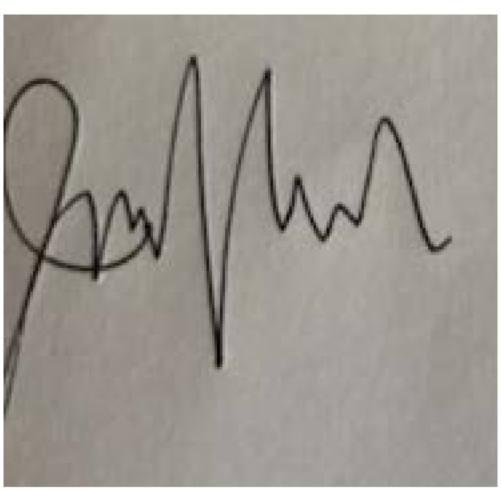
From Farm To [Pitch]Fork: An Agroecological Study of Pitchfork Farms in Petoskey, MI

Margaret Anderson

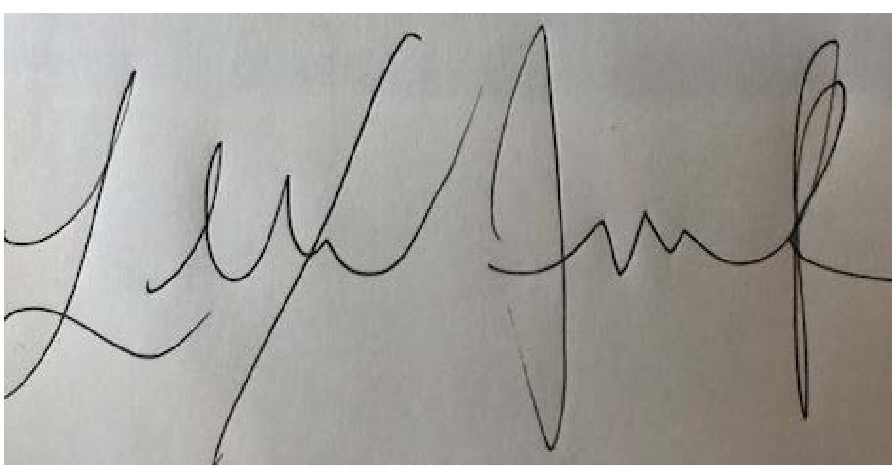
University of Michigan Biological Station
EEB 405 Agroecology
August 18th, 2018
Katie Goodall

From Farm To [Pitch]Fork: An Agroecological Study of Pitchfork Farms in Petoskey, MI

Lexi Frank

University of Michigan Biological Station
EEB 405 Agroecology
August 18th, 2018
Katie Goodall

From Farm To [Pitch]Fork: An Agroecological Study of Pitchfork Farms in Petoskey, MI

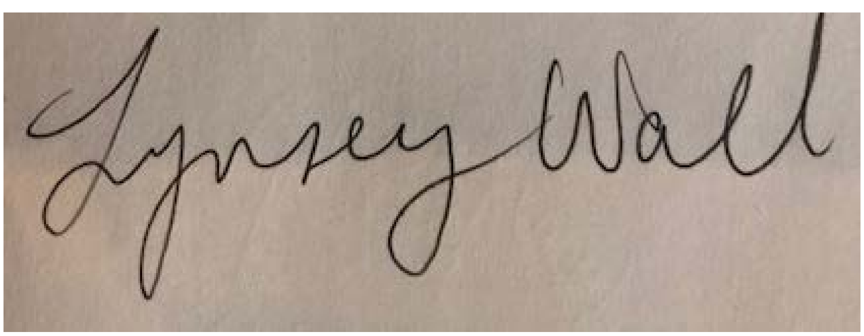
Jianella Macalino

University of Michigan Biological Station
EEB 405 Agroecology
August 18th, 2018
Katie Goodall

From Farm To [Pitch]Fork: An Agroecological Study of Pitchfork Farms in Petoskey, MI

Lynsey Wall

University of Michigan Biological Station
EEB 405 Agroecology
August 18th, 2018
Katie Goodall

Signed, 

From Farm to [Pitch]Fork: An agroecological study of Pitchfork Farms in Petoskey, Michigan

Marlee Anderson, Lexi Frank, Jianella Macalino, Lynsey Wall

18 August 2018

EEB 405 Agroecology - University of Michigan

Table of Contents

Introduction

Agroecology studies the science, movement, and practice of farming (Méndez *et al.,* 2016; Wezel *et al.,* 2009; Silci, 2014). The term “agroecology” manifested in the early 1900s from the studies of agronomy and ecology and focused on the use of ecological processes within agriculture. It was predominantly considered a science discipline and studied soil biology, plants in agricultural landscapes, etc. In the late 1900s and into the turn of the century, agroecology evolved to encompass a movement and practice in addition to the science. The movement evolved from a science into a larger focus on the food system and the sustainability and environmental efforts involved in agriculture, manufacturing, sales, and food access. A call for a more just and sustainable food system was adopted into the definition of agroecology. The practice involves applying principles studied in the science of agroecology to the farm and food producing processes (Wezel *et al.,* 2009). All three aspects are essential in creating the just and sustainable food system that agroecology aims for.

By studying farms through agroecological principles, much can be said about farm and environment interactions, farm management, farmer livelihood and much more. Farms are complex systems and all of the various parts of the farm work together in order to produce the food we eat. Individual farms can be involved in all three areas of agroecology and often times, these areas overlap and affect each other. Agroecological research approaches case studies holistically and looks at the farm as one agroecological system (Silici, 2014). Therefore, agroecological research is transdisciplinary and crosses various academic disciplines (Méndez *et al.,* 2016). Méndez *et al.* (2016) also describes a participatory, action-oriented approach (PAR). PAR involves the cycling of research, reflection, action and sharing. These are applied to agroecological research to encompass the three aspects of agroecology, the science, the practice and the movement, and holistically study a farm system.

This study approaches a small, family owned farm in Petoskey, Michigan that practices organic and sustainable farming and analyzes how the various aspects of agroecology display themselves on the farm. The six-week practicum involved working on the farm and with the farmers, participatory mapping, farmer interviews, and soil analysis. The first three weeks of the study at Pitchfork Farms was helping the farmer, Matt and Ellie Evans, with their farmwork. The goal of the farmwork portion of the study was to become associated with the farm and the farmers, and gain experience from and make observations on day to day farmwork. Participatory mapping allowed us to view the property from the farmer's perspective as Matt gave us a tour of the farm. A farm map was then created from this experience. A semi-structured farmer interview with both Ellie and Matt was conducted and delved further into questions about the farm, the farmers, and their perspectives of various parts of agriculture. Participatory mapping and farmer interviews analyzed livelihood assets that play a role in farmer livelihood and overall management of the farm. The last activity done on the farm was soil sampling, these samples came from areas of the farm where the farmers and us believed would be beneficial to explore the soil composition. These were ultimately done in the strawberry field and where chickens have grazed previously. This six-week objective with all of its different parts came together as a study of the agroecological system at Pitchfork Farms.

Site Description

Pitchfork farms is located in Petoskey, Michigan. It is a family-owned farm managed by Matt and Ellie who are also the only two workers on the farm. Ellie's father owns the land the farm is currently on as well as much of the surrounding property and currently farms hay and corn fields next to Pitchfork farms. Ellie's sister also lives on the property and does not farm on the land. The area currently being farmed by Matt and Ellie has been used for hay and pasturing in the past and for the years prior to the Evans family moving onto the property, the land stayed dormant and the house was rented out. The land is on a hill and overlooks Little Traverse Bay on Lake Michigan. It experiences loamy soil and Northern Michigan's long winters and short summers. Currently, Pitchfork farms raises meat chickens and has laying hens for eggs. They also have milking cows and a few pigs. Their current crops are strawberries, blackberries, raspberries, and saskatoons. It is in close proximity to downtown Petoskey and to the Petoskey and Harbor Springs Farmers' Markets and currently sells to both along with selling to local restaurants and institutions. This was also their first year running a u-pick strawberry stand on the property.

Literature Review Chapters

Methods of soil conservation for reduction of erosion and nutrient runoff

Soil conservation practices are vital to the health of the soil of an agroecosystem, and such measures are important to begin implementing before noticable changes to the nutrient profile and landscape begin to occur. This chapter examines the various methods that have been used as ways to reduce soil erosion and nutrient runoff in agriculture and construction settings. The purpose is to explore methods that would be applicable in future to agricultural settings, specifically Pitchfork Farms in northern Michigan. The main methods that were found to have application potential at Pitchfork Farms were weed stripping, intercropping, planting along the contour, and use of geotextiles.

Introduction

With intensity of agricultural working of a landscape, the quality and maintenance of the soil needs to be taken into consideration. The importance of soil quality is at the forefront of agricultural well-being because it influences land fertility, crop growth and yield, and the sustainability of the agroecosystem (Johnston, Poulton, & Coleman, 2009). The soil composition, meaning the proportions of clay, silt, and sand, result in differing textures and retention or drainage of moisture within the soil (Vereecken, 1989). Modern agricultural methods change the soil composition and structure by interfering with natural carbon, nitrogen, and phosphorus fluxes, leading to land that is less arable (McLauchlan, 2007). Tillage can cause aggregation of soils which then become more difficult to break apart and reduce the pore space within the soils (Gliessman, 2007; Kumar et al., 2017) Continual planting and use of the soils also depletes the nutrients within the soil (Alhameid, 2017). [Elaborate on the importance of soil quality in agriculture and how ag impacts soil quality such that constant maintenance is necessary]. These conditions include soil composition and structure, organic matter in the soil, nutrients, texture, acidity, and soil biota (Gliessman, 2007). This review will focus mainly on the issues of the organic horizon layer of soil and the soil and nutrient runoff caused by water flow. Throughout this review, use of water management practices are explored, including use of geotextiles, agricultural ditches and wetlands, weed stripping, agroforestry, and planting along contour lines.

While there are no current issues of erosion or known incidence of nutrient runoff at Pitchfork Farms, the topography and intensification of land use may put the farm at risk of nutrient and soil loss, especially as the midwest begins to experience more effects of climate change (Rotz, Skinner, Stoner, & Hayhoe, 2016). Pitchfork Farms has a rolling, hilly landscape (United States Geological Survey, 2013) and coarse-loamy to mixed soils with frigid soil regime (United States Department of Agriculture Soil Conservation Service, 1973) that, with continued agricultural use and without proper maintenance, would be susceptible to such detrimental soil depletion effects (Erik & Martin, 2018). The purpose of this review is to provide information about the various techniques that are used to prevent soil and nutrient runoff in agricultural settings.

Principles of Prevention: Soil Composition and Structure

Soil is the product of physical and chemical weathering of bedrock and of biotic processes (Gliessman, 2007). These processes create layers, or horizons, in the soil with the organic horizon being of particular emphasis and importance due to its function in supporting growth of plants. Retaining the organic layer is important and its retention is linked to what is growing in it and the texture of the soil (Tisdall & Oades, 1982). In a study of the role of root and fungal hyphae systems in macroaggregation of soils the role of macroaggregates on retention of soil moisture and stabilization to prevent the loss of soil in runoff, it was found that networks of roots and fungal hyphae lead to water retention of macroaggregate particles in the soil. Soil moisture decreases as the number of macroaggregates within the soil decreased, which occured when land was fallow or in production for agriculture, but increased with the use of land for pasturing of livestock (Tisdall & Oades, 1982).

As climate begins to change, it is important to acknowledge the necessity for change in agricultural processes in order to maintain resilience. There techniques within climate smart agriculture (CSA) which are integrated for the purpose of supporting greater resiliency of land in changing climates. Three common CSA techniques are agroforestry, soil and water conservation, and climate information services (Partey et al., 2007). Creation of platforms where policy is discussed is also important to further the integration of climate smart practices. Transdisciplinary approaches necessary for the successful scale-up and implementation of these techniques.

Methods of Control

Various methods of runoff control have been tested in regions around the world. In this review, methods thought to be most accessible and relevant for possible implementation at Pitchfork farms have been included. These methods include geotextiles, planting along contour lines and terracing, use of ditches and wetlands, weed stripping and intercropping. All these options have advantages and possible drawbacks which are important to consider when deciding which, if any, of these measures should be implemented into farming management practices.

Geotextiles

Geotextiles are mats that are woven out of natural fibers such as jute and straw which can be laid in between rows of crops. Examples of these can often be seen on the sides of highways after construction (Choudhury, Das, & Sanyal, 2008; Luo et al., 2013), after civil engineering projects (Agrawal, 2011), and in agriculture (Choudhury, Das, & Sanyal, 2008). The benefits of these are that they help to retain soil moisture (Bhattacharyya et al., 2012), prevent runoff and erosion (Bhattacharyya et al., 2012), and keep down the growth of weeds (Choudhury, Das, & Sanyal, 2008). The mats have the potential to be reused for multiple seasons (Bhattacharyya et al., 2012), but their lifespans are dependent on the local climate and weather as well as the types of treatments that are performed on the textiles (Agrawal, 2011). If the farm uses organic practices, as long as they are not treated with chemicals, the geotextiles can also be tilled into the soil after use and can increase the biomass and nutrients within the soil.

