Cultural connections to soil and agronomic impacts of the maize, bean, squash polyculture methods in 5 Indigenous Communities of the Upper US Midwest

by

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DEDICATION

I dedicate this thesis to Grandmother Earth, to the Meskwaki community, to my dad, Darrel Wanatee, to Georgia Sanache, to my wife, Summer, to my nieces, my nephews, my sister, and to the rest of my friends and family. Without all your help pushing me to graduate, I do not think that I could have been successful.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Page

NOMENCLATURE

3SI	Three Sisters Intercropping
AES	Agricultural Extension Specialist
DIY	Do-it-yourself
ISU	Iowa State University
SHKM	Soil Health Kit Manual
TEK	Traditional Ecological Knowledge

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ABSTRACT

A mutually dependent relationship between Earth, maize (*Zea mays*), bean (*Phaseolus vulgaris*) and squash (*Cucurbita pepo*), and different Native American communities of the US Midwest has existed since time immemorial. These Native Nations valued the maize, bean, and squash cropping system as each of the crops seem to help one another throughout the growing season, and because of this, they have historically referred to the cropping practice as growing the “Three Sisters”. This thesis presents findings from ethnography and results from a randomized, replicated Three Sisters Intercropping (3SI) experiment, which are a research segment of an overall project that aims to help Native American communities increase their produce yields from their gardens to help support their food sovereignty goals. The ethnographic component helped me to develop targeted agricultural workshop events to ensure my research benefited partnering Native communities, as well as learn from Native growers how they view soil as a culturally important feature. Over two growing seasons, the 3SI in our ISU experiment on average decreased salt extractable nitrate by 33%, increased soil respiration by 13%, and decreased extractable sulfate by 32%, compared to the average of monoculture crops. The purpose of this project is to demonstrate techniques we used to build collaborative and beneficial relationships between our agricultural university and Native American communities, to develop a deeper understanding of soil’s place within the cultural fabric of five Midwestern Native American nations, and to explore how intercropping can make agroecosystems more sustainable for people and the environment.

GENERAL INTRODUCTION

The focus of my research within the overall Three Sisters project is to: 1) analyze the effects on the soil by single cropping heirloom varieties of maize, bean, and squash, using historical Native American intercropping gardening methods; 2) understand how five Upper Midwestern Native communities understand soil as a component of their traditional cultural worldview; and 3) support those same five Midwestern Native communities in their efforts to build up the health of the soil in their gardening systems so that they can grow healthy foods and support their community. We used different outreach events within the Native Nations to develop awareness within each community of our project and how gardeners could participate in it. We also used these events to teach community members different scientific methods to boost crop yields in their gardens, while encouraging growers to plant research blocks consisting of 4 individual gardens (maize + bean + squash, single crop maize, single crop bean, and single crop squash) with the hopes that they would allow us to take soil samples for data analysis. Acting as a participant observer in the collaborating communities during activities related to garden prepping, harvesting, and food storage allowed me to get a better understanding of how growers were interacting with Earth to grow food for themselves and their families. Outreach events and Advisory Board meetings were times when we sought input from collaborator gardeners about how we should conduct our research in their communities and how to act respectfully towards the crop seed varieties we were using for the ISU research plots.

Native American peoples have been practicing agricultural methods across the American Midwest states of Nebraska, Iowa, Southern Minnesota, and up on into the Great Lakes Region for hundreds of years, and they were able to build food production systems that fed them and their families all without the aid of modern agricultural sciences and technology. Using cropping practices that originated with their ancestors and were refined over millennia, they worked to build sustainable communities that revolved around an acknowledged relationship with Earth[1] that demanded humble and respectful interactions.

The technique of growing maize (*Zea mays* L.), beans (*Glycine max*), and squash (*Cucurbita pepo*), together in the same growing space in a season was created by different Native American peoples long before the practice of single cropping became dominant during the colonization of the Americas, and is a form of intercropping, defined by Dwight Holmes and Gary Barrett as the: "simultaneous cultivation of two or more crops in the same field" (1997, 312). Single cropping, practiced by some Native nations to a degree, is an efficient method of growing crops for sale in a market economy as it can be easily mechanized and managed at scale, while the maize, bean, and squash intercropping method known as the Three Sisters in Native American communities was designed for sustenance purposes and sustainability. Different worldviews and value systems support the two cropping techniques.

From early 2019 and until the beginning of the 2022 growing season, I was a member of both a soil science and an anthropology unit of the ISU Three Sisters Intercropping project. We interacted with five Native American communities in the Upper Great Lakes region of the United States to understanding the effects of their gardening practices on the soil and their communities. I acted as an ethnopedologist during my time in the field, a discipline defined by Barrera-Bassols and Zink as the studying of: "…the soil and land knowledge systems of rural populations" (171, 2003). I also learned from our collaborators during the time I spent teaching workshops about agronomic techniques to help them grow more productive gardens. Combining the disciplines and techniques of soil science with anthropology allowed me to more deeply understand the

[1] Earth, defined as: "the metaphysical source of all life and the substance that plant seeds and the dead are deposited into".

relationship between Native people and the soil impacted both my interviewees and Earth.

Interviewees and informants

The common theme that unites collaborators within our project is their interest in Native American cropping practices and soil. Individual collaborators within our project ranged from backyard home gardeners to organizations associated with by Native American community colleges. I conducted this research in Native American communities in Iowa, Nebraska, Minnesota, and Wisconsin. We were able to reach all the Native communities within one day's drive, and the closer proximity allowed for multiple trips in a single growing season.

In western Iowa, we have collaborators in the Sioux City Native community. In Nebraska we collaborate with members of the Omaha Nation and the Santee Sioux Nation. In Wisconsin, we collaborate with members of the Oneida Nation as well as members of the Menominee. In Minnesota, we are interacting with a Native-owned food growing Co-op called Dream of Wild Health. Within each Native community, we identified key informants who are knowledgeable about their community gardening practices, and these informants have also helped us to network and meet other collaborators who may be interested in our project using the snowball sampling technique. Different community members have participated at different levels of collaboration with our project. Some collaborators have participated in interviews but do not grow research blocks; some do not have research blocks but have a Three Sisters Garden; and some Native growers have interviewed with us and but do not grow research gardens with us but are still interested in our project and attend the workshops we put together.

Positionality

Cultural anthropology was a new field of research for me coming into this project because my undergrad degree is in agronomy, specifically crop production. However, living on the Meskwaki Settlement as a young adult, I felt like I understood the inquisitive nature that accompanies anthropology's pursuits into different cultures. Despite my ability to duck in and out of different cultures with relative ease as is necessary when being a Native person living in a predominantly Euro-American inhabited city like Ames, Iowa, studying cultural anthropology and conducting ethnographic research would challenge my thoughts in ways I was not expecting.

Having lived on and next to the Meskwaki Settlement as an enrolled member, I felt a unique sense of connectivity to the project and collaborator communities. This, to me, was not because I felt a desire to learn more about the cultures I was researching to share with the outside world, acting as an "insider anthropologist" (Long-Cerroni, 1995), but the experience was more of a way to learn about myself and my own Native American culture. As a member of a minority ethnicity, I rarely found myself amongst people with similar life experiences while attending Iowa State University or living in the city of Ames. Traveling to the collaborating Native communities and acting as a participant-observer within the Three Sisters Intercropping Project would eventually activate a more profound interest in myself about my Meskwaki culture.

My status as a member of a Native community with a casino also brought added personal obstacles that I had to navigate during my trips and interactions in the field. Some of the communities that were part of the project are located in extremely remote areas where their businesses are less successful as a result. Seeing individuals living in extreme poverty without the ability to directly help them was challenging for me. In addition, having studied the history and effects of knowledge extraction in Native communities (Simonsen, 2006), the destruction of Native knowledge systems throughout history by Federal Government-sponsored schools (Adams, 1995; Miewald, 1995; Ricciardelli, 1963), as well learning how researchers have upset long-seated community relationships or have ultimately conducted research that is useless to Native communities (Daubenmier, 2008; Deloria, 1988), I felt myself sometimes struggling with feelings of guilt about whether I and the university I represented was benefiting more from the overall project than were the Native communities interacting with us. The experience helped me to understand why Eric Gable, writes about anthropological fieldwork, describing it as an: "…intrinsically guilty act" (239, 2014).

This anthropological scholarship impacted how I interacted with Native growers as an agronomist. Despite me having undergone years of university-level agronomic science training before entering the collaborating communities as part of the Three Sisters Project, I worked to communicate my knowledge to the collaborators in less technical vocabulary so I would not come across as arrogant. I was aware that many of the community members do not have the university education background that I and others on the team have, and I felt it would be more useful to our collaborators if I was relatable. Doing so would help our team to develop a more collaborative relationship. Interestingly though, I would come to realize that I was learning a significant amount of information about soil health from the collaborators themselves that I would never have been able to access within published literature.

I noticed that being a member of the Meskwaki Nation who has spent time on the Settlement throughout my life gave me the ability to interact with my home community in a way that was noticeably not afforded to my colleagues. This gave me the opportunity to expand my own ethnographic research to a community that was not previously partnering with the ISU team. I was able to secure two interviews with cultural knowledge holders in the Meskwaki community whom I sincerely admire, but I was not able to secure those same courtesies for the other researchers on the project. One interviewee even directly told me that she would sit down with me to help me on my career path, but she would not be assisting the faculty at ISU on theirs. Another interviewee refused to answer food sovereignty questions that a colleague asked me to introduce during my interviews because I had previously told him that my research only focused on the human-Earth relationship. He knew that the questions I began asking him were not the subject of my personal research and he did not want to be involved with anyone else's research on the team.

