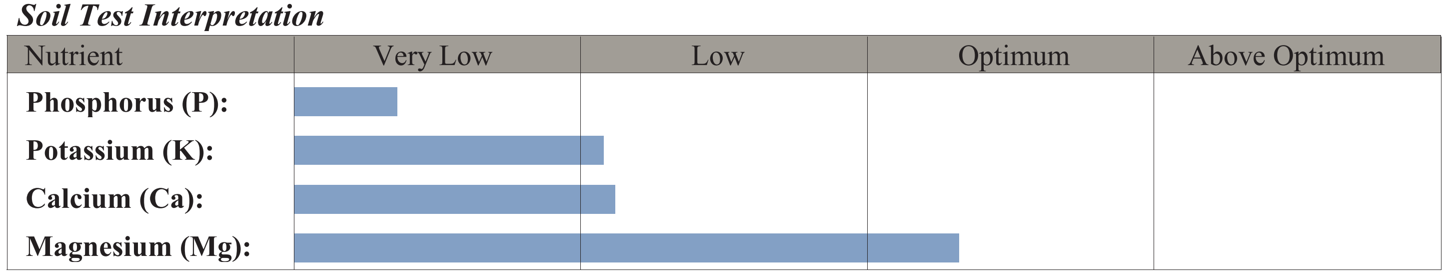
### Results

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Soil pH (1:1, H2O)** | 5.2 | |
| **Modified Morgan extractable, ppm** | | |
| *Macronutrients* | | |
| Phosphorus (P) | 0.7 | 4-14 |
| Potassium (K) | 55 | 100-160 |
| Calcium (Ca) | 560 | 1000-1500 |
| Magnesium (Mg) | 74 | 50-120 |
| Sulfur (S) | 8.7 | >10 |
| *Micronutrients* * | | |
| Boron (B) | 0.1 | 0.1-0.5 |
| Manganese (Mn) | 39.4 | 1.1-6.3 |
| Zinc (Zn) | 0.7 | 1.0-7.6 |
| Copper (Cu) | 0.2 | 0.3-0.6 |
| Iron (Fe) | 4.5 | 2.7-9.4 |
| Aluminum (Al) | 41 | <75 |
| Lead (Pb) | 0.5 | <22 |

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Cation Exch. Capacity, meq/100g** | 9.3 | |
| **Exch. Acidity, meq/100g** | 5.7 | |
| **Base Saturation, %** | | |
| Calcium Base Saturation | 30 | 50-80 |
| Magnesium Base Saturation | 7 | 10-30 |
| Potassium Base Saturation | 2 | 2.0-7.0 |
| **Scoop Density, g/cc** | 1.12 | |

* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

***Soil Test Interpretation***



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## *Soil Test Report*

**Sample Information:**
Sample ID: 15

Order Number: 24651
Lab Number: S160810-217
Area Sampled: 1 acres
Received: 8/10/2016
Reported: 8/16/2016