Geotextiles can take many forms and be made from materials that are local to the areas in which they are used. Jute and straw geotextiles were the most prevalent in studies and straw would likely be the most accessible for midwest farms because jute is grown in Bangladesh, China, and Thailand, with the majority of the global supply of jute grown in India (National Jute Board, 2018) while straw is grown throughout the US. The benefit of geotextile is that it also increases biomass, suppresses weeds, and prevents moisture loss, which are all issues pertinent to Pitchfork Farms. Bhattacharyya et al, (2012) conducted a study across China, Thailand, Vietnam and Lithuania and specifically looked at the use of biological geotextiles and their impact on biomass production. Biological textiles are often used for soil erosion control, and this study found that they also increased above ground biomass of crops by 6 - 53% and the areas where the geotextiles were used saw an increase in yield of their respective crops.

Jute geotextiles are used as a method to control nutrient and soil runoff and to retain soil moisture on tea farms at the Institute of Soil and Water Conservation in India (Manivannan et al., 2018). The most tightly woven jute geotextile, 700 grams per square meter (GSM), is the most effective for preventing runoff, loss of nutrients, and for retention of moisture within the soil. However, 500 GSM and 600 GSM jute biotextiles allow for better growth of plants and result in plants that were taller than those grown with the use of the 700 GSM geotextile. The tightness of the weave chosen for soil conservation is an important factor to consider for the desired outcome within the system.

Straw is also used for geotextiles and would be able to be locally sourced in Michigan. Shade net, non-woven fabrics, and straw mat geotextiles to reduce soil loss and runoff in highway construction zones in China had varying results. In Beijing-Chengde, construction of highways causes damage to the land because of exposure from construction and caused by the sloping landscape. Rainfall simulations were conducted on each of the three experimental geotextiles and it was found that while all three were found to be effective, straw mats were the most effective at reducing runoff compared to the exposed slope (Luo et al., 2013).

Contour Planting

Contour planting is the method by which the lines of planted rows of crops follow the contour and topography of the landscape. This is done so that when water runs down the slope of a landscape, the roots of the crops are trapping any soils and nutrients that would otherwise be runoff. Additionally, the use of contour planting creates micro terraces that trap water and allow for better drainage and absorption of water into the soil (Chow, Rees, & Daigle 1999). This both nourishes the plants and prevents flooding in low-lying areas of the landscape.

Soil erosion due to potato production and the slopes of the agricultural land was an issue in Canada. Graded diversions and grassed waterways were used to control some of the runoff. The two strategies were used in conjunction, with the terraces creating a diversion for the runoff and the grassed waterways allowing an area for the water to be reabsorbed and preventing flooding. The terraces increased the surface area of the slope and therefore allowed for better absorption of water. The two-part system reduced erosion and for potato crops is most effective when the system is created under the crop of plants (Chow, Rees, & Daigle 1999).

Water and soil management practices in Ethiopia have been explored in relation to their effectiveness during drought and provide an environment conducive to the study of yield effect of terracing. Terraced land better retains soil moisture and prevents soil erosion. However, yield on terraces is lower than yield of crops grown on un-terraced land. Despite this, during the drought season in 2015, terraces in Ethiopia farms allowed for better resilience during times of drought (Kosmoswski, 2018).

Changing the direction of tillage can help to reduce soil erosion on a slope and to show that the erosion on contour lines, while less than other methods, is still significant (Petr & Josef, 2018). Plot gradient, contouring, and the equipment that was used for tilling were taken into account to examine the impacts of tillage on soil erosion, specifically the effects of erosion in areas of secondary tillage, which are often more erosive than primary tilling events. It was found that the most erosive technique is when the soil is tilled at a downhill angle, and these effects are reduced when tillage occurs either at an uphill angle or on level ground. Soil erosion did still occur even when tilled along the contour lines (Petr & Josef, 2018).

Ditches and Wetlands

Prevention of runoff will preserve the farm but also to mitigate the detrimental effects of increased nutrients in waterways that affect the local, and even regional community. The use of agricultural ditches and wetlands can be used to improve water quality. Considerations of watershed are important to make and methods such as agricultural ditches and wetlands can be employed to mitigate detrimental effects of agriculture on their local and regional waterways. Channels and two-stage ditches are found to be useful for collecting nitrogen and phosphorus runoff and preventing it from flowing into waterways (Kalcic et al., 2018).

Weed Stripping & Intercropping

Weed stripping is when weeds and grasses are allowed to grow between rows of crops and can be maintained by mowing or use of chicken tractors. Allowing weeds to remain would allow the root systems of the weed plants to prevent soil runoff (Lenka et al., 2017). An issue with this would be especially with low growing plants, competition for resources such as sunlight, water, and space. Intercropping is similar to weed stripping in that a row of vegetation is grown between the rows, except that the planting of the crop that is between rows is intentional. For the crop that is grown between the rows of the primary crop, there are the conditions of use that need to be considered. Possible uses of the second crop are for sale and human use, for use as feed for livestock, or a ground cover to keep the weeds down or to use as a green mulch that can be tilled back into the soil.

Weeds in between crop rows can be beneficial to the health of the farm soil, and allowing weeds to grow in the rows would also save time that would otherwise be spent weeding the areas. Use of weeds in the strips between crops has been studied in India, in an area where terracing was not accepted because it is cost-intensive to create. The crops were grown on a 40% slope and included corn, groundnut, and natural vegetation strips. Crop rotation, planting on contour lines, and maintenance of the natural vegetation were monitored as the various techniques under study. It was found that the weed strips led to the creation of little terraces that allowed for better water absorption and less runoff, soil erosion, and nutrient loss (Lenka et al., 2017).

Intercropping is an effective way to retain soil nutrients and mass. Vineyards in the Mediterranean area account for a large portion of the crop harvested in the area, and the current practices led to soil erosion which resulted in nutrient loss and contamination of waterways. In this areas, it was found that planting a perennial grass within the grape crop prevented the soil erosion by 68% of what was lost in previous years (Napoli, Marta, Zanchi, & Orlandini, 2016).

Efforts to prevent agricultural erosion in the Himalayan Valley region included the use of blocked planting, alley farming, and contour planting of maize, grass, and clean fallow. Annual monsoon rainfall was tracked along with the resulting erosion over a 9 year period. It was found that contour planting reduced runoff by 27-45% and that erosion was further prevented when there was integration of tree rows and other living barrier strips such as hedgerows and micro terraces (Narain, Singh, Sindhwal, & Joshie, 1998). Integration of living barriers was recommended in these areas to prevent against soil erosion. The block plantations, which are higher density tree lines, were recommended on very steep slopes to prevent massive erosion. Contour planting would provide this same sort of living barrier at Pitchfork Farms.

Discussion

Of the methods examined in this review that would be the least time-, money-, and labor-intensive to implement were weed stripping and intercropping, planting along the contour, and geotextiles. All the the methods would confer some degree of efficacy in reducing soil runoff and nutrient loss. Implementations of some methods, such as terracing and creation of ditches and wetlands would be more intense and would greatly alter the landscape of farms where they were used. Other methods of soil runoff prevention, such as planting along contour lines, weed stripping, intercropping, and use of geotextiles would be less labor intensive to implement and require less economic inputs. These measures would have the added benefit of weed control, moisture retention, and could contribute to biomass increase within the organic horizon if it were able to be tilled into the soil after use.

During the participatory mapping activity, Matt pointed out the current and future areas for planting crops and grazing livestock. All of the areas that were identified for strawberries have a slight to moderate slope to their landscape, which might be a concern for future erosion and nutrient runoff. During the interviewing, it was learned that the soil was currently good and nutritious, and that it hadn't been worked for many years. This long fallow period likely contributed to the wealth of the soil, and maintenance is important to prevent nutrient runoff, which is where these techniques could possibly be implemented for use.

References

Agrawal, B. (2011). Geotextile: it's application to civil engineering. *National Conference on Recent Trends in Engineering & Technology,* 1-6.

Alhameid, A., Chervet, A., Weisskopf, P., Sturny, W., Etana, A., Stettler, M.,..., Keller, T. (2016).
Two decades of no-till in the Oberacker long-term field experiment: Part I. Crop yield, soil organic carbon and nutrient distribution in the soil profile. *Soil & Tillage Research, 163,* 141-151.

Bhattacharyya, R., Yi, Z., Yongmei, L., Li, T. Panomtaranichagul, M., Peukrai, S.… Booth, C.A. (2012). Effects of biological geotextiles on aboveground biomass production in selected agroecosystems. Field Crops Research 126, 23-36.

Choudhury, P., Das, A., Sanyal, T. (2008). Jute geotextile and its application in civil engineering, agri-horticulture and forestry. *New Horizons in Earth Reinforcement,* 239-242

Chow, T.L., Rees, H.W., Daigle, J.L.(1999). Effectiveness of terraces/grassed waterway systems for soil and water conservation: a field evaluation. *Journal of Soil and Water Conservation,* 577-583.

Erik, G., Martin, N. (2018).Estimating the impact of agri-environmental payments on nutrient runoff using a unique combination of data. *Land Use Policy, 75*, 388-398.

Gliessman, S. Soil. (2007). In *Agroecology: the ecology of sustainable food systems* (89-103).CRC Press.

Johnston, A., Poulton, P., Coleman, K. (2009). Chapter 1 soil organic matter: its importance in sustainable agriculture and carbon dioxide fluxes. *Advances in Agronomy, 101,* 1-57.

Kalcic, M., Crumpton, W., Liu, X., D'Ambrosio, J., Ward, A., Witter, J. (2018). Assessment of beyond-the-field nutrient management practices for agricultural crop systems with subsurface drainage. *Journal of Soil and Water Conservation, 73,* 1.

Kosmowski, F. (2018). Soil water management practices (terraces) helped to mitigate the 2015 drought in Ethiopia. *Agricultural Water Management, 204,* 11-16.

Kumar, A., Dorodnikov, M., Splettstößer, T., Kuzyakov, Y., Pausch, J. (2017). Effects of maize roots on aggregate stability and enzyme activities in soil. *Geoderma, 306,* 50-57.

Lenka, N.K., Satapathy, K.K., Lal, R., Singh, R.K., Singh, N.A.K., Agrawal, P.K…. Rathore, A. (2017). Weed strip management for minimizing soil erosion and enhancing productivity in the sloping lands of north-eastern India. FINISH THIS CITATION

Luo, H., Zhao, T., Dong, M., Gao, J., Peng, X., Guo, Y… Liang, C. (2013). Field studies on the effects of three geotextiles on runoff and erosion of road slope in Beijing, China. *Catena, 109,* 150-156.

Manivannan, S., Khola, O., Kannan, K., Choudhury, P., Thilagam, V. (2018). Efficacy of open weave jute geotextiles in controlling soil erosion and its impact on hill slope stabilization. Indian Journal of Agricultural Sciences, 88(5), 679-684.

McLauchlan, K. (2007). The nature and longevity of agricultural impacts on soil carbon and nutrients: a review. *Ecosystems, 9*(8), 1364-1382.

Napoli, M., Marta, A.D., Zanchi, C.A., Orlandini, S. (2016). Assessment of soil and nutrient losses by runoff under different soil management practices in an Italian hilly vineyard. Soil & Tillage Research. 168, 71-80.

Narain, P., Singh, R.K., Sindhwal, N.S., Joshie, P. (1998). Agroforestry for soil and water conservation in the western Himalayan Valley Region of India. *Agroforestry Systems, 39,* 175-189.

National Jute Board. (2018). *Ministry of Textiles: Government of India.* Retrieved from http://www.jute.com/about-us/faq

Partey, S., Zougmore, R., Ouedraogo, M., Campbell, B. (2018). Developing climate-smart agriculture to face climate variability in West Africa: challenges and lessons learnt. Journal of Cleaner Production, 187, 285-295.

Petr, N., Josef, H. (2018). Translocation of soil particles during secondary soil tillage along contour lines. *Water, 10,* 568.

Rotz, C., Skinner, R., Stoner, A., Hayhoe, K. (2016). Evaluation greenhouse gas mitigation and climate change adaptation in dairy production using farm simulation. *American Society of Agricultural and Biological Engineers, 59*(6), 1771-1781.

Tisdall, J., Oades, J. (1982). Organic matter and water-stable aggregates in soils. Journal of Soil Science, 33, 141-163.

United States Department of Agriculture Soil Conservation Service. (1973). Soil Survey of Emmet County, Michigan. Retrieved from https://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/michigan/emmetMI1973/emmetMI1973.pdf

United States Geological Survey. (2013). *USGS Topographic Quadrangle Maps by County: Petoskey* [map]. US Department of the Interior. Retrieved from http://www.dnr.state.mi.us/spatialdatalibrary/pdf_maps/topomaps/PETOSKEY.pdf

Vereecken, H. (1989). Estimating the soil moisture retention characteristic from texture, bulk density, and carbon content. *Soil Science, 148*(6), 389.

Agroecological Insect Pest Management

Pest management is an important aspect of every farm. The more knowledgeable a farmer is about potential pest populations, the better they will be able to identify and combat problems that arise over the years. It is important to have some methods for insect control already implemented or prepared to implement when pests arrive in an area. Climate change is bringing about many changes to our environment in the coming years. That means pest behavior will be even more unpredictable than it is now. Having pest management methods, like agro biodiversity, built into a farm will help prevent pest species from becoming out of control.