Being a male made part of my research particularly challenging because it is typically a woman's position within the Native communities collaborating with our project to be the gardener for the household. There were days in the field doing research where I would spend very little time amongst other males because the project's research topic (food gardening) is a realm where the Native American men did not hold the same levels of cultural knowledge that women do. Furthermore, Native women in the communities may have felt less comfortable sharing features about their culture that are reserved for women only. While men in each of the communities were actively working towards growing Three Sisters gardens in some capacity or another, the vast majority of the cultural knowledge holders collaborating with us and interviewed as part of this project were women. Because women were historically the garden tenders for the Native communities collaborating with this project, it should come as no surprise they are still the dominant source of agricultural information for their communities.

Methodology

Analysis of the Soil Effects from the Three Sisters Intercropping Technique

As part of this project, we are interested in comparing the effects that growing the Three Sisters has on the soils supporting them to the soil effects caused by single cropping. Our hypothesis going into the research is that growing the Three Sisters affects the soil in a way that boosts the soil's health rather than depletes it—the opposite effect of continuously growing a single crop. To test our hypothesis, we took soil samples at the beginning and end of each growing season from research plots where we maintained Three Sisters gardens, to compare them with soil samples from a research plot where we only grew maize, beans, or squash. Doing this helped us to better understand the biogeochemical interactions between intercropping and the soil, and how those differ from the effects caused by single cropping.

The ISU Three Sisters Project maintained a research garden at the university's Horticulture Research Station near Ames, Iowa. We planted four research blocks; each block contained four different plots: 1) Three Sisters; 2) single crop maize; 3) single crop beans; and 4) single crop squash. We used seed varieties and cropping practices indigenous to the regions and people we are collaborating with on our project to examine the soil effects. Doing this also helped support our goals of giving seeds back to the communities they originated from, an act that Gray defines as rematriation: "…an embodied praxis of recovery and return, and a sociopolitical mode of resurgence and refusal" (2022, 1). We asked for collaborator input at all points in our research garden through the advisory board we created, which helped us remain humble with the culturally significant seed varieties we were using. Collaborators in each community grew research blocks and Three Sisters gardens in 2020 and 2021 to supplement the data we collected at the horticulture research station. Unfortunately, only the ISU research garden was suitable for the data collection we needed to make publishable claims.

Soil samples were taken at the beginning and end of every growing season at our garden, with analysis of those soils focusing on: DNA, microbial biomass carbon, total organic carbon, micro and macronutrient levels, percent organic matter, pH, soil CO_2 respiration, and C:N ratio. Not all Native communities plant their crops in the same manner, but because the Native nations that collaborated with us on our project historically used raised bed mounds to plant their seeds into, we chose to duplicate this method and incorporated garden mounds into our experiment design as well. We built our experimental garden mounds at the beginning of every growing season with 16 mounds (4x4) per plot for a total of 16 plots. The soil samples were taken directly from each plot's four center mounds.

Another component of the soil science research was the creation of a soil health kit and manual, spearheaded by project PI, Dr. McDaniel, to help the Native collaborators understand how different management practices affect soil characteristics. The kit focused on five different soil health measurements that examined macroinvertebrate populations, water holding capacity, microbial activity, bulk density, and aggregate stability, and could be conducted using household materials commonly found in most people's kitchen cupboards. Even though the tests were simple to run with everyday items, the results gathered are scientifically robust and comparable to the results gathered when the tests were conducted in the McDaniel Lab at ISU (See Appendix).

We used the do-it-yourself (DIY) kit to gather data from our research block, and it included the deployment of two different types of teas to analyze how their decay rates varied between the Three Sisters replicates and the single crop replicates. Burying these items allowed us to gauge the soil microbial activity based on how it interacted with decomposable materials with different C: N ratios. These were exciting observations when we combined them with the biochemical data we collected in the lab. We buried the two different tea types and retrieved them after 95 days for us to compare how the teas decomposed in comparison to each other underneath the different cropping practices.

Ethnographic Methods: Gaining Entry to The Communities

Most of the work building the network with the Native collaborators associated with this project was already completed before I was invited on to this project. Dr. Gish Hill had already identified key people in each of the Native Nations who would act as liaisons between us (ISU personnel) and them and would also help us expand our social networks within each Native community. I was first introduced to our key informants within the communities at the end of March in 2019 when Dr. Gish Hill arranged a "meet and greet" event where everybody on the project at that time was able to introduce themselves to the rest of the team formally.

Prior to joining the project, I had no previous formal training in ethnography, the science defined by Clifford Geertz as: "…providing a vocabulary which what symbolic action has to say about itself—that is, about the role of culture in human life—can be expressed" (38, 1973). Ethnography is the study of customs and cultures, and is relevant wherever people are relevant (Princeton, 2022). Ethnography strives to understand social interactions in cultures through the perspectives of those being observed (Atkinson and Hammersley, 1998), and is based on participant observation, a method defined by James Spradley as: "… observations of community members, physical characteristics of the social situation, and what it feels like to be a part of the scene" (Spradley 1980, 33). Because the focus of my research was centered around working to understand how Native communities interact with Earth while growing food items, using ethnographic methods was the best way for me to contextualize what I experienced while out in the field. Questions I took with me into the field included: How are Native people using soil to grow food? Is soil viewed as a culturally significant substance, and how so? What does the relationship between Native people and their soil look like? What kind of cultural stories exist that pertain to soil? By being physically present within the communities I was studying, with them within their gardens, I acted as a participant observer, which allowed me to develop a holistic picture of the answers to my research with different perspectives (Manolchev and Foley, 2021).

In the summer of 2019, Dr. Gish Hill and I traveled to the collaborator communities to act as participant observers as well as to collect soil samples from collaborator gardens. Spring that year was very cool and excessively wet, so much so that many collaborator gardeners had trouble finding a dry enough window in the week where they could get into their fields and plant. Our trips early that summer consisted of slogging through deep puddles and muddy fields, and more than once did I worry I would twist an ankle while trying to retrieve soil samples.

Despite the difficulties involved, actually going into collaborator gardens with the gardeners while taking soil samples turned out to be a powerful way to connect with them. While out in their gardens, many times, gardeners would not hesitate to talk about the issues they were experiencing that they thought were holding them back from the garden yields that they wanted. Gardeners spoke about the different spaces within their gardens, how they interacted with those spaces, memories they shared with their families, and even how they would interact with the garden in the future.

These early visits to the communities were when we discussed the project in its entirety with the collaborators. One of the project features that we were mindful of discussing was the hopes that Dr. Gish Hill and I could interview each grower at some point. During 2019, the ISU team and the collaborators freely intermingled and socialized, with much of my participant observations happening over a meal or in preparation for one. Our last major in-person social event for the Three-Sisters Intercropping project would be in February of 2020, right as the Covid-19 pandemic was beginning to cause alarm around the world. We were unable to travel to the communities again until the summer of 2021.

Despite the administrators at Iowa State University restricting travel so much that we couldn't physically meet in person with the collaborator gardeners in their communities, we still had to continue with our project. Using email and different video chatting programs such as Webex and Zoom enabled us to maintain connectivity between the collaborators and us. However, this was mostly restricted to preplanned conversations within a specific small window of time. Some participants chose not to even turn on their web cameras during our chats, a massive shift from the type of human-to-human transfer that happens when one is physically present alongside another person in a shared space. Bodily social cues were easier to miss, and there were quite a few moments where there was overlapping dialogue during conversations. Trust may have been more difficult to build during some of the interviews because we weren't physically in the same room, which would have allowed for a more natural and personable conversation rather than one where each person talks at a computer monitor.

I conducted 12 interviews, some of them with Dr. Christina Gish Hill, and some by myself. I identified culturally knowledgeable informants within Native communities, some that were affiliated with the ISU Three Sisters project and some that were not. Through my interactions with collaborators from the Nebraska Indian Community College in Niobrara, Nebraska, I met interviewee, Shelly Kosola. I also secured interviews from collaborators with the project from the Oneida Nation (Laura Manthe, Marlon Skenadore, Dan Cornelius, Lois Stevens, Becky Webster, and Cynthia Dauer) and one of the farm managers at Dream of Wild Health (Jessika Greendeer). The Meskwaki Nation was not a formal collaborating member of the overall project, but I still sought out interviewees there because I have familial roots in the area. I chose to interview the non-Native organic-method farm manager at Meskwaki Red Earth Gardens to understand his perspective about soil as he leads the community's major food production space (Grant Shadden), the Historical Preservation Director for the Meskwaki Nation (Johnathon Buffalo), and some of the leaders of the Meskwaki Food Sovereignty Initiative (Luke Kapayou and Shelley Buffalo). The interviews were conducted either in person (in the case of my interview with John Buffalo) or online through video-chatting software. Interviews conducted online suffered from connection lags and occasional call drops, and sometimes garbled audio issues.

My questions about soil during the interviews (interview questions are reproduced in appendices in chapters 3,4, and 5) focused on trying to learn how soil fit into the participant's culture and worldview, trying to understand who taught the interviewees about their cultural relationship to Earth, any conservation values that the interviewees felt were important to know when dealing with soil as a crop grower, ways of managing soil to produce crops more sustainably, benefits of engaging with soil regularly, and key characteristics associated with healthy soil. I provided each interviewee a consent form before the interview outlining how the recording of their discussion would be stored and used.