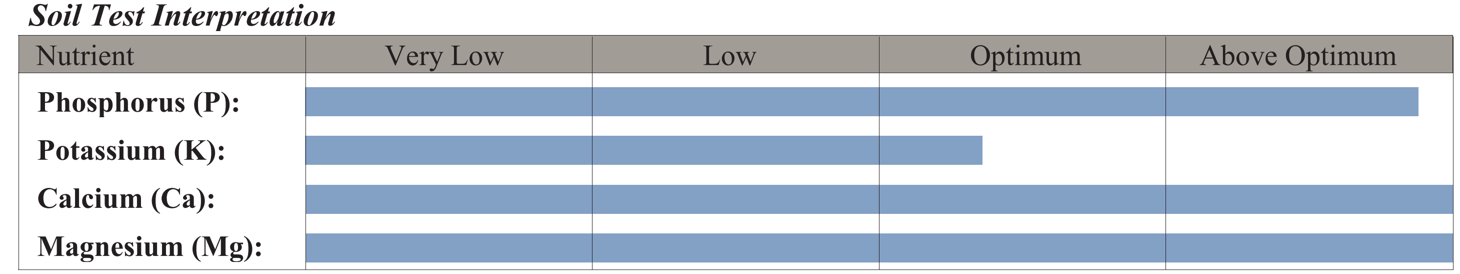
### Results

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Soil pH (1:1, H2O)** | 7.4 | |
| **Modified Morgan extractable, ppm** | | |
| *Macronutrients* | | |
| Phosphorus (P) | 36.5 | 4-14 |
| Potassium (K) | 118 | 100-160 |
| Calcium (Ca) | 2825 | 1000-1500 |
| Magnesium (Mg) | 221 | 50-120 |
| Sulfur (S) | 19.4 | >10 |
| *Micronutrients* * | | |
| Boron (B) | 0.7 | 0.1-0.5 |
| Manganese (Mn) | 15.6 | 1.1-6.3 |
| Zinc (Zn) | 0.8 | 1.0-7.6 |
| Copper (Cu) | 0.2 | 0.3-0.6 |
| Iron (Fe) | 1.9 | 2.7-9.4 |
| Aluminum (Al) | 4 | <75 |
| Lead (Pb) | 0.2 | <22 |

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Cation Exch. Capacity, meq/100g** | 16.2 | |
| **Exch. Acidity, meq/100g** | 0.0 | |
| **Base Saturation, %** | | |
| Calcium Base Saturation | 87 | 50-80 |
| Magnesium Base Saturation | 11 | 10-30 |
| Potassium Base Saturation | 2 | 2.0-7.0 |
| **Scoop Density, g/cc** | 1.16 | |

* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

***Soil Test Interpretation***



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# *Soil Test Report*

**Sample Information:**
Sample ID: 16

Order Number: 24651
Lab Number: S160810-218
Area Sampled: 0.75 acres
Received: 8/10/2016
Reported: 8/16/2016

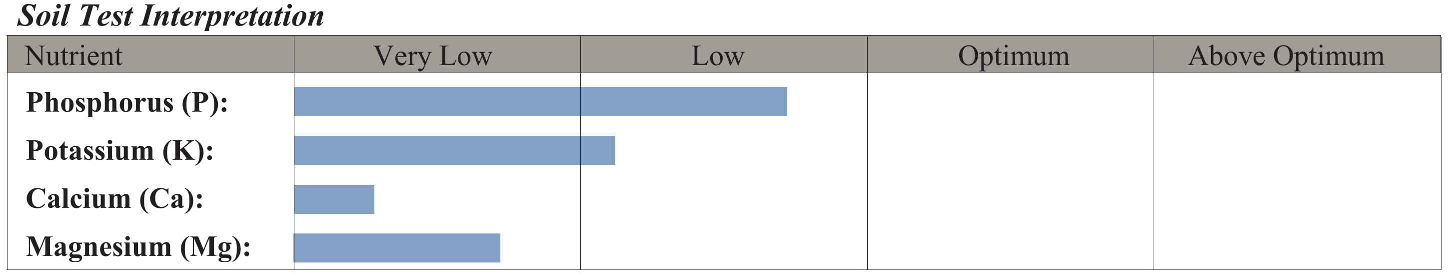
## Results

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Soil pH (1:1, H2O)** | 4.8 | |
| **Modified Morgan extractable, ppm** | | |
| *Macronutrients* | | |
| Phosphorus (P) | 3.4 | 4-14 |
| Potassium (K) | 55 | 100-160 |
| Calcium (Ca) | 140 | 1000-1500 |
| Magnesium (Mg) | 18 | 50-120 |
| Sulfur (S) | 5.0 | >10 |
| *Micronutrients* * | | |
| Boron (B) | 0.1 | 0.1-0.5 |
| Manganese (Mn) | 12.1 | 1.1-6.3 |
| Zinc (Zn) | 0.7 | 1.0-7.6 |
| Copper (Cu) | 0.1 | 0.3-0.6 |
| Iron (Fe) | 11.2 | 2.7-9.4 |
| Aluminum (Al) | 59 | <75 |
| Lead (Pb) | 0.6 | <22 |

| *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|
| **Cation Exch. Capacity, meq/100g** | 7.6 | |
| **Exch. Acidity, meq/100g** | 6.6 | |
| **Base Saturation, %** | | |
| Calcium Base Saturation | 9 | 50-80 |
| Magnesium Base Saturation | 2 | 10-30 |
| Potassium Base Saturation | 2 | 2.0-7.0 |
| **Scoop Density, g/cc** | 1.39 | |

* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

### *Soil Test Interpretation*



# APPENDIX C

| Common Name | Latin Name | Quantity 6/4/16 | 7/23/16 | 10/18/16 | Location Stop 1 | Stop 2 | Stop 3 | Stop 4 | Stop 5 | Stop 6 | Stop 7 | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| American crow | Corvus brachyrhynchos | 3 | - | 1 | x | x | | | | | | |
| American goldfinch | Spinus tristis | 3 | - | 7 | | x | x | | x | | | |
| American robin | Turdus migratorius | 9 | ? | - | | x | | x | | | x | |
| Barn swallow | Hirundo rustica | 1 | - | - | | x | | | | | | |
| Black capped chickadee | Poecile atricapillus | 2 | - | 3 | | x | x | | | x | | |
| Blue jay | Cyanocitta cristata | 6 | ? | 12 | x | x | x | | x | x | x | |
| Brown-headed cowbird | Molothrus ater | 9 | - | - | | | | | x | | | |
| Canada goose | Branta canadensis | 11 | - | 2, 50 | x | x | | | | x | | |
| Cedar waxwing | Bombycilla cedrorum | - | - | 10 | | | | | x | | | |
| Chimney swift | Chaetura pelagica | 2 | - | - | x | | | | | | | |
| Chipping sparrow | Spizella passerina | 1 | - | - | x | | | | | | | |
| Eastern bluebird | Sialia sialis | - | - | 2 | | | | | | x | | |
| Eastern wood-pewee | Contopus virens | 2 | 1 | - | | | | | | | x | |
| European starling | Sturnus vulgaris | ? | - | 20 | | x | | | | | | W field and Industrial Park |
| Field sparrow | Spizella pusilla | - | - | 3 | | x | | | | | | |
| Gray catbird | Dumetella carolinensis | 3 | 1 | 1 | | | x | x | | | x | |
| House finch | Haemorhous mexicanus | - | - | 30 | | x | | | | x | | |
| Killdeer | Charadrius vociferus | 4 | - | - | | x | | | | | | |
| Mourning dove | Zenaida macroura | 8 | 1 | 6 | x | x | | | | | x | |
| Northern cardinal | Cardinalis cardinalis | 8 | - | 1 | x | | | x | | x | | |
| Northern flicker | Colaptes auratus | 1 | - | - | | | | | | | | |
| Northern rough winged swallow | Stelgidopteryx serripennis | 1 | - | - | | | | | | | | |
| Orchard oriole | Icterus spurius | 1 | - | - | | | | | x | | | |
| Red bellied woodpecker | Melanerpes carolinus | 2 | - | 2 | x | | | x | | x | | |
| Red-tailed hawk | Buteo jamaicensis | - | - | 1 | | | | | x | | | |
| Red-winged blackbird | Agelaius phoeniceus | 14 | - | - | x | x | x | | | | | |
| Rose breasted grosbeak | Pheucticus ludovicianus | 1 | - | - | | | | | | | | |
| Song sparrow | Melospiza melodia | 2 | 1 | - | | x | | | | | x | Maple Swamp |
| Sparrow sp. | | 3 | - | 5 | | x | | | x | | | |
| Swallow sp. | Hirundinidae family | 5 | ? | - | | | | | | | x | |
| Tufted titmouse | Baeolophus bicolor | 4 | - | - | x | | | | | | | |
| Turkey vulture | Cathartes aura | 4 | - | 5 | x | | | | x | | | |
| White breasted nuthatch | Sitta carolinensis | 2 | - | 2 | x | | x | | | | | |
| White crowned sparrow | Zonotrichia leucophrys | - | - | 2 | | x | | | | | | |
| Woodpecker (downy or hairy) | Picoides sp. | - | - | 1 | | | x | | | | | |
| Yellow warbler | Setophaga petechia | 4 | - | - | | | | | | | | |
| | | Quantity | | | | | | | Location | | | |
| | Total Species | 29 | 7 | 20 | | | | | | | | |

Avian survey sightings, counts, and locations.