Introduction

Agriculture characteristically simplifies nature's biodiversity and requires the constant manipulation of humans for this order to be maintained. This fosters an unbalanced ecosystem on the farm that is continually disrupted by outside forces of nature and by human intervention. One disrupting force is animals, such as insects, that destroy crops or harm livestock. In terms of agriculture, pests are considered to be any animal that causes harm to crops or livestock (Hill, 1983). In economic terms, any damage to crops caused by insect populations that leads to a decreased yield or quality of crops, and therefore profits, are considered to be an insect pest (Hill, 1983). Individual populations of certain typical pest species are not always considered pest populations. Populations are regulated by abundance of natural enemies, host resistance and other biological interactions. If any of these processes are not checking these population sizes effectively, then periodic pest outbreaks will occur (Berryman, 1982). These pests can spread disease, ruin fruits, stunt growth and have many other adverse effects on crops. The pest problem is continually irritated by monocrops, intensification and other industrial farming techniques that drastically change the environment, such as the overuse of chemical pesticides. Populations are also driven to the pest levels by increasing temperatures due to climate change that alter the life cycles of insects and the environmental conditions (Bale et al., 2002). Even as we strive to manage pests in today's conditions, the environment is changing due to global warming. As temperatures rise, insect behavior, distribution, and range are changing (Bale et al, 2002). The basic prediction is that increasing global temperatures will cause the species to shift their geographical ranges closer to the poles or to higher elevations, and increase their population size (Cammell and Knight, 1992). Many models, case studies and predictions must be used to determine how agriculture will be affected and how to combat pest populations will climate change.

There are various methods that are used to combat these pests that can range from chemical pesticides to increasing biodiversity through the use of a biologically diverse range of crops and non-crops that prevent any one species from becoming a pest (Altieri et. al, 2004). Chemical pesticides continue to cause health and safety issues and ecological disruptions (Lewis et al, 1997). Chemical pesticides only offer short-term solutions to pests. A long term resolution can only be achieved by restructuring these systems and managing them as a total system. The shift from viewing agriculture as a direct line from inputs to outputs to a holistic, total system is outlined by agroecology. Agroecology is defined as the integrative study of the ecology of the entire food system, encompassing ecological, economic and social dimensions (Francis, 2003). An agroecological approach to farm management and structure supports long term, sustainable solutions to pests and provides other ecosystem services to the farm (Lewis, 1997). These services could be flood control, soil erosion prevention, weed control, decreased disease and other benefits depending on what aspects of agroecology are incorporated on a farm. This review will focus on agroecological management of pests through increased agrobiodiversity and a holistic view of the farm and the how insect pest management could change due to climate change in the future.

Biodiversity

The incorporation of more agrobiodiversity into agriculture can produce benefits for the management of pests. The existence of this biodiversity, such as a diverse group of varieties, ages of plants or species of plants, can lead to enhancement of natural pest enemies, decreased damage to crops and to other beneficial 'bottom up effects' (Solomon et al., 2010). Some natural enemies are known to act as vital natural limiting factors in the development of pest population (Alan, 1982). Increasing biodiversity can be very simple to more complex and still lead to benefits. Increases in biodiversity often start with reducing aspects of industrialized farming. Monocultures are one aspect that can be changed relatively simply. The lowest level of change would be to vary the ages of the crop within the field. This would help pest management because as an older row is harvested, natural pest enemies can migrate to the adjacent row and be present for pests on that row. The natural enemies migrate around the one field and continually offer protection from pests. They are never completely wiped out by a full harvest on a field, so they can continue to prevent pest level population sizes throughout the season (Gurr, 2001). This technique is sometimes referred to as strip cutting or strip cropping and is an alternative to harvesting an entire field at a time (Altieri et al., 2004). This technique would also help because some insect pests prefer or only attack certain stages of development of plants.

The next step up to increasing biodiversity in a monoculture would be to grow a mix of varieties or closely related species of crop (Gurr, 2001). Studies have shown that oviposition and damage were lowered in mixtures of multiple varieties (Peacock & Herrick, 2000). Also, this method would slow the progression of diseases through a field (Wolfe, 2000). Insects often prefer or rely on certain varieties of a plant for growth and nutrients which would prevent the pest from traveling through the entire field quickly. The resource concentration hypothesis (Root 1973) predicts that specialist herbivorous insects will be more abundant in large patches of host plants because these insects are more likely to find and reside longer in those patches. One way to combat large patches of monocultures is to incorporate weeds into the field. This could be done through strip cropping or borders around the field to reduce competition with crops (Hill, 1983). Weeds will increase biodiversity and prevent the negative effects of monocropping. Weed populations favor natural enemies by providing pollen and nectar and habitat (Cook et al, 2007). Competition between weeds and crops is one trade-off to incorporation of weeds into a field however strip cropping or bordering reduces this competition. Non-weed plants, like cover crops, can also be used in the same way when introduced as strips within the field (Swezey, 2014). These strips can provide over wintering habitat and migration corridors for natural enemies (Chiverton, 1986). A variation of this would be to place these non-crops just adjacent to the crops as a border instead of in strips within the field. This could be done with trees and hedges as well which would provide a wind buffer for crops (Gurr, 2001).

The next step away from a monoculture that favors pest management is abandoning the monoculture all together. This can be done with simple techniques, such as intercropping, to complex matrices of polycultures. One specific method is trap cropping. Trap crops are used to attract insects and other pest organisms to protect target crops from pest attacks, prevent the pests from reaching the crop or concentrating in them so they are economically destroyed (Shelton and Badenes-Perez, 2006). For example, some trap crops contain oviposition or gustatory stimulants that help retain pest populations in the trap crop (Cook et al., 2007).Trap cropping can vary based on target crop characteristics, trap crop characteristics and how they are distributed in time and space (Hokkanen, 1991). One method of trap cropping is called dead-end trap cropping because the trap crop is highly attractive to insects however, their offspring cannot survive on it. This serves as a sink for pests and prevents future movement back to the crop. These crops are best placed where they can intercept insects and reduce damage to the main crop (e.g. field borders) (Hill, 1983). Multiple trap crops can be used to trap multiple types of insects or to increase the control of one insect by enticing it at different growth stages. Trap crops also sometimes have the ability to recruit natural enemies (Hokkanen, 1991). This means that the natural predators or competitors of a pest insect are attracted to an area by the trap crop to keep the population of the pest smaller (Hokkanen, 1991). Natural enemies can control pest populations through predation, avoidance behavior and competition for resources (Cook et al., 2007).

The insect's stage in life is very important to designing an effective trap crop management strategy. This is so important because certain insects do damage to crops at different stages in life (Gurr, 2001). For example, in some insects the damage to crops is done during oviposition of eggs into fruit. Other insects damage plants through herbivory or by spreading diseases as adults (Hokkanen, 1991). There is no specific trap crop that works on every field. The type of pest, main crop, climate and soil conditions will play a big role in choosing a trap crop. There are some limitations to trap cropping. Because they are not nearly as effective as broad spectrum pesticides, they are not always the first choice in pest management. They also require heavy planning and a large knowledge base (Shelton and Badenes-Perez, 2006). The success of trap cropping is also highly variable and research has shown variable levels of success (Cook et al., 2007). However, success is increased by proper research into what trap crops can work for the conditions of a specific farm (Cook et al., 2007). Despite the limitations, trap cropping can provide sustainable, long term management when it is implemented correctly and it is biologically based. This method likely requires a multifaceted approach that involves more research and extension in the future to better develop its use (Shelton and Badenes-Perez, 2006). Trap cropping is one way that biodiversity can be used to the advantage of the crops in a system.

Biodiversity is a clear advantage, in terms of pest management, when it is executed properly (Gurr, 2001). When biodiversity decreases the effects of pests, the need for pesticide inputs also decreases. This could lead to improved crop quality, higher yields, and economic benefits (Gurr, 2001). Money can be saved by using biodiversity as a tool to control pests in the long term instead of paying for pesticides every season. The use of biodiversity also promotes ecosystem services for other aspects of the farm besides pest management. If biodiversity has been added through the introduction of leguminous plants, then atmospheric nitrogen will be fixed and benefit crops planted in the future (Franche, 2009). The addition of trees introduces a wind break for crops and livestock shelter. Trees also provide aesthetic, recreational, and conservation value. Diverse vegetation prevents soil erosion by wind and water (Jose, 2009). This in turn helps prevent or reduce eutrophication of waterways by input nutrients like nitrogen and phosphate from runoff (Edwards and Abivardi, 1998). These methods of using biodiversity outline the benefits to pest management and other secondary benefits. The degree of the benefits from biodiversity depends on the extent to which biodiversity is incorporated into the management of a farm (Gurr, 2003). Benefits would also be influenced by the location, soil, pests, economics, and wildlife ecology of the farm and surrounding area. Incorporating biodiversity means looking at the farm as a whole and as a part of the surrounding environment (Lewis et al., 1997).

All of the methods above lead to a more holistic view of the farm in terms of pest management. The major problems generated by industrial farming like toxic residues, pest resistance to pesticides, secondary pests and pest resurgence can be diminished or avoided by using the ecosystem to the advantage of the farm through careful and planned management (Lewis et al., 1997). This is because the components of an agricultural ecosystem interact through a set of feedback loops to maintain balance within functional bounds (Wezel et al., 1997). An example of this is when a plant in the natural ecosystem is eaten by an insect and then produces toxins to discourage herbivory. It takes a certain amount of herbivory to trigger to production of toxins but then those toxins prevent a detrimental amount of herbivory and therefore reaching pest level population sizes (Wittstock, 2002). Without allowing a certain amount of herbivory, the pests are not stopped naturally by the plant. Considering the crop as an active component of the interactions of the environment is a necessary part of an agroecological approach. The crop does not exist in isolation with inputs, outputs and negative influences acting on it. The farm influences the surrounding area and is influenced by it. Actions on the farm, such as using monocrops, attract pest and cause their populations to exceed normal levels because the resources are so abundant and in close proximity. A change to an agroecological approach for pest management through a greater use of inherent strengths based on a good understanding of interactions within an ecosystem will create a more stable and sustainable system (Lewis et al., 1997).

Insect Pests and Climate Change

The latest assessment report from the Intergovernmental Panel on Climate Change (IPCC) expects an increase in average temperature from 1.1 to 5.4°C toward the year 2100 (Meehl et al. 2007). An increase of this scale is predicted to affect global agriculture significantly (Cannon 1998). In addition, such changes in climatic conditions could profoundly affect the population dynamics and the status of insect pests of crops (Porter et al. 1991; Cammell and Knight 1992; Woiwod 1997). The leading abiotic factor of climate change that directly affects herbivorous insects has been identified as temperature change (Bale et al., 2002). Factors such as CO_2, UVB, and precipitation have shown little evidence of direct effects or have yet to be extensively studied. Therefore, this section will focus on how temperature effects herbivorous insects. Rising temperature can lead to changes in the rate of development, voltinism (number of broods per year), population density, size, genetic composition, extent of host plant exploitation and local and geographical ranges (Dukes et al. 2010).

All of these factors could have effects on pest population and activity in agricultural fields. However, not all insects will be affected in the same way by climate change because of their differing life histories and adaptability (Estay, 2009). Insects that live in extreme environments, such as the arctic, are likely to have the most pronounced effects on their life cycle and ranges because they require very particular habitats. They may suffer contraction of their current range because movement to higher latitudes is often quite limited. However, insect species that occupy many habitats across a range of latitudes and altitudes and have genotypic and phenotypic plasticity are expected to be less adversely affected by climate change. They may even experience an increase in population size and expansion of their geographic ranges to increasing latitudes and altitudes as temperatures rise (Cammell and Knight 1992). In the absence of cold winters, insect pests may breed continuously throughout the year and not be killed by frost and cold as frequently (Hill, 1983). They may also be able to migrate earlier in the season (Duke et al., 2010). This is supported by fossil evidence that shows that insects were more likely to track climate change than stay in their current environment and adapt to it (Bale et al., 2002). As the southernmost boundaries of a geographic range become too warm, insect species will move northward. So what does this mean for agriculture? This means that insect species could move from lower latitudes to higher latitudes, affecting farms that have not previously seen that species. There may also be a loss of native species in higher latitudes and altitudes (Cammell and Knight 1992). Insect species arrive earlier in the season because of higher temperatures and be able to proliferate multiple times over the season. To try to predict how insect distribution might be affected by climate change, a bioclimatic model can be used. Bioclimatic models consider climatic variables and correlate them with observed distributions to predict future distributions (Pearson, Dawson, 2003). This model however can range from simply using climate data to using many data points, such as competition, biotic factors, and resource availability. More complex models tend to be more accurate but also more subjected to inaccurate or incomplete data being used (Pearson, Dawson, 2003).

Despite this research and fossil evidence, it is difficult to tell what exactly will happen because of climate change since there are so many factors that affect it. Uncertainty plagues all the models and predictions made by scientists (Dukes et al., 2010). For example, increasing extreme weather events may have a more profound effect on insects than temperature (Rosenzweig et al., 2001). Also, direct effects of climate change are hard to distinguish from indirect effects because every factor is so connected with other factors. The models we build have inherent limitations and there is a great complexity to natural systems (Pearson, Dawson, 2003). We must employ different scenarios when the reliability of the predictions is not clear, which is the case of the predicted future climate change (Cammell and Knight 1992). Enhanced climate forecasts, case studies and multiple models would assist farmers in preparing for changing seasonal and annual conditions, and improves pesticide management while minimizing environmental damage (Rosenzweig et al., 2001).