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Core questions were created by the research team to be asked during the interviews to get targeted responses about each interviewee's viewpoint on soil's importance, but the interviews were also guided by what the interviewees disclosed during the conversations. Out of the 12 total interviews, I conducted all but one over web cameras. Collaborators chose whether or not to be video and audio recorded, and there were some instances when the interviewee asked me to stop recording while they talked about personally sensitive topics. Collaborators answered questions they felt most comfortable, which sometimes included not answering the question at all. I sometimes developed follow-up questions which built on the responses provided by the interviewee.

Significance

Current agricultural science is fully aware of the effects on the ecosystem from common Industrial farming practices, ranging from annual soil loss (Reganold et al., 1990), to polluted rivers and streams from agricultural runoff (Kremen and Miles, 2012), to the destruction of habitat for insects and animals (Thrupp, 2000). Using soil science methods to analyze a cropping system designed in prehistoric conditions for direct food consumption purposes may help modern agricultural scientists inform the public and policymakers about ways to help current mainstream agriculture design more efficient cropping systems that maximize the food yielded per area of land. Scholars of sustainable agriculture may find this research informative because of the way it layers soil science with anthropological research provide insight into the impacts of polyculture systems.

Indigenous peoples may find value in this thesis as it brings awareness to the wisdom that their ancestors had when they created the Three Sisters cropping technique. Indigenous peoples were growing food crops in the Midwest such as the Three Sisters for hundreds of years before the formation of the United States (Gilmore, 1919; Hart, 2008; Whittaker et al., 2015; Yarnell, 1966). This research is significant because it provides insight into a worldview about crop production different from those seen in mainstream agriculture, while incorporating the soil effects from these agricultural methods. The ethnographic research contained within can be used to inform agricultural researchers and extension specialists as they work to build more collaborative projects with Indigenous communities.

CONCLUSION

Combining the two disciplines of soil science and anthropology to analyze the effects of Three Sisters intercropping gives us a well-rounded understanding about the significance of the Three Sisters cropping system, how it functions both on the soil and within different Native

American communities, and whether or not it could be adopted into mainstream agriculture as it currently exists. Key points of interest learned from this research include how Three Sisters intercropping affects the soil and how those effects compare to the soil effects from single crop maize, bean, or squash; and learning about the significance of soil in fie different Midwestern Native American communities. The knowledge collected from this research will hopefully be used in ways that benefit the Native communities that collaborated with us within the Three Sisters Intercropping project as well as non-Natives.

This thesis is organized into six different chapters. In Chapter 2, I review the literature concerning Indigenous soil knowledge, ethnopedology, and historical interactions between Indigenous peoples of the Great Lakes Region and soil, and the effects on the soil from Three Sisters intercropping. Chapter 3 addresses methods to build collaborative research with Native communities for someone working in a university-extension capacity. Chapter 4 contextualizes a health link between a dynamic relationship between Native American people and soil. In Chapter 5, I examine the soil effects of Three Sisters intercropping and how it compares with management practices associated with single cropping. Chapter 6 is the thesis conclusion, where I pull out common themes gathered from the research and describe how my work could be used to further the understanding of sustainable agriculture. I have included an appendix with the Soil Health Kit Manual and other important tables and images so that readers can assess these materials themselves.

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CHAPTER 2. Literature Review

In this chapter I will review the literature about local soil knowledge[2] and how local Growers gain and use soil knowledge within their culture to grow food, the agroecological effects of the Three Sisters Indigenous cropping practice as analyzed through modern soil science, a brief history of the four different Native American Nations this research project currently collaborates with, and how non-Native agricultural instruction has been received in Native communities. This review of literature reveals that there are gaps in the knowledge focusing on how Native American peoples interact with soil for intergenerational survival.

Defining Local Soil Knowledge

As described by Barrera-Bassols & Zinck, *ethnopedology* is a discipline focused on recording and understanding how local populations interact with, value, classify, and perceive the soil (2003, 172). Much of this research consists of University-trained scholars visiting Indigenous communities and listening to how locals are managing soil to improve the health of their cropping systems, while using modern scientific methods to collect data about Indigenous agricultural methods to try and more deeply understand the locals' management techniques (Birmingham, 2003). Roman Pawluk et al., view this avenue of soil research as useful to efforts underway to make modern industrialized practices more sustainable (1992). Because local communities around the world may have cultural values that differ from those that operate based on the global commodity market (Nabhan, 1989), it may be advantageous for scholars to understand how these cultures appreciate and interact with soil to better critique the long-term sustainability of industrialized agricultural practices in developed countries.

[2] local soil knowledge: a body of knowledge about the human and soil relationship that is unique to individual cultures and communities

The research into Indigenous cropping practices and how they affect ecosystems pales in comparison to the amount of research effort that has gone into studying the effects of industrial agricultural techniques. What does exist centers on trying to unravel how these cropping systems are placed on the landscape and managed in sustainable ways. Unlike the practices associated with industrial agriculture, characterized by the conversion of entire landscapes to row crops for their eventual sale in a commodity market, local cropping practices differ by intentionally targeting soils on a landscape that are already fertile and choosing to place cropping systems there. When the crop yields in that space are lower than desired, growers sometimes use a fallow period to rebuild the soil's fertility (Winklerprins, 1997). Rather than following modernist tropes and "controlling nature" by altering it to satisfy commodity market demands, Indigenous cropping practices are instead structured along a line of reasoning best described by Juan Salazar et al. as "following nature", allowing it to show a grower the best place and methods for crop production (2020, 158).

Lars Krogh and Bjarke Paarup-Laursen recorded Indigenous peoples of Burkina Faso, West Africa, following nature while in their gardens by choosing to plant crop seeds only after the conclusion of a heavy rain event because they knew the period after rainstorms led to the best rates of seed germination (1997). Johnathon Sandor et al. describe local growers in Zuni pueblo, a Native nation in the United States, following nature by choosing to place their home gardens in the naturally fertile alluvial soils caused by flowing water. The same scholars have noticed Indigenous Amazonian peoples pairing particular crops with different concentric zones on a landscape. They reason that these Indigenous farmers practice the methods because these areas on the landscape would have been more naturally fertile when compared to other locations (J. Sandor et al., 2002). Johnathon Sandor and Louanna Furbee found that local growers in Peru had a soil classification system within their culture with 46 different soil designations that they would use to make decisions about the landscape positioning of their cropping systems, with soil texture most often being the defining characteristic (1996). At its core, local soil knowledge is dependent on knowledge passed down through generations of food growers developed through a longstanding relationship with the soil.

Indigenous soil knowledge also contains methods of enhancing the crop production capacity of a soil to add to its innate natural fertility. Dorkas Kaiser et al. conducted research in Burkina Faso, West Africa, and found growers there using termites and termite mounds as garden fertilizers to enhance the soil fertility of their systems (2016). Devika Tamang describes local growers in the hills of Nepal as being highly attuned to the effects on the soil in their cropping system when they incorporate compost, in addition to the impact on their crop yields (1993). In the 1930s when grower Tall Woman, a member of the Navaho nation in the southwestern U.S., needed her garden space to have healthy soil quickly, she sometimes would transplant in soil from different areas on the landscape she was familiar with (Frisbie et al., 2018). Native American people in the 1600s living within the present day state of Virginia were recorded as using fish as a fertilizer in their garden mounds, which had to be protected at night against hungry wolves (Delabarre & Wilder, 1920).

According to research conducted by Norman Schwartz and Amilcar Rolando Corzo, local peoples in Guatemala, Mexico, growing a maize -beans- and squash intercropping system enhance their soil's natural fertility by burning organic matter and incorporating the ashes into the soil to supplement the benefits of the fallow periods they use within their cropping plans (2015). This method has been used by Indigenous peoples to enhance soil fertility, including Native peoples of North America (Corral, 2019; J. A. Sandor & Furbee, 1996; Wilken, 1972).

Ronald Nigh and Stewart Diemont spent time conducting research in Mexico and Central America studying how local people there were interacting with soil, and found that the growers there enhanced their soil's productivity through different types of fires; hot fires across a soil were used to rid the soil of weed seeds while a cooler fire was used to create charcoal as a soil amendment (2013). According to observations recorded in the early 1600s, Native American people in present day Virginia also used fire to bring down trees and open up spaces for gardening purposes (Delabarre & Wilder, 1920). In her biography, Buffalo Bird Woman described her Hidatsa community using fire to soften up soil for management purposes (Wilson, 1917). Native nations comprising the Eastern woodlands such as the Iroquois were growing fields of corn prior to the year 1000 A.D. (Monaghan et al., 2014).

Another facet of local soil knowledge focuses on the movement of soil into distinctly raised mounds. "Linear or curvilinear ridgelike surface features of varying lengths and cross-dimensions…" is how professor of anthropology at the University of Wisconsin, Bob Sasso, describes the prehistoric garden beds in his state created by Native nations. In the early 1900's, Native American people along the Missouri river were recorded as scooping soil into hills for use as a structure to plant potatoes into (Gilmore, 1919), while other scholars have found that Native people historically used hilled garden beds for the planting of maize, beans, and squash (Sasso, 2019). Buffalo Bird Woman described her Hidatsa community in the 1800's as using a digging stick to first till up the soil for their garden mounds before the untilled ground was scraped clear with a bone-hoe (Wilson, 1917).