# APPENDIX D

| Common Name | Order | Family | Plant Association | Other | Location |
|---|---|---|---|---|---|
| black swallowtail | Lepidoptera | Papilionidae | | pollinator | Inside Fence |
| blowfly | Diptera | Calliphoridae | | pollinator/detritivore | |
| bumblebee | Hymenoptera | Apidae | Rudbeckia | pollinator | |
| cabbage white butterfly | Lepidoptera | Pieridae | | pest | |
| Carolina locust | Orthoptera | Acrididae | | pest | |
| clouded sulphur | Lepidoptera | Pieridae | | pollinator | |
| cuckoo wasp | Hymenoptera | Chrysididae | | pollinator | |
| digger bee | Hymenoptera | Apidae | Rudbeckia | pollinator | |
| Eastern carpenter bumblebee | Hymenoptera | Apidae | | pollinator | |
| flower fly | Diptera | Syrphidae | | pollinator/biocontrol | |
| grasshopper | Orthoptera | Acrididae | | potential pest | |
| handsome locust | Orthoptera | Acrididae | | potential pest | |
| horsefly | Diptera | Tabanidae | | pollinator | |
| housefly | Diptera | Muscidae | | detritivore | |
| Japanese beetle | Coleoptera | Scarabaeidae | Sorrel | pest | |
| leaf beetle | Hymenoptera | Chrysomelidae | Monarda fistulosa | pollinator | |
| leaf cutting bee | Hymenoptera | Megachilidae | | pollinator/biocontrol | |
| leafhopper | Hemiptera | Cicadellidae | | pest | |
| lightning bug | Coleoptera | Lampyridae | | biocontrol | |
| long-legged fly | Diptera | Dolichopodidae | | biocontrol | |
| millipede | | | | detritivore | |
| paper wasp | Hymenoptera | Vespidae | | pollinator/biocontrol/pest | |
| potter wasp | Hymenoptera | Vespidae | | biocontrol/pest | |
| sawfly | Hymenoptera | Tenthredinidae | | pollinator/potential/pest | |
| seed bug | Hemiptera | Lygaeidae | | pest | |
| skimmer | Odonata | Libellulidae | | biocontrol | |
| skipper | Lepidoptera | Hesperiidae | | pollinator | |
| spotted cucumber beetle | Coleoptera | Chrysomelidae | | pest | |
| spotted lady beetle | Coleoptera | Coccinellidae | | biocontrol | |
| squash bug | Hemiptera | Coridae | | pest | |
| stink bug | Hemiptera | Pentatomidae | | pest | |
| striped cucumber beetle | Coleoptera | Chrysomelidae | | pest | |
| sweatbee | Hymenoptera | Halictidae | | pollinator | |
| tent caterpillar | Lepidoptera | Lasiocampidae | | pest | |
| yellow jacket | Hymenoptera | Vespidae | | pollinator/biocontrol | |
| | Hemiptera | Miridae | | pest | |
| flower fly | Diptera | Syrphidae | | pollinator | Maple Swamp Edge |
| Gorgone checkerspot | Lepidoptera | Nymphalidae | | pollinator | |
| grasshopper | Orthoptera | Acrididae | | potential pest | |
| lacewing | Neuroptera | Chrysopidae | | biocontrol | |
| leaf beetle | Hymenoptera | Chrysomelidae | | pollinator | |
| leafhopper | Hemiptera | Cicadellidae | | pest | |
| long horn beetle | Coleoptera | Cerambycidae | | pest | |
| moth | Lepidoptera | Geometridae | | pollinator | |
| robber fly | Diptera | Asilidae | | biocontrol | |
| stink bug | Hemiptera | Pentatomidae | | pest | |
| Japanese beetle | Coleoptera | Scarabaeidae | alfalfa | pest | E field - alfalfa |
| leafhopper | Hemiptera | Cicadellidae | alfalfa | pest | |
| seed bug | Hemiptera | Lygaeidae | alfalfa | pest | |
| spittle bug | Hemiptera | | alfalfa | potential pest | |
| spotted lady beetle | Coleoptera | Coccinellidae | alfalfa | biocontrol | |
| sweatbee | Hymenoptera | Halictidae | alfalfa | pollinator | |