Implications on Pitchfork Farms

At the University of Michigan Biological Station, the Agroecology class for the 2018 summer semester worked with Pitchfork Farms in Petoskey to learn about agroecological concepts. Currently, Pitchfork Farms grows strawberries, raspberries and saskatoons and raises cows, laying hens and meat chickens. For dealing with pest management with climate change, watching pests that affect crops south of Petoskey and monitoring their movement to the north would help for being aware of coming pest issues. The MSU extension website makes posts every year about which pests have been detected in which areas and how to tell if they are on your crops. To incorporate biodiversity, starting with small changes first could work. Adding other varieties of strawberries to the field would add biodiversity at a small scale. Then slowly adding elements like trap crops and intercropping over the years to increase biodiversity. Putting a few trap crops in place if strawberry pests are determined to be in the area would be helpful. One thing to be aware of is that placing trap crops before pests are identified on a farms plants can sometimes attract the pest that is supposed to be deterred (Shelton and Badenes-Perez, 2006). Some trap crops that have been identified for strawberries are corn, alfalfa, and wheat depending on which insect is the pest (Hokkanen, 1991). Truly lasting and successful solutions to pest problems requires a shift to understanding and promoting naturally occurring biological agents and other inherent strengths of the ecosystem as components of total agricultural ecosystems and designing cropping systems so that natural forces keep the pests from exceeding acceptable bounds (Lewis et al., 1997).

References

Altieri, M., Nicholls, C. (2004). Biodiversity and Pest Management in Agroecosystems, Second Edition. Boca Raton: CRC Press.

Bale, J. S., Masters, G. J., Hodkinson, I. D., Awmack, C., Bezemer, T. M., Brown, V. K., ... & Good, J. E. (2002). Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. Global change biology, 8(1), 1-16.

Berryman, Alan A.(1982). Biological Control, Thresholds, and Pest Outbreaks , *Environmental Entomology*, Volume 11, Issue 3, 1 June 1982, Pages 544–549, https://doi.org/10.1093/ee/11.3.544

Cammell M, Knight J (1992). Effects of climatic change on the population dynamics of crop pests. *Adv. Ecol. Res.* **22**, 117–162.

Cannon R (1998). The implications of predicted climate change for insect pests in the UK, with emphasis on non‐indigenous species. *Glob. Chang. Biol.* **4**, 785–796.

Chiverton P (1986). Predator density manipulation and its effects on populations of Rhopalosiphum padi (Hom: Aphi- didae) in spring barley. Annals of Applied Biology 109: 49–60.

Cook, S. M., Khan, Z. R., & Pickett, J. A. (2007). The use of push-pull strategies in integrated pest management. Annual review of entomology, 52.

Dukes, J. S., Pontius, J., Orwig, D., Garnas, J. R., Rodgers, V. L., Brazee, N., ... & Ehrenfeld, J. (2009). Responses of insect pests, pathogens, and invasive plant species to climate change in the forests of northeastern North America: What can we predict?. *Canadian journal of forest research*, *39*(2), 231-248.

Edwards PJ, Abivardi C (1998) The value of biodiversity: where ecology and economy blend. Biological Conserva- tion 83: 239–246.

Estay, S. A., Lima, M., & Labra, F. A. (2009). Predicting insect pest status under climate change scenarios: combining experimental data and population dynamics modelling. *Journal of Applied Entomology*, *133*(7), 491-499.

Franche, C., Lindström, K., & Elmerich, C. (2009). Nitrogen-fixing bacteria associated with leguminous and non-leguminous plants. *Plant and soil*, *321*(1-2), 35-59.

Francis, C., Lieblein, G., Gliessman, S., Breland, T. A., Creamer, N., Harwood, R., ... & Wiedenhoeft, M. (2003). Agroecology: the ecology of food systems. *Journal of sustainable agriculture*, *22*(3), 99-118.

Gurr, G. M., Wratten, S. D., & Luna, J. M. (2003). Multi-function agricultural biodiversity: pest management and other benefits. Basic and Applied Ecology, 4(2), 107-116.

Hill, D. S. (1983). *Agricultural insect pests of the tropics and their control*. CUP Archive.

Hokkanen, H. M. (1991). Trap cropping in pest management. Annual Review of Entomology, 36(1), 119-138.

Jose, S. (2009). Agroforestry for ecosystem services and environmental benefits: an overview. *Agroforestry systems*, *76*(1), 1-10.

Lewis, W. J., Van Lenteren, J. C., Phatak, S. C., & Tumlinson, J. H. (1997). A total system approach to sustainable pest management. Proceedings of the National Academy of Sciences, 94(23), 12243-12248.

Meehl G, Stocker T, Collins W, Friedlingstein P, Gaye A, Solomon S, Qin D, Manning M, Chen Z, Marquis M (2007). *Climate Change, 2007: the Physical Science Basis. Contribution of Working group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK and New York, NY, USA.

Peacock L, Herrick S (2000) Responses of the willow beetle Phratora vulgatissima to genetically and spatially diverse Salix spp. plantations. Journal of Applied Ecology 37: 821–831.

Pearson, R. G., & Dawson, T. P. (2003). Predicting the impacts of climate change on the distribution of species: are bioclimate envelope models useful?. *Global ecology and biogeography*, *12*(5), 361-371.

Porter JH, Parry ML, Carter TR (1991). The potential effects of climatic change on agricultural insect pest. *Agric. For. Meteorol.* **57**, 221–240.

Root RB (1973). Organization of a plant-arthropod association in simple and diverse habitats: the fauna of collards (Brassica oleracea). Ecol Monogr 43:95–124

Rosenzweig, C., Iglesias, A., Yang, X. B., Epstein, P. R., & Chivian, E. (2001). Climate change and extreme weather events; implications for food production, plant diseases, and pests. *Global change and human health*, *2*(2), 90-104.

Scherm, H. (2004). Climate change: can we predict the impacts on plant pathology and pest management?. Canadian Journal of Plant Pathology, 26(3), 267-273.
Sideman, E. (1988). Organic Strawberry Production. Maine Organic Farmers and

Gardeners Association.

Shelton, A. M., & Badenes-Perez, F. R. (2006). Concepts and applications of trap cropping in pest management. Annu. Rev. Entomol., 51, 285-308.

Solomon, M. G., Jay, C. N., Innocenzi, P. J., Fitzgerald, J. D., Crook, D., Crook, A. M., ... & Cross, J. V. (2001). Natural enemies and biocontrol of pests of strawberry in northern and central Europe. Biocontrol Science and Technology, 11(2), 165-216.

Swezey, S. L., Nieto, D. J., & Bryer, J. A. (2014). Control of western tarnished plant bug Lygus hesperus Knight (Hemiptera: Miridae) in California organic strawberries using alfalfa trap crops and tractor-mounted vacuums. Environmental entomology, 36(6), 1457-1465.

Walsh, D. B., Bolda, M. P., Goodhue, R. E., Dreves, A. J., Lee, J., Bruck, D. J., ... & Zalom, F. G.
(2011). Drosophila suzukii (Diptera: Drosophilidae): invasive pest of ripening soft fruit expanding its geographic range and damage potential. Journal of Integrated Pest Management, 2(1), G1-G7.

Wittstock, U., & Gershenzon, J. (2002). Constitutive plant toxins and their role in defense against herbivores and pathogens. *Current opinion in plant biology*, *5*(4), 300-30

Woiwod I (1997). Detecting the effects of climate change on Lepidoptera. *J. Insect Conserv.* **1**, 149–158.

Wolfe MS (2000). Crop strength through diversity. Nature 406: 681–682.

Strawberry Cover Cropping through Intercropping and Living Mulches

Cover cropping describes living ground cover grown among a primary crop for ecosystem services. Pitchfork Farms has expressed interest in cover cropping their strawberry fields during rest years to prevent soil degradation. Such a practice could also be an effective form of weed control among the strawberry rows. This chapter discusses different forms of cover cropping, the factors necessary to consider when choosing a cover crop, and the many ecosystem services that cover cropping can provide. It also considers different end-of-season uses for cover crops within a sustainable agricultural framework.

Introduction

Pitchfork Farms in Petoskey, Michigan grows strawberries as a predominant cash crop, primarily selling them through "U-Pick" consumer harvesting in the summer season. The Honeoye strawberry variety grown at Pitchfork is cultivated in a three-year cycle, in which seedling crowns planted in the first year are subsequently harvested in the second and third year before they are removed from production. At the time of this paper's creation in the summer of 2018, Pitchfork Farms harvested berries grown in its inaugural strawberry field for the first time, and intended to stop cultivation on these plots for a one-year rest period. This cyclical process is highly labor intensive for the farmers due to their commitment to natural farming techniques, as extensive hand weeding and pruning is required throughout maturation years without the use of inorganic pesticides. Additionally, although frequent resting periods between production years are necessary for maintaining yield capability and minimizing pathogen presence, they also pose a possibility of erosion and nutrient loss if left fallow (Gliessman & Engles, 2007).

Given these limitations, Pitchfork Farms has expressed interested in cover cropping during rest years as a protective measure for soil health. This proposal has high practical value if it is able to satisfy the agroecological needs of the farm while also meeting its management and economic capabilities. Cover cropping can provide numerous ecosystem services beyond just soil retention if carefully integrated into the agroecosystem, including those of direct interest to Pitchfork Farms such as weed control, prevention of water and nutrient runoff, and production of fodder (Ramirez-Garcia, 2015). The family-run operation of the farm also lends itself to potential cover cropping; Pound *et al*. describe the ideal cover cropping partners as those that engage in a “medium- to high- intensity of land use, combined with low external-input use,” qualifications which closely match the smallholder organic farming model used by Pitchfork Farms (1999). Considering the interests and management abilities of the farmers, Pitchfork Farms is a good candidate for cover cropping within their strawberry production across multiple scales and techniques.

What is cover cropping?

The definition of cover cropping is variable and continually developing. Generally, it can be described as any non-predominant crop grown, either temporally or spatially, among land used for the production of primary crops with the intention of providing ecosystem services (Hartwig & Ammon, 2002; Pound *et al*., 1999). A distinctive characteristic of cover cropping models is a focus on maintaining ground cover over idle land. Rotational systems that ignore this aspect in favor of other structural or ecosystem needs are not typically considered cover cropping, despite any services they produce. While this definition encompasses many traditional crop rotation systems, intercropping and living mulch techniques have emerged as the most popular modern iterations of these systems due to their broad applicability and numerous benefits.

Intercropping is the cultivation of a cover species within idle ground between the rows or fields of a primary crop. The cover species can decrease weed presence, mitigate nutrient loss, or fix atmospheric nitrogen, while also adding aesthetic value to the farm or acting as a secondary cash crop (Pound et al., 1999). Living mulch generally describes any form of crop-based ground cover, although here I will use it to mean vegetative ground cover grown over resting fields that would otherwise remain fallow (Hartwig & Ammon, 2002). Once the resting period has ended, this crop can be left within the field as a green manure to control the release of nutrients back into the field in accordance with the needs of the primary crop, or it can be removed from the field for uses such as livestock fodder or consumer sale (like with grains such as rye). Both intercropping and living mulch techniques could be implemented at Pitchfork Farms to address some of their agroecological concerns, and I will evaluate the potential applications and benefits of both within the context of their current strawberry cultivation.

Choosing a Cover Crop

Selecting an appropriate species for a cover cropping system can be challenging and error-prone. Every possible combination of primary crops and cover crops will yield different interactions based on both the innate characteristics of the plants and the localized restrictions of the environment. Renewed agroecological interest in cover cropping has led to hundreds of studies about specific crops and their benefits; in a cursory literature review, four studies alone listed over a dozen species as potential strawberry cover crops, including brown mustard (*Brassica juncea*), white clover (*Trifolium repens*), perennial ryegrass (*Lolium perenne*), sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*), soybean (Glycine max), velvet bean (Mucuna deeringiana), rapeseed (*Brassica napus*), buckwheat (*Fagopyrum esculentum*), black oat (*Avena strigosa*), black-eyed Susan (*Rudbeckia hirta*), marigold (*Tagetes erecta*), big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), and Indiangrass (*Sorghastrum nutans*) (Muramoto *et al*., 2014; Neuweiler *et al*., 2003; Shanks & Chamberlain, 1993; Garland *et al*., 2011; Portz & Nonnecke, 2011).

In order to choose between such varied options, farmers must identify both the outcomes they are hoping to achieve and potential negative interactions. These negative interactions can have repercussions for farm productivity and management long after they occur, so identifying weaknesses in the primary crop can be crucial. One significant concern in the selection of a strawberry cover crop is the existence of Verticillium wilt "host species" (Muramoto *et al*., 2014). Strawberries are particularly vulnerable to Verticillium wilt, and infected plant matter can remain in the soil and harm crops years after the initial diseased season. "Host species" may attract and harbor the pathogen responsible for Verticillium wilt, *Verticillium dahliae,* and pass the disease along to neighboring strawberries or contaminate the soil. While the majority of Verticillium host species are vegetables such as lettuce and tomatoes, some experiments have suggested that perennial ryegrass (*L. perenne*) is a potential host of the disease (Portz & Nonnecke, 2011). Intraspecific competition is another notable issue in cover cropping interactions. Strawberries are high-energy crops with a shallow root system, and are thus easily susceptible to being outcompeted by adjacent crops that vie for the same resources. White clover (T. *repens*) is a relatively popular strawberry cover crop, but several experiments have shown that competitive nature of the species frequently leads to decreased fruit yield over several seasons (Neuweiler et al., 2003; Shanks & Chamberlain, 1993). Eliminating perennial ryegrass and white clover from consideration as potential cover crops, the abundance of remaining options is nonetheless still daunting. In the following sections, I will examine potential cover cropping ecosystem services that are of most interest to Pitchfork Farms, and make recommendations as to which cover crop species best satisfy these utilities.