Research conducted by Thomas Riley and Glen Freimuth shows that a significant benefit of these mounded raised bed gardening features is how they act as a way to prevent frost damage on growing plants; if the mound is built up high enough, the frost may lay too low on the soil surface to have any effect on the plant life (1979). Lovis and Bogdan describe how flooding events could be negated when a grower uses the ridge gardening technique because the troughs between the ridges can act as a way to contain excess water (2004). Prehistoric raised garden beds were especially found in the heavily timbered state of Wisconsin along the banks of large lakes and rivers (Gallagher et al., 1985). These garden beds in Wisconsin are attributed to the Oneota, Sauk, Fox, Winnebago, Menominee, Ojibwa, and Potawatomi (Gallagher et al., 1985).

Ethnopedology within Indigenous communities

According to Joanna Troufflard, rural Amazonia peoples have been practicing some form of subsistence agriculture since at least the year 1000 BC (2013), giving researchers the ability to examine the agricultural practices of communities that have interacted and depended upon their soils for hundreds of years. Rural Amazonians were able to construct elaborate methods of slash and burn agricultural soil management that would work to enhance soil fertility through time rather than deplete it (Kawa, 2016; Posey, 1985). This family of highly human-managed dark soil in this area of the world is referred to colloquially as *terra preta do Indio, or "*Indian Black Earth*"* (Holliday & Gartner, 2007; Kawa, 2016). Fred Magdoff and Harold Van Es show that this soil is heavy and dark because it contains high amounts of charcoal (1993). Compared to uncultivated soils, terra preta soils have a higher pH, higher levels of nutrient availability, enhanced water holding capacities, and have even been lauded by some environmental scholars as a true model of 'sustainable agriculture" (Kawa, 2016, 56). Modern-day *terra preta* growers in Amazonia understand the benefits of transplanting high-quality soils into areas that are more ideal for agricultural practices, in addition to enhancing soils through fertilizer and amendment techniques that they use to create soils *in situ* (Posey, 1985).

Ethnopedologists have also investigated rural African communities to understand how they interact with soil in ways that may be labeled more sustainable than the methods employed by modern industrial agriculturalists. Victoria Frausin et al., found that similar to Amazonian *terra preta*, the African territories of Liberia, Sierra Leone, Guinea, and Ghana are also known for their carbon-rich and high fertility soil (2014). Growers in this region who create the *African Dark Earths* categorize the soils they interact with using a local soil taxonomy system based on the names of vegetation around the soil (2014) and how the particular soil responds to rainfall (Birmingham, 2003). Like Amazonian *terra preta*, African Dark Earth is created by Indigenous peoples through the heavy use of charcoal amendments to the soil. This organic amendment can have a beneficial impact on a growing system, such as raising the soil's nutrient and water holding capacity, that persists on extreme time scales (Beach et al., 2017). Gayle Fritz, renowned paleo ethnobotanist, constructed a map showing that inhabitants of the ancient Native American city of Cahokia may have been planting their customizing their cropping decisions in relation to wetland areas on a landscape and the soils present in those particular spaces (2019, 137). More important crops to the residents of Cahokia such as tobacco may have been planted closer to their homesites so they could give them more attention (2019, 141). Cropping strategies employed by Indigenous peoples prior to European colonialism were developed by them primarily to feed themselves and their families, and they relied upon a bank of intergenerational cultural knowledge that was site-specific to the area their community interacted with through their seasonal movement across the landscape.

Soil as Foundational to Indigenous Relationships With Earth

Dr. Robin Kimmerer, Professor of Environmental and Forest Biology and enrolled member of the Citizen Potawatomi Nation, writes about an acknowledged kinship relationship between Native people and soil in her book Braiding Sweetgrass: "This is really why I made my daughters learn to garden-so they would always have a mother to love them, long after I am gone" (2013, 135). Many Native cultures appreciate soil as the substance from which life originates and is born from, and choose to refer to it with familial kinship terms (Gilmore, 1919; Gould, 2018a; Pawluk et al., 1992). Kimmerer's quotes about teaching her children to garden shows how her culture understand the importance of an active human and soil relationship. Research by Billie Dewalt holistically describes Indigenous cultural knowledge systems as being based on survival goals that are dependent on local resources and sustainability (1994, 124), highlighting the level of deference many local cultural systems place themselves to Earth. Within these cultures, Earth is not a tool for exploitation but the ultimate source of all life.

Another example showcasing this acknowledgment of deference from local cultures towards Earth comes from Amanda Raster and Christina Gish, who describe an Ojibwe worldview that contextualizes individuals not as the controllers of the Earth, but as managers of their relationship with Earth (2016). Roxanne Gould, Professor of Indigenous Education at the University of Minnesota-Duluth writes that within Native communities, landscapes are recognized as areas of "… consciousness and an orientation to sacred ecology" (2018, 5). Kimmerer eloquently sums up how many Indigenous cultures feel Earth, its resources, and people must be connected for survival. She simply states "What we do to the land, we do to ourselves (2011, 258).

There are implications for this human and Earth relationship worldview held by different Native communities, most importantly the concepts of humility and reciprocity, as described by Berkes et al., (2000). James Cicarelli defines reciprocity as: "…gift giving or social exchange…with the expectation of deference or obligations in return for the value received" (2012, 97). Acting in a reciprocal way with the Earth is what many Native American cultures feel is the experience that allows them to harvest and receive sustenance from the Earth (Miller, 2008; Raster & Gish, 2016), and working against this type relationship is viewed by them as detrimental to the health of Earth and people (Gould, 2018; Tinker, 2016). Many Native cultures have a worldview that understands all living things as interconnected, which includes plants, animals, and cosmic forces (Champagne, 2015). Native peoples who interact with soil as described in previous sections are an enactment of this belief system.

Indigenous based cropping methodologies of the Upper Midwest

Indigenous peoples throughout the world made decisions about crop growing according to their cultural knowledge, and many peoples chose to intercrop as part of this process. Rob Brooker et al. define intercropping as, "…two or more crop species or genotypes growing together and coexisting for a time (2015, 108). Therefore, growing maize, bean, and squash in the Three Sisters gardening method fits this definition. Native Nations in the Upper Midwest have been intercropping their food gardens in ways like the 3SI for centuries (Firkus, 2010; Jones, 2020). A major point of synergism between the crops composing the Three Sisters Intercropping method occurs at the root zone; research conducted by Claire Kremen and Albie Miles comparing single crop systems to intercropping systems found that biodiverse cropping systems enhance the water holding capacity of a soil because the variety of root morphology and architecture add greater amounts of organic matter to the soil (2012, 10). Long Li et al. found that macronutrients in the soil such as phosphorus can be made available to plants within a biodiverse cropping system through interactions at the rhizosphere with other plants in the system (2014). Marshall McDaniel at el. found that intercropping as a whole, when compared to single cropping, has shown to result in a higher soil microbial biomass (2014). Research conducted by Simon Deng et al. found increased rates of soil organic matter decomposition within intercropping systems (2000), and Eria Rebollar et al., found that intercropping systems can neutralize soil pH (2017). Johannes Postma and Johnathan Lynch found that the Three

Sisters intercropping practice was more efficient at uptaking nutrients from the soil than a single species stand is capable of (2012), which implies less nutrients lost to the environment because they were more readily used.

Other ways the plants within intercropped agricultural systems like the Three Sisters method have synergistic effects amongst themselves occur aboveground. For example, Rob Brooker et al., describe intercropping as having the potential to regulate soil temperatures when plant species are selected by a grower that have extensive canopy architecture (2015, 110). Zhihua Zhang et al., found that biodiverse cropping systems may enhance the potential crop yield of a particular space if it is composed of poor or low-quality soils (2014, 1719). Yu Duan et al., researched the soil effects of intercropped agricultural systems when compared to single crop systems and found that long-term intercropped systems have reduced soil moisture loss (2019). Work by Karin Staudacher et al. shows that because diverse cropping systems such as the Three Sisters are composed of multiple plant species with unique and different biological impacts on the environment, these systems benefit from a lowered level of host plants per unit of land for insect pests (2017). Three Sisters cropping systems may also potentially benefit from intra-species allelopathic properties, enabling the use of less herbicides and pesticides to maintain the overall system as found in research by Jurgen Ehrmann & Karl Ritz (2013). Norman Schwartz & Amilicar Rolondo Corzo conducted research into the maize, bean, and squash intercropping system practiced by Indigenous food growers in remote areas of Central Mexico and found that it could produce crops for: "…an indefinite amount of time without irreparable damage to natural ecosystems" (2015, 79).

The Impact of European Contact on Native American relationships to Earth

Precontact, many Midwestern Native American communities practiced agriculture but supplemented it with foraging, hunting, and gathering. Hunting and foraging lifeways were deemed uncivilized in the perspectives of Euro-American settlers, who viewed large-scale agriculture for sale in commodity markets as the proper way that populations should be engaging with territories (Firkus, 2010; McGregor, 2004). Native American cultures stressed voluntary cooperation and cohesiveness within the community which included the sharing of resources (Hurt, 1987), while Euro-American capitalistic culture placed more value on individuality, assertiveness, private property, and responsibility (Hurt, 1987). These two clashing mindsets undoubtedly factored into the problems that plagued Native American communities when dealing with treaties and land disputes (Banner, 2005; Hurt, 1987; Neville & Anderson, 2013). As colonialism spread westward across the United States, the US Federal Government would come to eventually pass the Dawes Act of 1887 as a way to slowly assimilate Native American people to Euro-American market economies (Otis, 2014).