# APPENDIX E

| Season | Species | Location(s) Observed | Season | Species | Location(s) Observed |
|---|---|---|---|---|---|
| Spring | Alliaria petiolata | 2,3,4,6,9 | Summer | Circaea lutetiana | 1,2,4,5,6,7,10 |
| Spring | Cardamine concatenata | 6 | Summer | Cirsium arvense | 16 |
| Spring | Carex pensylvanica | 9 | Summer | Cornus sp. | 3,10,11 |
| Spring | Carex sp. | 1,4,9,11 | Summer | Dactylis glomerata | 14,18 |
| Spring | Carpinus caroliniana | 7 | Summer | Daucus carota | 17 |
| Spring | Carya laciniosa | 1 | Summer | Dendrolycopodium obscurum | 11 |
| Spring | Cirsium arvense | 16,20 | Summer | Desmodium glutinosum | 2,3,5,7,8,10 |
| Spring | Claytonia virginica | 2,9,11,12,16 | Summer | Elymus hystrix | 2,3 |
| Spring | Cornus sp. | 3,10,11 | Summer | Elymus repens | 15 |
| Spring | Daucus carota | 17 | Summer | Erigeron philadelphicus | 19 |
| Spring | Dentaria laciniata | 2,5,10 | Summer | Euthamia graminifolia | 13 |
| Spring | Fragaria virginiana | 7,8 | Summer | Fraxinus sp. | 2,3,4,5,7,8,9,10,14 |
| Spring | Fraxinus americana | 14 | Summer | Galium concinnum | 11 |
| Spring | Fraxinus sp. | 2,3,7,8,9,10 | Summer | Geranium maculatum | 1,4,9,11 |
| Spring | Galium aparine | 1,11 | Summer | Geum canadense | 1,2 |
| Spring | Galium sp. | 4,15 | Summer | Geum sp. | 9 |
| Spring | Geranium maculatum | 1,2,9,11,14 | Summer | Juncas tenuis | 19 |
| Spring | Glechoma hederacea | 15 | Summer | Lapsana communis | 1 |
| Spring | Lapsana communis | 2,15 | Summer | Leersia virginca | 14 |
| Spring | Leucanthemum vulgare | 12 | Summer | Leucanthemum vulgare | 12 |
| Spring | Medicago sativa | 12,16,20 | Summer | Lonicera maacki | 11 |
| Spring | Monarda fistulosa | 15 | Summer | Medicago sativa | 12,16,20 |
| Spring | Parthenocissus quinquefolia | 2,3,4,5,6,8,14 | Summer | Melilotus officinalis | 12 |
| Spring | Plantago lanceolata | 17,19 | Summer | Menispermum canadense | 5 |
| Spring | Plantago major | 19 | Summer | Monarda fistulos | 15 |
| Spring | Poa sp. | 12,13,14,16,17,18,19,20 | Summer | Onoclea sensibilis | 7 |
| Spring | Podophyllum peltatum | 14 | Summer | Parthenocissus quinquefolia | 1,2,3,4,5,6,8,9,10,14 |
| Spring | Polygonatum spp. | 9 | Summer | Phleum pratense | 12,19 |
| Spring | Prunus serotina | 4 | Summer | Pistia sp. | 10 |
| Spring | Rubus setosus | 2 | Summer | Pistia stratiotes | 6 |
| Spring | Rubus sp. | 4,6,11,18 | Summer | Plantago lanceolata | 17,19 |
| Spring | Sagittaria latifolia | 2,4,6 | Summer | Plantago major | 19 |
| Spring | Sanguinaria canadensis | 2 | Summer | Poa sp. | 11,15,16,17,18,20 |
| Spring | Smilax sp. | 5 | Summer | Polyganum virginianum | 1,2,4 |