Combating “Yield Decline”

Strawberry cultivation is extremely taxing on soil health because it depletes nutrients while attracting pathogenic organisms (Muramoto et al., 2014). Growing strawberries on a single plot of land continuously without breaks between seasons can lead to significant yield decline in an extremely short timespan; farmers have vested interest in preventing the threat that this reduction poses to their financial success. The optimal solution for combating yield decline without the use of chemical fumigants (which contradict Pitchfork Farm’s organic approach) is the implementation of fallow periods, but these periods can be expensive for farmers. Three to five years of rest between cultivation periods are recommended by various sources, which represents a major opportunity cost in the loss of harvesting years as well as the labor sink necessary to maintain fallow fields (Muramoto et al., 2014; Portz & Nonnecke, 2011). The ability to shorten rest periods through cover cropping by expediting necessary soil improvements therefore constitutes one of the greatest justifications for cover cropping in modern agriculture.

Cover crops facilitate the acceleration of resting years through several different ecological processes, which vary in their usefulness depending on the needs of a particular farm.

One of the chief limitations on any crop yield is the amount of soil nitrogen that is available for plants to use. Leguminous crops like soybean or hairy vetch fix atmospheric nitrogen and convert it into organic compounds that can then be taken by neighboring crops, contributing to the overall nitrogen content of a field (Cherr *et al*., 2006). Nitrogen fixation can be incorporated in to either intercropping or living mulch systems based on seasonal needs; interseeding legumes among primary crops with high ongoing nitrogen demands can force the legumes to continually convert and release organic nitrogen throughout the duration of a season, while cover cropping fields with legumes during rest periods and then integrating the plants in to the soil as a green manure can restore depleted nitrogen and time its release to meet the early nutritional requirements of the next batch of primary crops (Cherr *et al*., 2006).

A specific limitation on strawberry crop yields is the presence of parasitic nematodes in soil. These pathogens increase in concentration with successive strawberry cultivation, and the avoidance of chemical fumigation can complicate their removal. One natural method of eliminating parasitic nematodes is promoting the soil inoculation of native mycorrhizal fungi, which reside in the root system of a crop and facilitate mineral and water absorption (Garland *et al*., 2011). Mycorrhizal fungi compete with soil pathogens while lending mutualistic advantages to crops such as increased nutrient uptake ability. By planting mycorrhizal-friendly living mulches such as sorghum (*S. bicolor*) on idle or resting land, farmers can attract the colonization of these fungi into production fields.

Lastly, cover crops can increase the soil organic matter (SOM) of a field if plant biomass is left to decompose rather than harvested (Cherr *et al*., 2006) Increased SOMs can improve the formation of soil aggregates and the overall tilth of a field, which in turn enhances the root growth, nutrient uptake, and drainage of future crop cultivation (Gliessman & Engles, 2007).

The potential for cover crops to improve the long-term soil quality of a farm while maintaining yield expectations is immense; Muramoto *et al*. concluded that appropriate cover crop management could produce yield improvements from a single rest year that rivaled those obtained after three or more fallow years (Muramoto *et al*., 2014). Incorporating a version of these systems into the strawberry cultivation at Pitchfork Farm's could aid the farmers in achieving future productive stability as they expand their fields and venture into future harvesting years.

Weed Control

Weed control is chief concern for the owners of Pitchfork Farms. The farm's strawberry fields experience extreme weed growth during the summer months, and the farmers have found few organic sprays that are effective in combating this invasion. A significant portion of their weekly labor must therefore be dedicated to weeding the strawberries by hand, a process that is greatly stressful given the need to sustain strawberry crops for two years prior to harvest. They have also identified the need to maintain walking paths between strawberry rows for their "U-Pick" customers, and any cover plant grown within these rows must sustain the daily disturbance of being walked over.

With these considerations in mind, cover crops can act as an extremely efficient form of weed deterrent that requires less ongoing labor than traditional organic methods such as hand pulling or natural spraying. Both intercropping and living mulches present attractive weed control options at different times in the season. The basic avenue through which cover crops prevent weed growth is competition, as they are able to control the resources that are necessary for weed survival (a corollary observation of this activity is that cover crop species may also compete for resources with the primary crop – see the earlier discussion of white clover) (Neuweiler et al., 2003; Shanks & Chamberlain, 1993). Species that produce high dry biomass and extensive cover, like pearl millet or grasses, are the best at outcompeting weeds (Garland *et al*., 2011). In addition to preventing new weed colonization maintaining any plant growth on a field continuously will act to disrupt the existing seed bed, and intervene in the growth cycle of weeds which may promote their continuing survival despite a farmer's best efforts. A particularly effective weed deterrent is allelopathic crops, which are those plants that possess a natural defense mechanism against weed competition by releasing antagonistic chemicals into the soil. Winter rye (*Secale cereal*) and subterranean clover (*Trifolium subterraneum*) are two popular cover cropping species with allelopathic effects, and their incorporation into a primary crop through interseeding can act to suppress weed growth throughout a field (Hartwig & Ammon, 2002).

Interseeding strawberry fields with a high biomass crop could prevent the excessive seasonal weed growth that Pitchfork Farms experiences. Grass intercropping may be a viable option for a weed deterrent within strawberry rows that could withstand human disturbance during the summer months, while maintaining a living mulch cover of a species such as winter rye on resting fields could help prevent or decrease the severity of future weed invasion.

Erosion and Runoff Prevention

Soil degradation is a constant problem within agriculture that has been investigated extensively over the last century. The yearly tilling that is necessary to produce annual crops represents a massive disturbance of the soil strata, and leaving fields fallow exposes them to erosion by wind or water. Additionally, water can leech essential nutrients from the soil and wash external inputs out of fields and into crucial waterways (Hartwig & Ammon, 2002). Fertilizer runoff is a major modern environmental issue. Cover cropping can help combat erosion and runoff because cover species establish stabilizing root structures and slow the movement of nutrients through agricultural matrices (Hartwig & Ammon, 2002). The owners of Pitchfork Farms have a high concern for soil quality due to their views of conventional agriculture, citing it as one of the most important qualities of agricultural sustainability. By growing cover crops during resting years, they can help reduce the removal of soil from their farm while barring nutrient drainage into the surrounding ecosystem. Further, portions of their strawberry production lie on inclines that may promote uneven nutrient distribution between fields and consequently result in diminished yield. Intercropping within these fields can allow cover crops to act as nutrient catches, stabilizing the equal release of resources among every level of production.

Living Mulch Uses: Green Manure vs. Fodder

While living mulches can perform numerous ecosystem services throughout their tenure if properly integrated into a farm, much of their utility also derives from what happens when the primary crop is re-planted. Sustainable agroecosystems seek to maximize the potential uses for every input and output in the landscape, and post-season applications for cover crops (especially living mulches) are no exception. Pitchfork Farms has expressed interest in using cover crops as either a green manure or livestock fodder at the end of resting seasons, and the decision to implement one procedure or the other will be a determining factor in which cover crops to grow.

In a green manure approach, the cover crop would be integrated into the soil bed before strawberry planting begins and allowed to decompose in place. The release of nitrogen and SOMs into the field could be accelerated by reaping the cover crop and mixing its biomass into the soil through tillage, or slowed by planting strawberries directly into the dead remains of the cover crop. This technique can be especially effective at increasing productivity in the plow layer of the soil, and should be implement if the farmers are concerned about yield declines from soil degradation (see 'Combating "Yield Decline"') (Cherr *et al*., 2006). Cover species such as mustards and vetches are most suited for use as a green manure because they have a low carbon to nitrogen ratio and decompose easily (Ramirez-Garcia *et al*., 2015). In a fodder approach, cover crops may be harvested at the end of the season and processed into livestock feed, allowing farmers to conserve energy within their own property without outsourcing resources from commercial parties. Cover species such as grasses are most suited for use as fodder because they have a high fiber content and are easily digestible by livestock (Ramirez-Garcia *et al*., 2015). Pitchfork Farms should evaluate the economic benefit to be obtained by stabilizing future strawberry yield versus producing livestock feed internally, and choose an appropriate cover cropping species accordingly.

Discussion

Pitchfork Farms is an excellent candidate for the introduction of cover cropping into their current strawberry production. Intercropping active strawberry fields with a cover crop can help mitigate the current weed problem, as well as provide additional soil organic matter and nitrogen fixation (if a leguminous species is chosen) to neighboring strawberries plants. Species choice should be influenced by their ability to withstand disturbances from U-Pick customers, and grasses or vetches are proposed as potential options. Growing living mulches during rest years will protect their soil from erosion and nutrient runoff, while increasing productive potential through nutrient addition, weed deterrence, and pathogen prevention. Several options are available for this approach depending on the farmer's intended goals: sorghum is effective in combating parasitic nematodes, mustards and vetches add high organic matter to the soil while decomposing easily, and grasses provide good fodder for livestock. Integrating cover crops into farming operations can be a remarkably sustainable way of achieving agroecological goals without resorting to external inputs. Given the organic agricultural views and organizational resources of Pitchfork Farms, cover cropping poses a novel solution to current management concerns that meets farming needs while promoting greater harmony with the surrounding environment.

References

Cherr, C. M., Scholberg, J. M. S., & McSorley, R. (2006). Green manure approaches to crop production: A synthesis. *Agronomy Journal, 98*(2), 302-319. Retrieved from http://proxy.lib.umich.edu/login?url=https://search-proquest-com.proxy.lib.umich.edu/docview/194511171?accountid=14667

Garland, B. C., Schroeder-Moreno, M. S., Fernandez, G. E., & Creamer, N. C. (2011). Influence of Summer Cover Crops and Mycorrhizal Fungi on Strawberry Production in the Southeastern United States. *Horticultural Science,46*(7), 985-991. Retrieved July 14, 2018.

Gliessman, S. R., & Engles, E. W. (2007). Soils. In Agroecology: The ecology of sustainable food systems (pp. 89-102). Bosa Roca Fla.: CRC Press.

Muramoto, J., Gliessman, S.R., Koike, S.T., Shennan, C., Bull, C.T., Klonsky, K. & Swezey, S. (2014). Integrated Biological and Cultural Practices Can Reduce Crop Rotation Period of Organic Strawberries, *Agroecology and Sustainable Food Systems*, 38:5, 603-631, DOI:10.1080/21683565.2013.878429

Hartwig, N.L., & Ammon, H.U. (2002). Cover Crops and Living Mulches. *Weed Science, 50*(6), 688-699. Retrieved from http://www.jstor.org/stable/4046641

Neuweiler, R., Bertschinger, L., Stamp, P., & Feil, B. (2003). The Impact of Ground Cover Management on Soil Nitrogen Levels, Parameters of Vegetative Crop Development, Yield and Fruit Quality of Strawberries. *European Journal of Horticultural Science,86*(4), 183-191. Retrieved July 14, 2018.

Pound, B., Anderson, S., & Gundel, S. (1999). Species for Niches: When and for Whom Are Cover Crops Appropriate? *Mountain Research and Development, 19*(4), 307-312. Retrieved from http://www.jstor.org/stable/25164046

Portz, D. N., & Nonnecke, G. R. (2011). Rotation with Cover Crops Suppresses Weeds and Increases Plant Density and Yield of Strawberries. *Horticultural Science, 46*(10), 1363-1366. Retrieved July 14, 2018.

Ramirez-Garcia, J., Gabriel, J. L., Alonso-Ayuso, M., & Quemada, M. (2015). Quantitative characterization of five cover crop species. *The Journal of Agricultural Science, 153*(7), 1174-1185. doi:http://dx.doi.org.proxy.lib.umich.edu/10.1017/S0021859614000811

Shanks, C. H., Jr., & Chamberlain, J. D. (1993). Strawberry Fruit Yield and Vegetative Growth and Pest Populations in Plantings with and without Cover Crops. *Horticultural Science, 28*(12), 1172-1173. Retrieved July 14, 2018.

Marketing Expansion and Community Involvement

Apart from producing food, a farm is also a business that is a part of the local community and requires marketing strategies and business plans. A farmer is more than just someone who produces food, they are also running a business on their farm. This chapter explores increasing efficiency in making profit on the farm through various ventures and opportunities. The ventures outlined can be particularly beneficial for local farms that practice sustainable and organic practices as there is the movement in support of that type of agriculture. These marketing and business ventures explored for Pitchfork farms are agritourism, market stands, certifications, and community partnerships.

Introduction

Many different industries today are changing and emerging constantly to follow advancements of technology and serve the evolving interests of consumers. One of the oldest and largest industries is the agriculture industry. In 2015, agriculture, food and related industries $992 billion to U.S. growth domestic product (GDP) and American farms contributed $136.7 billion of it (United States Department of Agriculture: Economic Research Service, 2016). Although farmers provide food for the world, the agriculture industry and its value to the United States is more than just farm output. Food services, manufacturing, fishing, and more are included among the “agriculture, food and related industries” contribution to U.S. GDP (United

States Department of Agriculture: Economic Research Service, 2016) . These various components in the food system are potential opportunities for farmers to diversify their revenue and find alternative income sources from their farm.