Pre-colonialism, many Native Nations in the American Midwest subsisted on a diet high in proteins, high in carbohydrates, and low in fats, and there were practically no incidents of diabetes (Miewald 1995). Their food consisted of wild game, foraged and cultivated plant items, and even fungi (Firkus, 2010; Hurt, 1987; Christina Miewald, 1995; Tanner, 1987). Historically, communities divided daily activities based on well-defined gender roles, with women often being the agriculturalists for their families and men being the warriors and hunters (Delabarre & Wilder, 1920; Gallagher et al., 1985; Robert Sasso, 2003). Through the colonialism process, these gender roles and community expectations were thrown into chaos (C. Miewald, 1995). The forced movement of Native communities across the landscape by the US Federal Government through the Removal and reservation process caused many Native Nations to be placed into areas where they did not have significant pre-existing cultural knowledge about the soil, plants, or patterns of the animals that were present.

This process allowed non-Native farmers to move into Indigenously managed lands and implement Euro-American farmer practices. Today, monoculture is the dominant cropping practice in the American Midwest and is characterized by the large tracts of land that produce the same crop annually (Power & Follet, 1987). Amanda Bennet et al. describe the choice a farmer makes for engaging in monoculture activities as one that is influenced by the pressure upon them to maximize profits in the market economy (2012). Despite the dominance of monoculture farming across the American Midwest, research by Bennet et al. found many examples of experiments showing yields from monoculture cropping systems becoming eventually lower than intercropped systems (2012, 53). Monoculture cropping systems depend upon a vast amount of inorganic fertilizers, herbicides, and pesticides to keep them successful, and grain yields in monoculture now typically range from sixty to one hundred and twenty bushels per acre (Mt. Pleasant, 2011). There are harmful impacts to the environment to obtaining these yields, though.

Research conducted by James Murray and Leland Vaughn found that airborne pesticide droplets can contaminate areas four miles from where they are applied (1970), representing a larger ecological footprint for farming practices than many people initially attribute to it. Patrick Belmont et al. point to large-scale agricultural tillage practices and the field tile drainage associated with modern farming as prime reasons why a lake along the Mississippi River has had its sediment load increase 10-fold over the past 150 years (2011). Erin Tegtmeier and Michael Duffy calculated the external costs to the environment and human health from crop production in the United States at $4969.3 – 16,150.5 million per year (1993, 14), showcasing the immense impact that industrial agricultural practices have upon what Paul Hawken et al. refer to as Earth's 'natural capital' (2013. 126).

These cropping practices have aided in the separation of most Americans from food production, including a decline in knowledge of how to produce food. Christina Miewald writes that, like Euro-Americans, the percentage of modern day Midwestern Natives that get even fifty percent of their yearly vegetables and fruits that they consume from their own home garden is amazingly small (1995). Native American communities have been struggling with poor health caused by hunger since the 1860s (Gould, 2018), which coincides with the US Reservation era when Native American controlled territories were drastically reduced by force from the US Federal Government. Currently, Native populations have higher rates of annual doctor visits than non-Natives (Small-Rodriguez & Akee, 2021), higher rates of heart disease than non-Natives (Cobb et al., 2014), and suffer from chronic illnesses from poor nutrition such as diabetes at rates higher than any ethnic class in the United States (Gould, 2018; Jaimes, 1991).

Current gardening and soil projects in Midwestern Native American communities fill a different niche than before colonialism. Instead of growing fruits and vegetables for subsistence purposes, some communities that all but lost gardens and the knowledge associated with maintaining a healthy garden are now re-introducing gardens in order to become more food sovereign (Gould, 2018). Raj Patel has described food sovereignty as: "…a call for people's rights to shape and craft food policy" (1, 2009) and the People's Food Sovereignty Network as:

> "…the right of peoples to define their own food and agriculture; to protect and regulate domestic agricultural production and trade in order to achieve sustainable development objectives; to determine the extent to which they want to be self-reliant; to restrict the dumping of products in their markets; and to provide local fisheries-based communities the priority in managing the use of and the rights to aquatic resources" (Windfuhr & Jonsen, 2005).

Using these definitions we can begin to picture what this looks like in many Native American communities. Examples of this are the growing community interest in home and community gardening programs which gets community members interacting with ancient crop varieties and increasing their demands for culturally relevant foods (Gould, 2018). Research by Kyle Whyte found that this resurgence for culturally appropriate food may act as a tool for cultural continuance and reinvention (2016).

One of the Most Fertile Regions

The food sovereignty movement has taken off among Indigenous people throughout the Great Plains and the Midwest. Jay Gordan Arbuckle defines the narrow band of area in the United States starting near Omaha, Nebraska, and generally covering Iowa sweeping eastward towards the Great Lakes as "one the most fertile regions of the United States (2020, 35). Growing seasons in this area are limited to the 120 average frost-free days in upper Wisconsin (Riley & Freimuth, 1979) to 170 average frost-free days that occur each year in the lower latitudes of the American Midwest (Gartner 2003, 29). J. Power and R. Follet describe Iowa and the flat landscape of the Great Plains as once being home to a native prairie that was destroyed through the invention of the steel plow in the 19th century (1987). Parts of Wisconsin on the other hand has had a historical lack of glacial activity, and now this space is characterized by steep hills and heavily forested deep river valleys, a remnant of a more ancient time earning the title the driftless *area* by modern-day scholars (Gallagher et al., 1987). This rich landscape and careful observation of the natural world enabled the Indigenous peoples of the region to create intensive but sustainable agricultural systems. The remnants of these cropping practices can still be found in these areas including Iowa and Wisconsin (Gartner, 2011), because these areas have been relatively free from glacial disturbances starting around fifteen thousand years ago (Shay, 2022).

This research was conducted with several Native communities throughout this region that have begun pursuing food sovereignty efforts, Oneida, Omaha, Santee Sioux, Meskwaki, and a

Native American food growing co-op serving the Minneapolis-St. Paul area called Dream of Wild Health. The Oneida Nation, despite currently residing on a territory near Green Bay, Wisconsin, were not always located in the Upper Midwest. They instead resided for generations in the area of present day New York state (Ricciardelli, 1963). In the 1760s and after decades of living and interacting with Europeans, a faction of Christianity-practicing Oneida were under the authority of Elezear Williams, while the rest of the Nation was practicing their ancestral pre-contact religion (Hauptman, 1999). Williams feared the decimation of the Oneida Nation through land grabbing by European colonialists and began a concerted effort to get Christianized Oneida people to emigrate westward towards present day Wisconsin, a feat Williams successfully completed in 1821 (Hauptman, 1999).

Jennifer Hill-Kelly notes that the current Oneida Reservation near Green Bay Wisconsin was formed in a treaty in 1838 (2017). After their emigration to Wisconsin, the Oneida increasingly engaged with the Fur Trade, and by the 1870s, their lives were heavily dominated by the cash economy associated with European colonialists (Hauptman, 1999). The passage of the Dawes Act in 1887 allowed non-Native peoples the ability to lay claim to lands formerly held by the Oneida community through private ownership, shrinking the ability of Oneida people to access landscapes that they may have used to practice their pre-contact ways of life (Hauptmann & McLester, 1999)

The Omaha were first recorded on European maps in the late 1600s in the present day area of SW Minnesota and Northwestern Iowa (Boughter, 1998). They were primarily horticulturalists up until the early 1700s when they came into possession of European horses and guns which shifted their culture to one that was more dependent on buffalo (Boughter 1998). Crops grown by the Omaha prior to being forced onto a Reservation by the US Federal

Government included maize, beans, and squash, which would have supplemented wild fruits and tubers that they would have foraged (C. Miewald, 1995).

In 1825, the Omaha signed what the US Federal Government called a 'Peace and Friendship' agreement, which stated that the Omaha understood Euro-Americans as supreme and needing American assistance with their trading, and by 1830, the Omaha had ceded their first parcel of land to the US Government (Boughter, 1998). By 1855, the vast majority of Omaha were largely dependent upon European goods and annuities (C. Miewald, 1995). The Dawes Act in 1887 shrank the size of the Omaha's Federally recognized land base, from 302,800 acres in 1854, to 119,000 acres in 1893 (C. Miewald 1995, 90) This loss of land further hindered the Omaha's ability to feed themselves using their ancestrally-based cultural knowledge as it existed prior to contact. By 1915, Omaha people were actively commodity crop farming and Federal Government funds were used by the Agricultural Extension Service to have farming specialists visit their the Omaha community for agricultural extension purposes and to vaccinate their hogs (Firkus, 2010). Omaha were supplementing or replacing their home gardening plots with commodity crop fields for the market economy (Firkus, 2010).

The first recorded interactions between the Santee Sioux and European people happened in the current state of Minnesota starting in the 1640s, but the oral history told by Santee Sioux describes themselves as originating from areas along the Atlantic seaboard (Mniyo & et al., 2020). Like other Native communities in this region of the United States before colonialism and up into the Reservation period in American history, the Santee Sioux were horticulturalists and foragers who lived primarily along major rivers and streams. After accepting being confined to a Reservation in 1851 through the Treaty of Traverse des Sioux, the Santee Sioux community began to suffer from extreme hunger when the annuities allotted to them by the US Federal

Government were either not used to buy provisions for the community or were not paid to them (Hughes, 1929) .