| Spring | Solidago sp. | 13,14,15,18 | Summer | Polygonum sp. | 9,10 |
| Spring | Taraxacum officinale | 4,15,17,18,19,20 | Summer | Potentilla simplex | 12 |
| Spring | Thalictrum dioicum | 6,7,10 | Summer | Prenanthes alba | 5 |
| Spring | Tilia americana | 4,8 | Summer | Prunus sp. | 4 |
| Spring | Toxicodendron radicans | 3,4,15 | Summer | Quercus rubra | 14 |
| Spring | Trifolium pratense | 12 | Summer | Rhamnus sp. | 18 |
| Spring | Trifolium sp. | 19,20 | Summer | Ribes cynosbati | 10 |
| Spring | Trillium grandiflorum | 1,4,7 | Summer | Rubus allegheniensis | 4 |
| Spring | Trillium sp. | 6 | Summer | Rubus sp. | 2,8,11,14,18 |
| Spring | Ulmus americana | 2,6 | Summer | Sanguinaria canadensis | 2 |
| Spring | Viola sp. | 2,3,7,10 | Summer | Setaria pumila | 12 |
| Summer | Acer sp. | 2,4,6,8 | Summer | Solidago canadensis | 13,14,15,18 |
| Summer | Agrimonia sp. | 7,9 | Summer | Solidago gigantea | 18 |
| Summer | Agrimony gryposepala | 1 | Summer | Solidago sp. | 19 |
| Summer | Alliaria petiolata | 6 | Summer | Symphyotrichum sp. | 2,17 |
| Summer | Ambrosia artmsiifolia | 12 | Summer | Taraxacum officinale | 15,16,19,20 |
| Summer | Amphicarpaea bracteata | 3,4 | Summer | Thalictrum sp. | 6,7,10 |
| Summer | Aster sp. | 12 | Summer | Toxicodendron radicans | 3,4,6,14 |
| Summer | Bromus sp. | 18 | Summer | Trifolium pratense | 12,16,19,20 |
| Summer | Carex blanda | 1,9,11 | Summer | Trillium sp. | 7 |
| Summer | Carex pensylvanica | 9 | Summer | Ulmus americana | 6,7,11 |
| Summer | Carex sp. | 4,9,17 | Summer | Viola sororia | 1,2 |
| Summer | Carpinus caroliniana | 18 | Summer | Viola sp. | 9 |
| Summer | Carya sp. | 6 | Summer | Vitis sp. | 6 |
| Summer | Chicorium intybus | 19 | Summer | Waldsteinia fragarioides | 7 |



# APPENDIX F

| Levine Farm Expected Herpetofauna | |
|---|---|
| **Common Name** | **Scientific Name** |
| Northern Leopard Frog* | *Rana pipiens* |
| Eastern Tiger Salamander* | *Amystoma tigrinum* |
| Four-toed Salamander | *Hemidactylium scutatum* |
| Red-backed Salamander | *Plethodon cinereus* |
| Red-spotted Newt | *Notophthalmus viridescens viridescens* |
| Butler's Garter Snake | *Thamnophis butleri butleri* |
| Eastern Milk Snake | *Lampropeltis triangulum triangulum* |
| Northern Brown Snake | *Storeria dekayi dekayi* |
| Northern Ribbon Snake | *Thamnophis sauritus septentrionalis* |
| Northern Water Snake | *Nerodia sipedon sipedon* |
| Blanding's Turtle | *Emydoidea blandingii* |
| Eastern Snapping Turtle | *Chelydra serpentina serpentina* |

⁎ Other species known to occur based on communication with property owners, but not observed during our surveys.