The city of Petoskey, Michigan's population estimates of 2017 is approximately 5,724 and has an estimated median household income (MHI) of $39,690 as of 2016 (United States Department of Commerce, 2017). Although the city of Petoskey itself has a lower MHI compared to Michigan's statewide MHI, driving through the area on US highway 31 may give off a different impression. The city is settled on the coast of Little Traverse Bay in Lake Michigan and is a popular vacation spot for many. Along the main highway, the coastline is filled with resorts and vacation homes. Downtown Petoskey is filled with trendy coffee shops, restaurants and souvenir shops. However, also in Petoskey is Pitchfork Farms, a family farm practicing organic and sustainable agriculture. In a tourist-heavy area like Petoskey, a small farm has the opportunity to fill niches in the food and agriculture market that can uniquely serve the demographics of the area. As support for local food systems and shorter streams of food production increases, farms such as Pitchfork have the opportunity to provide more for their community than just food that will benefit both the farm and the community. This chapter explores the different approaches to on-farm market stands, agritourism, support from local restaurants, and marketing of products that are viable for a sustainable farm in the Petoskey, Michigan area.

Agritourism

When talking to the farmers at Pitchfork, they acknowledged that consumers are increasingly interested in knowing where their food is coming from. This is an increasing trend nationally and there is a surge of urbanites interested in visiting rural places (Che, 2006). However, Pitchfork's main consumer base comes from the local population (M. Evans, personal communication, July 25, 2018). An increasing interest in food production outside of food producers would introduce an agritourism market at Pitchfork that would allow them to take advantage of the potential consumers of the tourist population in the area. Carpio, Wohlgenant and Boonsaeng (2008) define agritourism as "visits to farms, ranches and other agricultural settings with recreational purposes." This can include u-pick programs, hayrides, farm sales, educational events, etc. (Carpio *et al.,* 2008).

As tourism is one of Michigan's largest industries, there is great potential for success of agritourism (Wichtner-Zoia and Nicholls, 2015). Linking agriculture to a large and valued industry such as tourism can preserve more of Michigan's farming culture (Che, 2006). Pitchfork Farms also has an advantage in this aspect, due to its close proximity to downtown Petoskey. Michigan's tourism assets include the natural resources and scenic landscapes of the great lakes and agriculture fits into the natural aesthetic people look for when traveling to Michigan (Che, 2006). With Lake Michigan just across the street, Pitchfork can be a stop along the way that can diversify tourist's trips to the area. Agritourism not only allows for more revenue for the farm, it is a good marketing technique for products on the farm as well. Agritourism and on-site sales gives the general public the chance to see where their food is coming from as they're buying it. This exchange allows for the value of the food to be greater emphasized (Che, 2006). For a farm like Pitchfork, that values sustainable and organic practices, this exchange allows for a growing relationship of trust of the practices on the farm as well as awareness of the values of the farmers and their practices.

Agritourism is not only beneficial in providing farms more on-site traffic for marketing and additional revenue for farmers but also for the local community. Through expansion of existing agriculture towards agritourism, the land is transformed into multi-use land. This is more economically beneficial for a community as it has the potential to bring in more traffic to the community itself and these visitors can also invest in other local businesses and attractions (Bernardo, Valentin, and Leatherman, 2004). Agritourism also has the potential to involve the farm with the greater tourism community and give them access to resources outside of the local agricultural community. Agritourism does require large investment as many farms do not have the infrastructure, time and resources to being participating in an entirely new industry (Veeck, G., Che, and Veeck, A., 2006). However, Che (2006) suggests that farms close to major population centers may be better supported for agritourism operations. With Petoskey's influx of tourists in the summer months, agritourism has the potential to sufficiently support these type of attractions. An agritourism venture that connects an individual farm to a greater agritourism community as well as decreases the amount of investment for an individual farm is the implementation of agricultural trails. Food tourism originally focused on the food served at restaurants, hotels, and attractions of tourist areas but has now become the center of tourist travel as people look for food to experience and enjoy (Mason and O'Mahony, 2007). Although, there was no information about agricultural trails in and around Petoskey, agricultural trails are an attraction in Michigan. Mason and Oceana Counties have a joint agricultural trail map that connect various farms on the west side of the state along Lake Michigan (Mason & Oceana County Agricultural Trail Map, 2015). The trail encompasses various types of farms with different specialties and products. The implementation of an agricultural trail could be beneficial in an area like Petoskey, where there is a dense tourism center surrounded by farms like Pitchfork and could be the link between the commercial and retail heavy downtown Petoskey to the rural, farm abundant surrounding areas.

Market Stands

One means for creating revenue on the farm is through an on-farm market stand. This is a form of agritourism as it brings consumers onto the farm and can open up opportunities for more than just buying and selling food and can be combined with more agritourism attractions. This is the most direct producer-consumer interaction and allows for the most exchange of knowledge and information between the two groups. Gasteyer, Hultine, Cooperband and Curry (2008) explores the relationship between local food initiatives, such as farmers' markets, and urban and rural communities. they found contrasts between the markets in urban and rural areas. Rural areas struggled to find enough support in terms of bringing in customers and finding enough support in management and production for the market. Urban markets were found to draw consumers in for more than just purchasing food, urban markets were found to be more vibrant and consumers came for the ambiance and market environment. Differences in income levels between rural and urban areas also influenced the success rates of the markets (Gasteyer *et al.,* 2008). Although Pitchfork would be working at a smaller scale with a farm stand on the property, these patterns may still be relevant due to their overall community. The local community that they are currently serving, more closely resembles a rural community with its small population and lower average income, yet, they have they also have the tourist and seasonal populations. They would see less of a struggle in potential customers, especially in the summertime, if they advertise and market to tourists, but may struggle to find long-term management and employment for the work needed to support a market stand on the farm.

A market stand can be the first step in beginning farm expansion for agritourism. Beginning with direct product sales brings consumers onto the farm and also allows for more direct relationship between farmer and customer. Their consumers may become interested in operations of the farm or aspects of agriculture that may not be immediately seen or understood through just the direct sales and can be an opportunity for the farm to begin with agricultural education events or participatory farm experiences. Specifically for sustainable and environmentally conscious farms, having consumers come to the farm allows for the spread of awareness of the farmer’s values and the effort farmers put in to uphold those values through their agricultural practices. Pitchfork has expressed interest in showing consumers the production side of their food, to create relationships with their customers and show their customers their practices (M. Evans, personal communication, July 25, 2018).

Certifications

Allen and Kovach (2000) acknowledge the increase and production of organic food and its place as a major market trend. Since 2000, this trend has continued to increase and therefore, national and international governments have been involved in creating policy in order to regulate and standardize the production of organic food (Vogl, Kilcher, and Schmidt, 2008). Vogl *et al.* (2008) suggest a shortcoming to this government involvement is that much of organic farming practices are embedded in traditional and cultural knowledge, that may be different from country to country, region to region or even farm to farm. This makes it increasingly difficult for policy to encompass all of these unique practices and make overarching standards of organic agriculture

(Vogl *et al.,* 2008). Also within this trend of organic agriculture is an idea that it inherently aligns with sustainable agriculture (Schreck, Getz, and Feenstra, 2005). This is not typically the case due to the globalization of organic agriculture, there is a global market that involves importing and exporting organic goods. The transportation involved in global organic agriculture diminishes its environmental sustainability in comparison to other movements like the local food movement. As organic farming becomes a larger part of the agricultural industry and more policy is created, it must be more specific to uphold the values of individual regions and cultures (Vogl *et al.,* 2008). Without this specificity, the "organic" label may not fully encompass the values of sustainable agriculture. However, organic labels are some of the most popular seen in grocery stores and most demanded for people looking for sustainable food. This can be offset by closer farmer-consumer communication. If a farmer and a consumer have a relationship and there is trust there, certifications aren't as necessary because consumers trust the farmer's word about their practices and values.

Branding for farmers is a way for farmers to ensure their consumers of the quality of their food as well as uphold the values of the farmer without having to have a conversation with every customer (Che, 2006). This is especially important for farms looking to expand and diversify their farm revenue to keep a consistent reputation among consumers. Branding makes it easier for a farm to have a presence in multiple areas, from produce in different markets to agritourism attractions. Che (2006) also suggests the opportunity for brands to spread awareness of local and quality food. For sustainable and organic farms that do not specifically have the organic certification, consistent branding such as creating a logo to put on products and farm advertisements may be advantageous to attract customers who support their values of sustainability.

Community Partnerships

As local food movements have emerged and grown globally, the movement not only encompasses farms and producers, but also encompasses other parts of the food system downstream, such as vendors and manufacturers (Starr *et al.,* 2003). Another opportunity for farms to market and further involve themselves in the community is through working with other businesses and organizations in the local area such as restaurants, hotels, gift stores and gas stations (Veeck, Che, and Veeck, 2006). A study in central Iowa suggests that many restaurants and foodservice institutions (mainly school districts) were very interested in supporting local farmers. The study observed that although there was interest in supporting local food producers, there is a difference in the needs of institutions and restaurants. Institutions were more flexible in the seasonality of food whereas restaurants were more rigid in their orders because they have a set menu everyday (Strohbehn and Gregoire, 2003). Although there are situation-specific necessities and adjustments between farmer and institution, the willingness to support local food is still present in both institutions and restaurants.

This community partnership, where farmers are selling to other local businesses helps the farm in multiple ways. The first is diversifying the sources of revenue for farmers as they can depend on restaurant sales as well as direct consumer sales. Another benefit of working with local businesses is the marketing and advertising associated with working across industries. Many of the restaurants involved in using local food want their consumers to know of their sustainable practices and are willing to share what farms they are working with and typically, consumers who are also supportive of this movement will be attracted to their businesses (Starr *et al.,* 2003). This relationship is beneficial for many parties - the farms, the businesses, and the economy of the overall community.

Discussion

Diversification of farm revenue allows a farm to obtain more economic sustainability. This diversification can come in multiple forms but ultimately includes investment for farm expansion and building of infrastructure to accommodate growth of consumer traffic. Agritourism gives the farm the opportunity to further involve themselves in the local community. Especially in a tourist-heavy area like Petoskey, the agritourism is a viable option to tap into an already existing and thriving industry in the area. Among community involvement is also working with other local businesses and organizations which benefits the farm through increased revenue, advertising and resources outside of the agriculture industry. An on-farm market stand can become an initial step in farm expansion that can later serve agritourism programs. Market stands also allows farmers to directly show consumers their efforts for environmental sustainability on their farm. More direct selling of products as well as more consumers seeing the farm processes first-hand also diminishes the need for certifications monitored by international and national governments that may not be as beneficial for localized family farms. Diversifying revenue sources has many economic and social benefits and with growing movements for a more sustainable and local food system, there is are many opportunities for a farm to simultaneously do both.

References

Allen, P. and Kovach, M., The capitalist composition of organic: The potential of markets in fulfilling the promise of organic agriculture. Agriculture and Human Values, 17(3), pp. 221-232. https://doi.org/10.1023/A:1007640506965

Bernardo, D., Valentin, L., Leatherman, J. (2004). Agritourism: If we build it, will they come?, Manhattan: Kansas State University, Research & Extension.

Carpio, C. E., Wohlgenant, M. K., Boonsaeng, T. (2008). The Demand for Agritourism in the United States. Journal of Agricultural and Resource Economics, 33(2), pp. 254-269.

Che, Deborah. (2006). Select Michigan: Local Food Production, Food Safety, Culinary Heritage, and Branding in Michigan Agritourism. Tourism Review International, 9(4), pp. 349-363. https://doi.org/10.3727/154427206776330616.

Gasteyer, S., Hultine, S. A., Curry, P. M. (2008). PRODUCE SECTIONS, TOWN SQUARES, AND FARM STANDS: COMPARING LOCAL FOOD SYSTEMS IN COMMUNITY CONTEXT. Southern Rural Sociology, 23(1), pp. 47-71.

Mason and Oceana County Agricultural Trail Map. (2015). Pureludington.com; The Ludington/Mason County Cultural and Economic Development Task Force.

Mason, R., O'Mahony, B. (2007). On the Trail of Food and Wine: The tourist search for meaningful Experience. Annals of Leisure Research, 10:3-4, 498-517, DOI: 10.1080/11745398.2007.9686778

Shreck, A., Getz, C. & Feenstra, G. (2006). Social sustainability, farm labor, and organic agriculture: Findings from an exploratory analysis. Agriculture and Human Values, 23(4), pp. 439-449. https://doi.org/10.1007/s10460-006-9016-2.

Starr, A., Adrian, C., Benepe, C., *et al.* (2003). Sustaining local barriers and opportunities to direct marketing between farms and restaurants in Colorado. Agriculture and Human Values, 20(3), pp. 301-321. https://doi.org/10.1023/A:1026169122326

Strohbehn, C.H., Gregoire, M.B. (2003). Caste studies of local food purchasing by central Iowa restaurants and institutions. Food Service Research International, 14(1), pp. 53-64. https://doi.org/10.1111/j.1745-4506.2003.tb00177.x

U.S. Department of Commerce, U.S. Census Bureau. (2017). Quickfacts: Petoskey, Michigan. Retrieved from census.gov.