A drought in 1862 added woes to the story of the Santee Sioux who were already living on a reservation that was too small to support their population, which ultimately led to the Dakota War of 1862 after Santee Sioux men were accused of killing non-Native people in pursuit of food items because their Nation was not able to feed itself using their ancestrally-based food production systems (Mniyo & et al., 2020). Thirty eight Santee Sioux men were executed in a mass hanging event for their part in the Dakota War, a number radically lower than the 300 that were initially sentenced to be executed (Allen, 1896). After this event, the remaining Santee Sioux women and children were forced by the United States Government to Crow Creek, South Dakota where they struggled to survive (Allen, 1896). Colette Hyman refers to this period in Santee history as an "ethnic cleansing of Minnesota" by US Government forces. This period was a particularly stressful three yearlong event for the women and children of the communities because the vast majority of the able- bodied men of their Nation were imprisoned for participating in the Santee Uprising (2008, 150). The women, children, and elders of the Santee Nation that were imprisoned at Crow Creek struggled through illness, death, and especially hunger (Hyman, 2008).

According to Helen Tanner, Native people were being moved out of Minnesota or onto Reservation tracts long before 1851, affecting the Ojibwa, Ottawa, Menominee, and Winnebago Nations (1987, 167). Babcock describes how a treaty signed in 1851 forced the Sioux Nation to surrender most nearly all their territories in Minnesota besides a small track of land along the Minnesota River (1962, 32). A bill written by Government officials in 1862 lead to the removal of the Winnebago Nation from Minnesota (Lass 1963), while Treaties for other Natives Nations like the Ojibwe were written during this time that gave them lands to claim in Minnesota (Vizenor, 1989). Now there are currently around 79,000 Native Americans in Minnesota representing 1.4% of the state's total population, with roughly 8000 living in the Minneapolis-St Paul metropolitan area (Bureau, 2021). The Office of the Minnesota Secretary of State formally recognizes eleven Native Nations with Reservations within Minnesota, seven being Anishinaabe, and four Dakota (Secretary of State, 2022). Dream of Wild Health is an intertribal non-profit that operates on a 10-acre farm located within an one hour drive from downtown Minneapolis, with it's mission statement describing itself as working to: "…restore health and well-being in the Native community by recovering knowledge of, and access to, healthy Indigenous foods, medicines, and lifeways" (Gould, 2018)

European traders first interacted with Meskwaki peoples in present-day Wisconsin and Illinois (Steward & Hubbard, 1911), and they were referred to as the Fox (Kubiak, 1999). The Meskwaki were engaged in a conflict from 1712-to 1737 with the French centering on the fur trade. By the 1800s, the Meskwaki had abandoned their territories in the Great Lakes Region and taken up residence in the state of Iowa. By 1857, the Meskwaki had purchased 80 acres of land along the Iowa River in Tama County (Daubenmier, 2008), a land base that they have added to over the years and continue to reside in. The Meskwaki Nation currently operates a 40-acre self-sustaining farm within their Nation's boundaries, which allows them to both feed their community healthy food as well as create job opportunities and training programs for the area residents (Whyte et al., 2016)

Conclusion

Soil is described by Manuel Tironi et al. as a taken for granted commodity that is invisible to city inhabitants and politicians because of sociohistorical separations (2020).

Individuals living mainstream lifestyles within cities may have little contact with soil in their day to day lives, and the majority of the knowledge they have about soil is developed within educational institutions that produce universalistic and shallow observations (Krzywoszynska et al., 2020). Because the vast majority of individuals within modernized communities are able to operate without interacting with soil for their daily survival needs, the ecological harm associated with capitalist markets can happen without scrutiny. As described by Karl Marx, the gravity of the power bestowed upon those that privately own and control Earth to help feed populations may be problematic, and ultimately works to create an exploitative human and soil relationship: "All progress in capitalist agriculture is a progress in the art, not only of robbing the worker, but of robbing the soil" (1979, 506). Within the current market structure of capitalism, soil is not a commodity (or valued as such) because it is not: "…a product of human labor hence it is not reproducible" (Labban 2008, 40).

Currently, there is a noticeable lack of published literature about the soil effects from Three Sisters Intercropping on soil fertility and biology when compared to the amount published about the impacts of industrial agricultural practices. In addition to the scant literature on the soil science related to the Three Sisters cropping practice there is also a lack of available information available about worldviews from Native Nations regarding plant and soil interactions or human and soil interactions. Mauro Engel-Di Mauro and Levi Van Sant have written about the disentanglement from soil humans have allowed themselves to experience through the commodification process (2020, 56) and Anna Krzywoszynska et al. have written about the dangers of societies only understanding soils as taught to them through scientific institutions (2020). As mentioned in an earlier passage, there has been an extensive amount of ethnopedology conducted in Indigenous communities outside of the United States. But there is a lack of scholarship on Native American perspectives on soil, who interacted with the soils of the American continent for sustenance food production on the magnitude of thousands of years. Understanding a different cultural outlook on the importance of soil conservation and the crafting of ancestrally based sustenance agricultural systems could help inform those creating resource policies to think about alternative agricultural production methods than those that are currently accepted. For scholars to understand the perspective within Native communities about soil and its importance within the functions of the wider Earth, collaborative types of research methodologies should be used to be successful.

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CHAPTER 3. LESSONS FOR AGRICULTURAL EXTENSION IN NATIVE COMMUNITIES

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Abstract

Agricultural extension at universities is used to research and teach cropping practices in a way that is accessible to most anyone interested. It is intended for all growers, but historically communities of color have either been excluded from extension services or have been assigned different goals based on stereotypes about the needs of those communities. The US Congress first began funding agricultural education for Native American communities with the passage of the Civilization Fund of 1819, and individual treaty agreements between different Native Nations and the US government often contained provisions to hire reservation farmers (Firkus, 2010). Federal law makers assumed Native people needed more intensive education than an average Euro American farmer, because Native American communities historically did not grow crops in the same manner as Euro-Americans chose to. Ultimately, these educational interventions were designed with assimilation in mind.

Cooperative university-led agricultural extension has been a feature of American farming circles since the passage of the Smith-Lever Act of 1914 (Firkus, 2010; Mcdowell, 2003). In the present day, Agricultural Extension Specialists (AES) working to create new networks within Native communities may face significant hurdles because of the history that agricultural instruction has in Native communities. The historical and intergenerational trauma associated with the colonialism over Indigenous lands and lifeways by Euro-American descendants may

still cause lingering feelings of distrust and hostility when AES enter and interact within Native communities. This chapter examines how the Three Sisters Intercropping Project, composed of Iowa State University faculty and representing the disciplines of anthropology, soil science, horticulture, and dietetics, built collaborative networks within Native American communities with the goals of helping them be more food sovereign. The experiences of this team and the corrections they made demonstrate the challenges and successes involved in building collaborative Agricultural Extension agendas with Native communities.

Introduction

This chapter examines the intricacies and experiences that I had as a graduate student working on a Federally funded and university-led multidisciplinary project that took place in five Native American communities within the American Midwest region. Key project goals for the project included the creation of extension events and media to help Native community members grow successful gardens and encouraging community members to grow a research garden so they could share their plant and soil data with us. This chapter delineates some barriers we experienced as we worked to build a collaborative agronomic research project with Native growers, relating our efforts at overcoming these challenges, and revealing our successes with the goal of providing suggestions for designing more successful extension engagements in the future.

Work by Sue Buck on extension activities in minority communities found that diverse communities do not share the value system and worldview many extension specialists have (1997). Joyce Alves states: "…educational programming should differ from tribe to tribe, and community to community" (1993, 1). As described by James Mahan, Native communities may initially collaborate more with outside research entities if the Euro-American Agricultural Extension Specialist (AES) incorporates community involvement, friendship building, and group discussions into their extension plans (1984). A different and possibly unique barrier within Native communities to making inroads as a university Extension specialist is the concept of Indigenous traditional ecological knowledge (TEK), defined by Fikret Berkes as: "…a cumulative body of knowledge and beliefs, handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (1993, 3). Because Indigenous TEK is a holistic perspective on how to navigate one's interactions with the Earth for survival, the approach of science trained extension agents can be difficult for Native growers to integrate and even be seen as offensive, depending on the approach. An AES trying to work and build collaborations in communities outside of their normal audience would benefit from enlisting the help of disciplines that directly study cultural and interpersonal interactions.

This is where social science, particularly anthropology, can become useful for an extension agent to provide guidance for cross cultural communication. According to Clifford Geertz: "The aim of anthropology is the enlargement of the universe of human discourse…" (1973, 24). Using theories and methodologies associated with anthropology can allow a scholar to gain a deeper understanding of the meaning making that specific communities and cultures engage in. By understanding what each community values as meaningful, scholars can work collaboratively to help create culturally appropriate solutions to issues within different communities. Because many cultural anthropologists build relationships of trust between themselves and a community, they can more easily envision the worldview and motivations are important to a community. Famous anthropologist Bronislaw Malinowsky stated anthropology can be used to: "…grasp the Natives point of view…to realize his vision of his world" (1922, 19). Acting as participant observers helps anthropologists better conceptualize both an etic (outside perspective) and an emic (inside perspective) worldview about a culture being researched (Chilisa, 2019). These perspectives can provide valuable insight when an interested party is working to design educational experiences in a way that are impactful and culturally appropriate.

European vs Native American Agriculture

Native American agricultural systems were recorded very early in the colonialism process as: being biodiverse across space, and time (Delabarre & Wilder, 1920), primarily led by women (Doolittle, 1992; R. Sasso, 2019), and strategically placed in the naturally fertile soils along rivers and streams (Fowler 1969; Delabarre and Wilder 1920; Riley and Freimuth 1979; Fox et al., 1959). Plants were cultivated and tended to by Native people for their direct value as a source of food, medicine, and trade items, and the communities performed ceremonies to give thanks to the Earth for bountiful harvests (Mihesuah, 2003). Contextualizing the Earth as a giver of life put Native people in a position of deference to Earth and its inner workings, a concept described by Robin Wall Kimmerer (2013): “When we braid sweetgrass, we are braiding the hair of Mother Earth, showing her our loving attention, our care for her beauty and well-being, in gratitude for all she has given us” (18).

Euro-American agricultural practices operate on a different premise, and it is one that is shaped at least in part by the Christian religion historically practiced. Bible passages describe human domination over land, the unfailing willingness of God to supply the necessary rains for crops, and human dominion over animals (New King James Version, Deuteronomy 11:13-15), in addition to telling men than their true purpose in life is farming: “The LORD GOD took the man and put him in the garden of Eden to work it and keep it” (New King James Version, Genesis 2:15) . According to the bible, the Christian landowner that chooses agriculture as an occupation on his land inherently *knows* the best way to interact with that space, as described by Isaiah 28:26, 29: “The farmer knows just what to do, for God has given him understanding. The Lord of Heaven’s Armies is a wonderful teacher and he gives the farmer great wisdom” (New Living Translation).

Josh Nygren describes the mentality in the early 1900s from Euro-American farmers towards one another: “The solution for farmers thus was not to resist capitalism, but to embrace its business-like approaches. Only then could they make enough money to climb the agricultural ladder to landownership” (Nygren, 2015). Contrasting to Native American cultures who were mostly growing food items to feed their household, Euro-American farming is motivated by the market economy than for personal household dietary needs, a behavior described by Karl Marx as capitalist agriculture (Foster, 2000). The commodification of landscapes within the Euro-American culture evolved alongside the concept of private property rights (McCarthy & Prudham, 2004).

Euro American colonialists during this time regarded their own culture as superior to those of the Native American people and judged Native people who initially resisted assimilation into the market economy as inherently wrong (Neville & Anderson 2013, 241). Linda Smith describes part of the colonization process as: "defining legitimate knowledge" (1999, 225), and for most of America's history, Native American knowledge systems and the thought contained within them were deemed inferior by non-Native peoples who sought to control an increasing amount of the American landscape. Because Native American cultures did not operate in the same manner that Euro Americans with their financially-based market economy did, Native American people were characterized as below average brain functioning by critics who were of Euro American descent (Johnson & Murton, 2007; Lange, 1911; Ross, 1978; Vennum, 1988).

Interestingly up into the middle of the 20th century, Native American people were been portrayed in the Hollywood movies as being unintelligent but friendly as described by Vine Deloria (1969)

Historical roots of Extension in Native Communities

The Morill Land-Grant College Bill of 1861-62 mark the official beginning of the land grant university and Cooperative Extension Services. The Morrill Act ultimately gave Congressman in each State an endowment of 30,000 acres to be used to fund the creation of at least one college in their area that would specialize in agriculture and mechanics (Simon, 1963). The act was drafted to promote the sciences of agriculture and mechanic arts to educate working class individuals to enter the technical professions (Mcdowell, 2003). The Morrill act was then complemented by the Hatch Act of 1887, funding land grant colleges for creating agricultural experiment stations and extension services so the American public could more easily benefit from tax-payer-funded research (Flanagan et al., 2013).

George McDowell notes that the Lever Act of 1914 further enhanced the engagement of Land Grant Universities with the public by providing even more funding for extension programs and combined with the Morrill and Hatch Bills, was revolutionary because it provided access to knowledge to people who were previously unable to afford college education (2003, 34). As a result, by the 1950's, U.S. farmers were successfully competing with producers worldwide while being a significant sector of the U.S economy (Mcdowell, 2003). Nevertheless, the loss of land and the imposition of college educated experts frustrated many farming communities at that time (Zimdahl, 2003). Furthermore, the land used to create colleges through the Morrill Act had originally been secured from Native American people by the US Federal Government through various treaties.

While Federally-funded agricultural education may have historically benefitted non-Native growers, Native good growers have had a different experience it. The US Federal

Government used general agricultural education activities within Native communities to force assimilation onto the Native peoples through the passage of the Civilization fund in 1819 (Firkus 2010, 474). Fifth President of the United States, James Monroe, was recorded in his 1824 State of the Union Address as saying, “To civilize them (Native American people), and even to prevent their extinction, it seems to be indispensable that their interdependence as communities should cease, and that the control of the United States over them should be complete and undisputed” (Monroe, 2021). By the 1870s, the US Federal Government, along with the help of different church organizations, had begun a massive campaign of forced-agricultural education on Native American people of the Upper Midwest through Indian boarding schools for the Native youth. A few children willingly left their home communities to attend these schools at the encouragement of their families, but most were outright kidnapped from their families by military forces who would withhold rations from Native people or use other coercive tactics to remove children from their homes (Booth, 2005; Haskins & Jacobs, 2002; Purdue & Green, 2010).

Once at the boarding school under the watchful eyes of their school teachers, Native youth were forced to learn methods of growing crops like wheat, oats, and hay, all of which were culturally unfamiliar to them (Ricciardelli 1963), to farm in places that Native people would not have typically grown crops (Gartner 2003; Sasso 2003; Fox, Wahla, and Moll 1959), all while using techniques and worldviews that were unlike those held by Native peoples in their home communities (Ricciardelli 1963, 323). Many Native youth would eventually leave the boarding schools to find out that many of the things their schoolteachers taught them would be useless once they returned to their home community. The US Government had forced most Native people onto reservations composed of typically poor quality soil, furthermore, they did not having access to the high-quality farm implements they were trained on while at the boarding schools (Hurt, 1987).

By 1916, some county agricultural instructors across the Midwest US had already begun concerted efforts to interact with the adults in Native communities to help them with their farm and animal husbandry pursuits, but the vast majority of county agricultural instructors at that time were not interested in making in-roads with Native communities and instead preferred interacting more with other minority communities (Firkus 2010, 476). When agricultural instructors did visit Native communities, they actively worked to convince community members that the pre-contact worldviews held by Native people that helped them exist in their homeland for generations were subpar to European-based crop production practices (Purdue & Green, 2010). By 1928, Native Nations such as the Menominee were somewhat interested in agricultural advice offered by the county agents but became resistant when they tried to pressure the community into adopting radically different agricultural and animal husbandry practices than they were familiar with (Firkus 2010, 490). Crop yield data from the Menominee Nation shows that their farming success peaked before 1920 (Firkus 2010, 490). According to Ricciardelli, the Oneida were actively engaging with Quaker agricultural instructors by 1810 (1963, 324), who used model farms to showcase cropping practices associated with the market economy. Treaties signed in 1854 by the Omaha brought Federal Government-sponsored agricultural instructors to their territories, who introduced Omaha people to the idea of full-time sorghum cultivation in order to move them away from their subsistence economy (Miewald 1995, 87). In the 1860s, these same agricultural agents wrote that the Omaha were: "willing to cultivate the ground to raise sufficient amounts for their own food" but had little desire to produce crops for the market economy (Miewald 1995, 87).

Methods

I conducted the research that resulted in the writing of this chapter as part of a multidisciplinary project at Iowa State University called the Three Sisters Intercropping Project. The project's overarching goal is to work collaboratively with different Native communities located near Iowa State University to share knowledge about increasing soil health to help them be successful gardeners and propel any goals they have towards food sovereignty. We put together an advisory board composed of members from each of the collaborating communities to help us design project agendas that were directly useful to the individual gardeners we were interacting with, in addition to ensuring we were acting culturally appropriate with our behaviors towards the Indigenous seed varieties we used in our research. The advisory board also helped us select seed varieties they wanted us to bring to their communities through our project, as well as helped guide us in the collaborative research aspirations that the dieticians, horticulturalists, and anthropologists had.

My specific field of inquiry within the overall Three Sisters project was to motivate the Native collaborators to act as community scientists. This aspect of the project involved encouraging and assisting collaborators in planting a *research garden block* consisting of three single species (maize, bean, or corn) plots and one maize, bean, and squash intercropped plot. I also recruited growers in these collaborating communities to use a suite of do-it-yourself soil health measurements that I organized into a Soil Health Kit Manual (SHKM) and kit that came with a series of informational step-by-step instructional videos (APPENDIX X), with the ultimate hope that they would share the data they collected with the ISU team. We assembled the components of the soil health kit and wrote the manual associated with it with very little initial feedback from Native collaborators, but we posted the manual online, distributed it through emails, and even gave out hard copies when asked, all in order to try and open channels

Commented [HCG[3]: Put it in a footnote. See appendix X of communication between us and the collaborators about the SHKM. To boost engagement with this community science aspect of our project, we incorporated live demonstrations of the different SHKM tests into topics covered during virtual and in-person workshops, and we additionally we offered a monetary stipend to anyone that would participate in planting and maintaining a research block with the intention of sharing their data with us.

As part of the relationship building process during the Summer of 2019, the team offered to take soil samples from the garden of any collaborator that wanted one so they could gain insight into the macro and micronutrient levels in their garden soils. In addition, we also gave them the option to receive a detailed nutrient recommendation written up with the results from the soil testing, if they chose to. In 2019, I collected soil samples from over 25 home gardens in the collaborating communities for analysis and was able to deliver the nutrient recommendation writeups to each grower before the conclusion of the growing season so they could make nutrient adjustments if they chose to. For a few of the collaborators, they asked to receive recommendations such as ways to increase their soil's organic matter and different types of cover crops they could benefit from planting.