Veeck, G., Che, D. & Veeck, A. (2006). America's Changing Farmscape: A Study of Agricultural Tourism in Michigan. The Professional Geographer, 58(3), pp. 235-248. DOI: 10.1111/j.1467-9272.2006.00565.x

Vogl, C.R., Kilcher, L., & Schmidt, H. (2005). Are Standards and Regulations of Organic Farming Moving Away from Small Farmers' Knowledge? Journal of Sustainable Agriculture, 26(1), pp. 5-26. https://doi.org/10.1300/J064v26n01_03

Wichtner-Zoia, Y., Nicholls, S. (2015). Michigan's tourism industry continues to grow. Michigan State University Extension. Retrieved at: http://msue.anr.msu.edu/news/michigans_tourism_industry_continues_to_grow

Participatory Mapping

Introduction

Participatory mapping was performed by a farmer-led tour of the land.The purpose of this participatory mapping was to understand the layout of the farm and to gain better understanding of the way that the farmers saw the land (McCall & Minang, 2005), the reasoning behind the decisions they made regarding design and land use (McLain, Poe, & Biendenweg, 2013), and the current and potential issues they foresaw with the land. Going into the mapping exercise, the livelihood assets that we wanted to learn about were identified. Livelihood assets describe resources available to farmers that have a determining effect on their success (De Haan, 2012). The seven livelihood assets that we studied were physical, social, cultural, political, natural, human, and financial; we identified physical, social, cultural, and natural assets as being particularly relevant to the management of Pitchforks Farms and worthy of further inquiry. The social assets describe the community and educational assets of the farming agroecosystem that influence the way that it is managed and the success that it experiences. The natural assets that were looked for were related to topography and soil quality. We remained aware of these characteristics during the mapping activity in order to later inform the areas for soil sampling. The physical assets of the farm included its location in relation to farmers' markets and the irrigation source that is used for the farm. The cultural assets of the farm include the socioeconomic status of the Petoskey area and the way that family values shape the practices of the farm.

Methods

The land of interest was that which Matt and Ellie owned and cultivated, both currently and in past and future years. Because the land was originally owned by Ellie's father, they have the ability to expand their farm into adjacent lands in the future, so the property lines are less well-defined than if it had not been family-owned land. A map of the land was hand-drawn as the land was toured. The types of questions that were asked included those about what was planted where and why, how the landscape and built environment had changed over the years, and what the future plans for the farm were in terms of crop and livestock rotations as well as plans for market enterprises like the building of a farm stand.

Results

The map that resulted from this mapping activity (Figure 1), shows an aerial view of the farmland that is being worked currently or has plans to be worked in the future. The bottom left side of the farm map depicts the house and the the cattle and calf barns as well as the areas for grazing and compost piles. Towards the middle of the left side of the map shows the laying hen barn. To the left of the barn are the coops for meat poultry. Each coop contains a different age of chickens and they are rotated through the four coops as they mature to the age at which they are able to be butchered. The dashed lines show the presence of temporary fencing that can be moved so that the chickens and cows can be grazed in different areas. The current field that was used for the strawberry picking in July 2018 is located centrally on the map. East of the current strawberry field are the blackberries and raspberries and six rows of saskatoon berry bushes. North of the current strawberry field is a larger field of strawberries that were planted in July and August 2018. The open space between and behind the current strawberry fields that is now a hay field is planned for future expansion. Matt and Ellie plan to build a market stand here and rotate the strawberry fields around the stand as the strawberry crop needs to be rotated every three years.

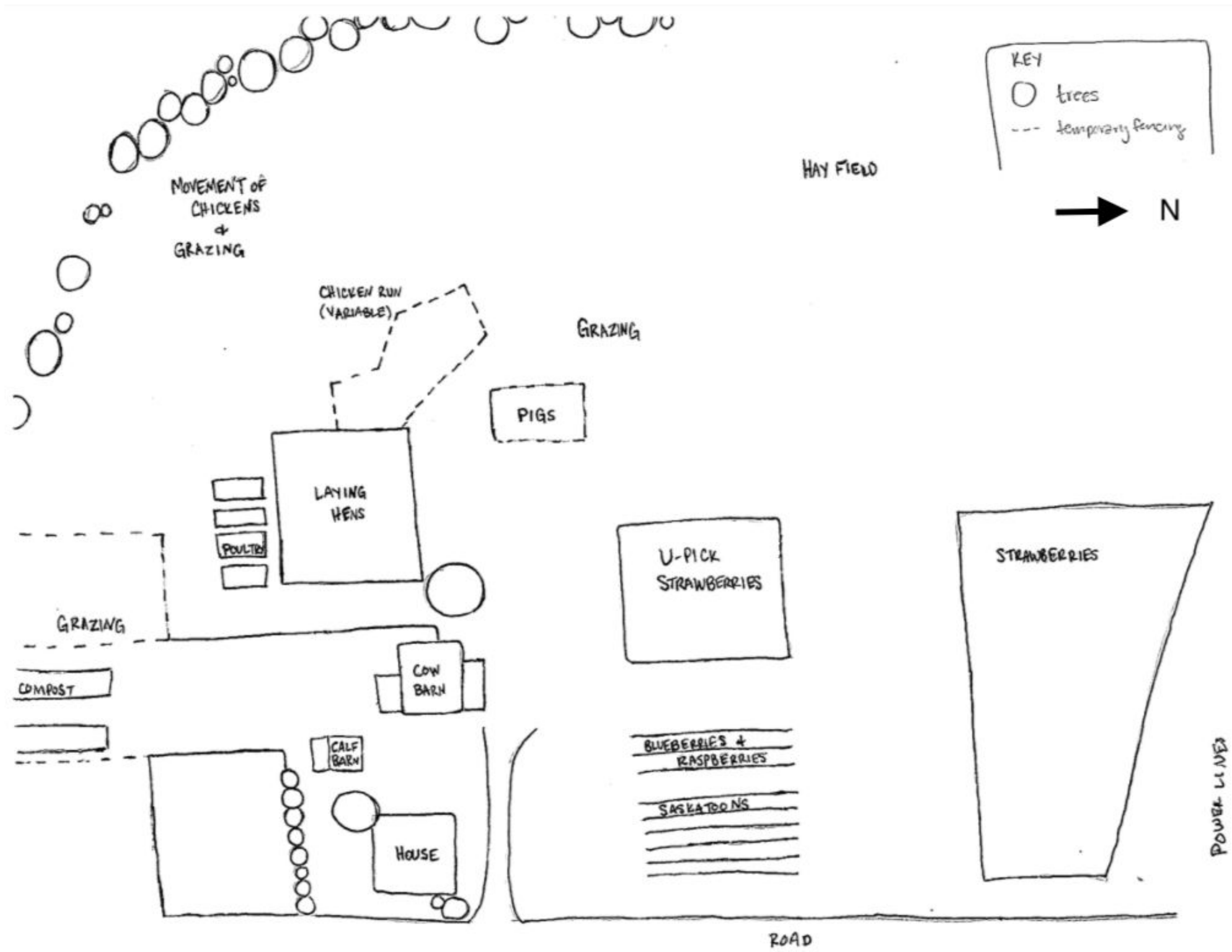


Figure 1. Map of Pitchfork Farms

Discussion

Creation of the map informed our understanding of where we would take soil samples, and will provide a record of the areas of crop production for planning future crop rotations. It demonstrates the farmers' perspective of the layout of the land and is likely influenced by the knowledge they had of how the farm had been in the past and their future plans for the land and infrastructure they plan to build. Their descriptions of the limitations to the farm were also included, such as the hilly, tree-dense area adjacent to their farm that had been sold but which Matt had expressed that he would have had use for. This example demonstrates how there are many things that happen on and to the farm that are out of the control of the decisions that farmers make.

Farmer Interview

Methods

Before organizing our interview, we reviewed the results of our participatory mapping and used the data to analyze the livelihood assets of Pitchfork Farms. Considering these assets, we formulated an interview script that would give us greater insight into our farmers' goals and values, as well as answer questions related to our chapter topics. Questions were organized into five categories: Introduction, Marketing and Social, Physical, Decision Making, and Sustainability and Nature. Within each category, questions were structured from least to most complex so that we could solidify practical details before delving into abstract concepts. Questions were also semi-structured and open ended, allowing the farmers to personally interpret them and answer as they found most appropriate. On July 25, we conducted an interview at Pitchfork Farms with both farmers present. Before beginning the interview, we informed the farmers that they could decline to answer any questions. We documented the interview on an electronic recorder, in addition to taking notes. After the interview was finished, we reviewed the notes to conclude our livelihood analysis and listened to the audio file for relevant farmer quotes.

Results

Our interview was an hour long. The farmers answered every questions, and Matt and Ellie alternated giving responses. Both farmers had experience in agriculture before starting

Pitchfork Farms; Ellie grew up on a family farm, and Matt attended the Michigan State University Dairy Program. Decisions about which commodities to produce have been influenced by the farmers' personal desires for their family. Ellie said, "Our farm has always come from what we wanted… Everything that we have done has been what we have wanted for ourselves, and that other people have shown interest in." In particular, she discussed wanting to grow strawberries for her children because her grandfather ran a strawberry farm when she was a child. Matt described their consumers to be local people with an interest in local food. As Ellie explained, "They want to know where their food comes from. They want to know who their farmer is. They want to see how you're doing it. They don't necessarily need you to be certified organic." Word-of-mouth is the most important aspect of advertising for Pitchfork Farms. One of their major goals for the farm is the construction of a market stand on the property because they believe it will help better facilitate personal interactions with their customers, as well as reduce their dependence on the local farmer's markets. They particularly identified greater efficiency and hired labor as two of the necessary steps for attaining this goal. The farm has experienced few ecological challenges. Skunks and coyotes have eaten some of the chickens in past seasons, but they have not experienced any other major pest or disease issues. In general, their soil is nutritious and conducive to farming because it was left dormant for years before Pitchfork began production. As Matt said, "We have good heavy ground... Ellie's dad has just been doing hay for a lot of years, so it hasn't had anything on it." Both Ellie's family and other local farmers are vital resources for decision-making and assistance. Discussing these relationships, Ellie said, "It's such a great community, and farmer want to see other farmers succeed... I've never felt that I'm competing against these other farmers." They attend many local farms and events, and expressed a desire to become more involved with this community if time allowed. The farmers believe that interest in the organic practices of their farm reflects a growing societal attitude, as Ellie stated, “It’s coming. In time, you’re gonna see it go the other way. The majority of agriculture is gonna be organic, because consumers want it.”

Discussion

The results of our interview gave us better insight into the four livelihood assets of Pitchfork Farms that we had chosen for study. The social assets of the farm largely depend on the interpersonal relationships between the farmers and their customers that Evans had identified. Both Petoskey and Harbor Springs have extremely popular weekly farmers markets, which reflect the local interest in supporting small farms and sustainable agriculture. By having a face to face interaction, customers are able to witness firsthand the methods that a farmer is practicing and know exactly what is going in to their food (Corsi & Novelli, 2015). Matt and Ellie cite this relationship as being crucial for customer loyalty and word-of-mouth advertising, especially considering modern organic farming certifications. Because the certification process is tedious and expensive, developing a connection with their customers allows Pitchfork Farms to prove the legitimacy of their practices without relying on governmental validation. The physical assets of the farm are influenced by both the farmers’ family history and their goals for the future. Because the property is family land, some extent structures impacted where they chose to construct new infrastructure like the barn or the cow pen. Proximity to family is both a physical and a social asset; Ellie’s family helps with the weekly chicken processing, and they often consult her father for advice. Decisions about infrastructure also center heavily around plans to build the market stand. Matt and Ellie want the strawberry patches to be easily accessible from the road because it will maximize interaction with the increased customer traffic they anticipate from building the market stand. Natural assets derive from the good soil quality present on the farm and relative lack of pest issues. The time that the farm spent idle before the Evans resumed production was likely very crucial to promoting good soil formation. Because Pitchfork Farms is managed organically, the farmers have great opportunity to prevent much of the soil degradation that is so prevalent in conventional agriculture. Considering all the beneficial aspects of the farm's ecosystem, the farmers must still work within the constraints of the local environment. The area is extremely hilly, promoting them to center production around flat open areas. The soil is loamy and more basic, which is inhospitable for certain crops like blueberries that need sandy acidic soil. The cultural assets of the farm originate from Matt and Ellie's personal desires for their family. They wanted their children to pick berries whenever they wanted, and to have access to fresh meat, milk, eggs, and produce. They found that consumers became interested in these enterprises because Pitchfork Farms has filled a need for many commodities in the local area. For example, they began as the only U-Pick farm in Petoskey. Both of the farmers believe that organic agriculture is growing nationwide because consumers are finally understanding the environmental repercussions of conventional agriculture. This societal awareness has grown with the enterprises of their farm (Yiridoe *et al*., 2005).

Soil Analysis

Methods

Soil samples were analyzed from Pitchfork Farms in two areas: the strawberry field and the chicken pasture. The strawberry field is on a hill that slopes down toward a ditch. This area was tested at the top of the hill, the middle of the hill, and at the bottom of the hill in order to determine if there was any type of nutrient runoff. The chicken pasture was sampled at three sites; where the chickens were this year (June 2018), where they were last year (2017), and were they were 2 years ago (2016). This was tested to determine what kind of nutrients the chickens added to the soil and how those nutrients were depleted over time. 5 sample replicates were taken at each of the three sites for the strawberry field and the chicken pasture. A 10 meter transect was placed and every 2 meters a soil sample was taken with a soil probe. 15 cm of soil from the soil probe was placed into a jar. The soil samples were sieved and then 0.1g measurements were taken out to be analyzed. Nutrients that were tested for were nitrogen, phosphorus, potassium, calcium, magnesium, sodium. pH was also tested for. These nutrients were chosen because they are often important for growing crops and can be limiting factors for plant growth. A Kruskal-Wallace statistical analysis was run to compare these nutrients between the 3 sites from the strawberry fields and the 3 sites from the chicken pasture. A pairwise analysis was also used to compare the sites to each other. These tests tell us whether or not the sites have different levels of nutrients and if they are different, if the difference is significant. The pairwise comparisons were run only if the p-values of the Kruskal-Wallace analysis showed significance differences between the levels in the samples to determine which samples differed.

Results

From this Kruskal-Wallace analysis of soil samples from the strawberry field reported that the results for ammonium was H=6.860 and p=0.032, potassium was H=8.060 and p=0.018, magnesium was H=7.440 and p=0.024, and calcium was H=6.740 and p=0.034. From this Kruskal-Wallace analysis of soil samples from the chicken pasture reported that the results for ammonium was H=.240 and p=0.887, potassium was H=8.060 and p=0.018, magnesium was H=0.560 and p=0.756, and calcium was H=5.40 and p=0.763. The chicken pasture potassium levels, strawberry ammonium, calcium, magnesium and potassium showed significant differences among the 3 sample sites for the two locations.

The results for the difference between the areas in the chicken-grazed pasture and the strawberry field are displayed in Table 1. Pairwise comparisons calculate a W-statistic and a p-value, a significant difference was determined by a p-value less than 0.05. Pairwise comparisons of the chicken pasture potassium levels showed that the chicken site from 2 months ago was significantly higher than the site from 2 years ago (Table 1). The site comparisons from 2 months ago and one year ago and 1 year ago and 2 years ago were not significantly different. From the strawberry field, ammonium (nitrogen content) was shown to be significantly different between the top and the bottom of the field. The bottom had more nitrogen. There was no significant difference between the top and middle and the bottom and middle comparisons. For calcium on the strawberry field, there was a significant difference between the middle and the bottom of the field. The middle had more calcium. There was no significant difference between the top and the middle and the top and the bottom comparisons. For magnesium in the strawberry field, there was a significant difference between the top and the middle (the middle was higher) and between the middle and the bottom (the middle was higher). There was a significant difference between the potassium in the top of the field and the bottom of the field. The bottom was higher in potassium. There was no significant difference between the top and the middle and the top and the bottom comparisons for potassium. The graphs (figure 1 and 2) show the differing levels of nutrients.

Table 1. Pairwise comparison of differences in Nutrients

	W-statistic	P-value
Chickens: Potassium		
2 months ago & 1 year ago	19	0.2222
2 months ago & 2 years ago	25	0.007937
1 year ago & 2 years ago	21	0.09524
Strawberries: Ammonium		
Top & Middle	4	0.09524
Top & Bottom	2	0.03175
Middle & Bottom	5	0.1508
Strawberries: Calcium		
Top & Middle	3	0.05556
Top & Bottom	9	0.5476
Middle & Bottom	24	0.01587
Strawberries: Magnesium		
Top & Middle	2	0.03175
Top & Bottom	9	0.5476
Middle & Bottom	24	0.01587
Strawberries: Potassium		
Top & Middle	3	0.05556
Top & Bottom	1	0.01587
Middle & Bottom	5	0.1508

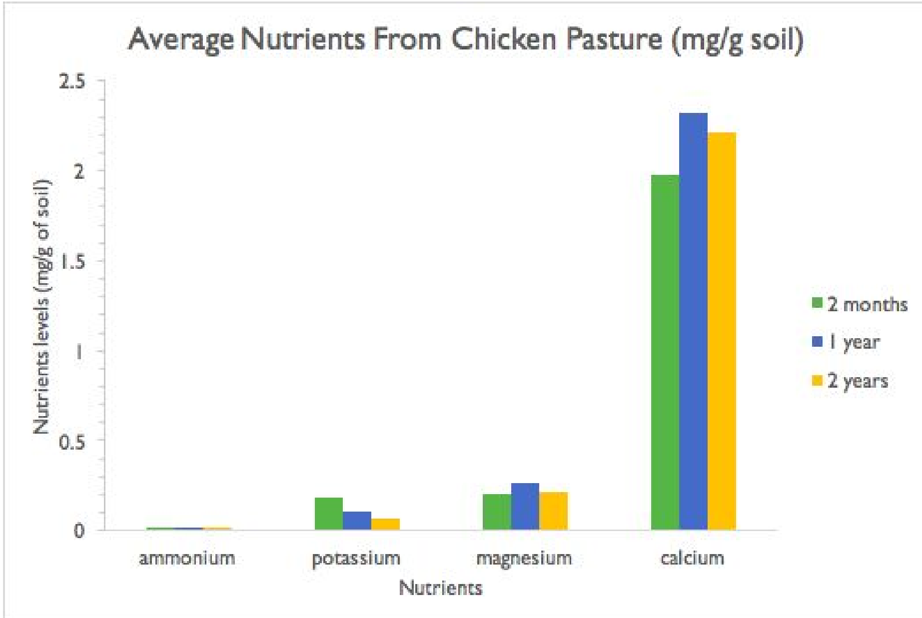


Figure 1. Average Nutrient levels in the Chicken Pasture

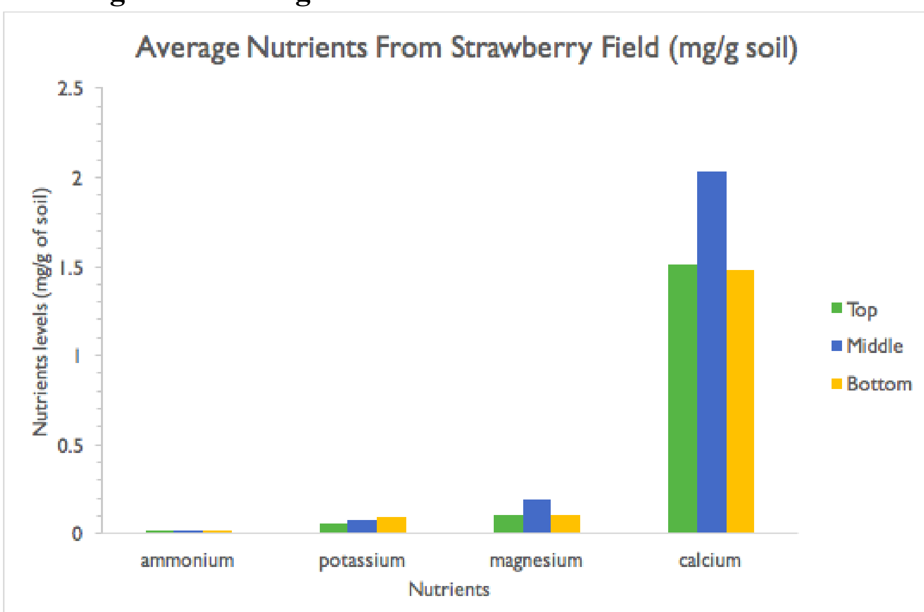


Figure 2. Average Nutrient levels in the Strawberry field

Discussion

These soil samples tell us that there is a loss of potassium from the chicken manure over two years but no significant loss of other nutrients.There were no significant differences in the other nutrients over time for the chicken pasture soil. This could be because the grasses that grow after the chickens are gone take up potassium quicker than they do other nutrients. This would deplete the store of potassium faster. Potassium could also be leached into the soil quicker than other nutrients.

In the strawberry field, the levels of nitrogen are highest at the bottom of the hill. This could be because of nutrient runoff. The highest levels of calcium are in the middle of the strawberry field and the highest levels of magnesium are also in the middle of the field. This could be due to the middle region of the field being covered in grasses and weeds instead of strawberry rows creating a barrier for these nutrients. The highest levels of potassium are at the bottom of the field. There were no significant differences in the other nutrients along the gradient of the hill. This may have been due to the atomic weights and charges of the nutrients affecting the amount and speed and which they moved through the soil. Nitrogen and phosphorus which were found at highest levels at the bottom the hill, both are anions with a charge of 3-, while calcium and magnesium which were found at highest levels at the middle of the fields are cations with a charge of 2+. These charges on the molecules affect their mobility through soil; anions are repelled by the charge of the soil and therefore move more quickly through the soil, while cations bind more tightly to soil and move less slowly over time (Goldy, 2013). The affinity with which nutrient molecules bind to soil is dependent on the cation exchange capacity. Soils with higher clay and organic content have higher cation exchange capacity, which leads to a greater affinity to cation nutrients (Michigan State University, 2018).

Overall Conclusions

Throughout the six-week study, the complexities of the agroecosystem of a farm evolved from working on the farm, participatory mapping, farmer interview, and soil analysis. The results of these various activities are all part of the same system that connect and work together to create the farm. The farmer, farmer background, and external factors explored in the interview process influence the overall layout of the farm that was mapped out in the participatory mapping exercise. The layout of the farm then affects the soil composition in the areas where the farmers choose to grow crops, raise animals, and cultivate pasture. Without a transdisciplinary, participatory, action-oriented approach, all of these factors that may influence the farm may not be fully realized (Méndez *et al.*, 2016). Connections between farm management, farmer livelihood, and the natural environment on a farm are present in every farm system and are all necessary in a thorough agroecological study. However, how the connections form and the way a farm runs may be different on every individual farm. Our visit to a biodynamic farm not far from Pitchfork was also owned and worked on by a couple, they had connections to their overall community, and practiced organic and sustainable practices. Those aspects were extremely similar to that of Pitchfork but their backgrounds prior to owning their farm and the way they apply organic and sustainable practices to their farm are very different than Pitchfork. These differences come from factors that are observed through working with the farm, getting to know the farmers and viewing the farm as an entire system.

Agroecological research must value both the research as well as traditional knowledge and both need to be present to understand the agricultural system (Vandermeer and Perfecto, 2012). In order to understand the larger complexities of food systems and agriculture, farmer knowledge must be a component in that understanding. Matt and Ellie guided us throughout our various activities on the farm and through our interactions with them, gave us the insight to better understand the farm and the farmers. Through working with Pitchfork farms, we have gained experience on a small scale about how a sustainable and organic farm runs and what it takes to do it. However, we also learned how vital these small operations are in the overall movement toward a just and sustainable food system. The participatory-action approach outlined by Méndez *et al.* (2012) requires more understanding of the farm than just this six week study. This baseline analysis of the farm gives an opportunity for further research at Pitchfork farms as the farm continues and expands its operations.

References

Corsi, A., & Novelli, S. (2015). The value of direct farmers-consumers relationships as determinants of consumers' purchase choices. In *Consumer Behavior in a Changing World: Food, Culture, Society*, 1-17. Agriculture and Applied Economics Association. Retrieved from http://ageconsearch.umn.edu/record/202749/files/263.pdf

De Haan, L. (2012). The livelihood approach: a critical exploration. *Erdkunde, 66*(4), 345-357.

Goldy, R. (2013). Anions and cations in plants, oh my! But why do we care? *Michigan State University Extension.* Retrieved from http://msue.anr.msu.edu/news/anions_and_cations_in_plants_oh_my_but_why_do_we_care

McCall, M., Minang, P. (2005). Assessing participatory GIS for community-based natural resource management: claiming community forests in Cameroon. *International Institute for GeoInformation Science and Earth Observation, 171*(4), 340-356.

McLain, R., Poe, M., Biedenweg, K. (2013). Making sense of human ecology mapping: an overview of approaches to integrating socio-spatial data into environmental planning. *Human Ecology, 41*(5), 651-665.

Mendez, V.E., C.M. Bacon, and R. Cohen (2016) Introduction: Agroecology as a transdisciplinary, participatory, and action-oriented approach. *In*: V.E. Méndez, C.M. Bacon, R. Cohen & S.R. Gliessman (eds). Agroecology: a transdisciplinary, participatory and action-oriented approach. Advances in Agroecology Series. CRC Press/Taylor and Francis.

Michigan State University. (2018). Soil test report. *Department of Geography, Environment, and Spatial Sciences.* Retrieved from http://www.spnl.msu.edu/_pdf/Soil_Test_Report.pdf

Silici, L. (2014) Agroecology: what it is and what it has to offer. IIED Issue Paper. International Institute for Environment and Development (IIED): London. www.iied.org

Vandermeer, J. and I.Perfecto (2012) Complex Traditions: Intersecting Theoretical Frameworks in Agroecological Research, Agroecology and Sustainable Food Systems, 37:1, 76-89.

Wezel, A., S. Bellon, T. Dore, C. Francis, D. Vallod and C. David (2009) Agroecology as a science, a movement and a practice. A review. Agronomy for Sustainable Development 29(4): 503-515.

Yiridoe, E. K., Bonti-Ankomah, S., & Martin, R. C. (2005). Comparison of consumer perceptions and preference toward organic versus conventionally produced foods: A review and update of the literature. *Renewable Agriculture and Food Systems,20*(04), 193-205. doi:10.1079/raf2005113