The ISU research team created our own randomized, replicated block-designed research experiment on ISU property at the Horticulture Research Station to test how Three Sisters intercropping affects the soil when compared to monoculture (See CHAPTER 5 for more details). We maintained a level of scientific rigor in our garden that often was not always possible in the collaborator communities because we had paid staff dedicated to its maintenance. Within our research garden, we added drip tape irrigation which helped our garden be successful, most especially during the 2021 growing season because we were affected by a multi-year drought. This feature alone set the chances of our garden's success substantially higher than those of our collaborators, many of whom were using rainfed techniques only. Our garden also had an asset that collaborator gardeners didn't have at their ready disposal--horticultural specialists and plant pathogen diagnostic laboratories. Our team had members on it with decades of experience looking at plant diseases and were able to mitigate any potential problems immediately when they arose. While we used these resources to help our collaborators when asked, our response was not as immediate. We had a dedicated gardener whose sole focus was to manage the garden for the entirety of the growing season. The garden manager was able to secure additional labor when it was necessary, which worked to keep our garden weeded and pest free. All of these features allowed us to maintain our research garden with a high degree of scientific rigor. Our Native collaborators ultimately did not have the resources to replicate this for this aspect of the project.

To fulfill our goals of offering university agricultural extension services back to the communities we engaged with, we compiled topics that were identified by the Native advisory board members as necessary to the collaborating communities and put on multiple informational workshops to address them. Because our project gained traction right as the Covid-19 pandemic started, we had to navigate conditions in less-than-ideal ways to keep everyone and ourselves safe. During the summer of 2021, our travel restrictions eased, and the research team visited two of the collaborating Native Nations to deliver informational workshops with an emphasis on outdoor events for the safety of all participants.

Gaining entry to a Native community

Building networks within Native communities as a non-Native with no connections already in place is not an easy task. For decades, many Native communities have been burdened by academic scholars and researchers. Many Natives critique these research practices, arguing the only ones who benefit from it are the researchers themselves who further their careers through it (S. Buffalo, 2020; Deloria, 1969; Bear Heart, 1996; Smith, 1999). Duane Champagne, Professor Emeritus of Sociology and American Indian Studies at UCLA, succinctly describes former methods of scholarly endeavors as described by a Native person: “Researchers emphasized academic theories, verification of theories, and engaged tribal members as objects of study” (2015, 73). Vine Deloria combats scholarly attempts at doing research on Native people by writing that they treat Natives as if they are objects to be manipulated in a scientific experiment (Deloria, 1969).

Edward Said’s comment about the Orient comes to mind when understanding the problem with academics using Native people for research subjects: “No one has ever devised a method for detaching the scholar from the circumstances of life, from the fact of his involvement (conscious or unconscious) with a class, a set of beliefs, a social position, or from the mere activity of being a member of a society” (1978, 10). When non-Native academics use their position to analyze what Native people are or are not doing, they are inherently bringing their own prejudices along the way to make their conclusions. Not allowing Native people to define and describe themselves to the non-Native world runs counter to well-known French philosopher Michael Foucault’s definition of the ‘right to life’, defined by him as: “…to one’s body, to health, to happiness, to the satisfaction of needs and, beyond all the oppressions or alienation, the right to rediscover what one is all that that one can be…” (1976, 199). While scholars write about their experiences studying Native people, Native people are hearing about what is being written about them and are responding; some authors argue that Native communities should be left alone for scientific research unless scholars have the capability to actually help the communities being researched (Deloria, 1969; Smith, 1999).

However, if an Agricultural Extension Agent (AEA) is working on networking with

Indigenous peoples, they must be sure that they can nurture an ongoing and reciprocal relationship between themselves and the members of the potential collaborating Native community. It also should be a high priority for the academic to ensure that their collaborating informants are community-wide respected members of the public that know the subject of interest (health, agriculture, etc.). Project plans could easily be derailed if the academic is working with an individual whom a community either distrusts or has an extreme amount of negative emotions toward. Furthermore, working with people who are not respected knowledge holders can not only damage the research, but can harm a scholar's reputation to the community.

Native scholars also often struggle to gain access to Native communities to conduct research but for different reasons. Unlike many non-Native communities, there isn't always the level of community prestige gained when a member from a Native Nation begins to work with university professionals. My own experience as a scholar has taught me that while there are times when being a Native student trying to do research in Native communities may potentially help a to gain access and more easily network within the community, there may also be times when being a Native person studying their own culture may present its own unique set of obstacles. Native people and others from marginalized communities may hold varying degrees of resistance to Science (Ramos, 2018), so seeing someone from their own community interacting with outside research entities may be even more problematic.

Non-Indigenous/Native scholars and researchers have described minority ethnicity populations as skeptical and suspicious of outside research entities entering their communities too though, (Birmingham, 2003; Daubenmier, 2008; Naaeke et al., 2011), so AES must be ready to face community suspicion of them no matter what their background may be. Ultimately, knowing that there is resistance in Native communities to interacting with university-sponsored research entities and understanding why, could help provide insight to an AEA in the event that their programs are not being received as expected in a potential collaborator community.

Building rapport

A central theme that a scholar working in university extension with Native Nations needs to consider when trying to begin to build a collaborative research project with a Native Nation is rapport. Rapport is hard to build but once attained, can also be easily lost. Ultimately, it is crucial for the researcher to maintain the rapport and respect of their core collaborators in order to maintain access to the community. Some ways of doing this are listening to concerns that collaborators might voice during the project *and responding to them*, staying true to one's word, being physically present in the community and “showing one's face” (Smith 1999, 269), and respecting cultural boundaries and differences. It is also essential to understand that securing trust from collaborators may mean that a different collaborator needs to be removed from the project for whatever reason, and it is vital to know how each collaborator is viewed by their respective community to know how to navigate these issues should they ever arise.

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Do you need both words? If so, why? If you keep them both, you need to distinguish them. Trust is more about doing the things you say you will and rapport is the relationship. But they’re also interchangeable. Make a decision and make it clear in your writing.

Bagele Chilisa describe the concept of reciprocal appropriation as an acknowledgement that scholars trying to do research within local communities are appropriating local culture to some capacity, and the scholar should be mindful to ensure that benefits are flowing toward the community being researched to be compensated for this (2019). Within our own project, the advisory board we created out of members from each of the collaborating communities may helped us helped us better understand the needs of the communities we interacted with. We kept regular meetings, having them both in-person and virtually when necessary, throughout the entirety of the project. During these meetings, we gave the spokesperson for each collaborator community the opportunity to discuss what they viewed as culturally significant behavior towards plants and seeds to guide us with our own research garden, as well as the opportunity to tell us how we could help their Nations. We developed workshop agendas through the discussions with the advisory board and covered topics they found valuable to their cropping systems, helped them plan out future gardening plots, learned the seed varieties they would like access to, and shared stories with one another. The virtual advisory board meetings and workshops were difficult to navigate when we were trying to create personal relationships with our collaborators but this issue was less impactful when were physically gathered together. During the extended trips to the collaborator communities over the summers of 2019 and 2021, we spent enough time with gardeners in each of the locations to get a broad understanding of what they were experiencing and what their needs were with respect to their cropping systems.

Being physically present is paramount to building trust and acceptance in Native communities, and there is no real shortcut to this (Smith 2021, 269). Scholars and those working in agronomy-extension who are familiar with collaborating with modern industrial farmers for agronomic data collection may feel anxious when Native growers ask them for time to become acquainted with one another before talking about collecting plant or soil data. Examples of activities that collaborators may ask a scholar to participate in include community ceremonies and parties, day-to-day chores they need help with, or even just hanging out and enjoying a meal together. Smith describes Māori language as having a 'seen face' concept, which she describes as: "…showing your face, turning up at cultural events – cements your membership within a community in an ongoing way and is part of how one's credibility is continually developed and maintained" (1999, 15). Consistently not being able to commit to being physically present when asked by collaborators is akin to telling the communities that they are not important enough for the extension specialist to create memories and friendships with. Not spending the quality time necessary to build the trust between the Native community and an academic could lead to faulty interpretations when Native people are trying to communicate their needs (Smith 1999, 69). A truly collaborative project between the scholar and Native Nations will avoid this behavior.

One way to help build and maintain the collaborator community's trust and respect is by remaining predictable and not allowing oneself to deviate with regard to how the AES introduces potential projects to a Native community. Changing projects or outreach goals/agendas during the execution phases of the project makes the Extension specialist appear to the community as if they are not thinking clearly about the task at hand or are an irrational actor, both of which may negatively affect the community's acceptance of a research project. As described by Smith, "Indigenous people and communities should not have to guess a researcher's identity or their agenda. There are still examples being told of the use by researchers of subterfuge, treating people as if they are dumb, and outright lying in order to gain access to Indigenous communities and Indigenous knowledge" (1999, 194). While an AES may have obtained a higher level of education when compared to the vast majority of potential collaborators in a Native community, that should not allow the AES to feel a level of intellectual superiority.

Remaining consistent and predictable during interactions with the Native community shows them that the Extension specialists are level-headed. It also shows the Native community that the Extension specialist is trustworthy. The longer an Extension specialist or researcher is in a community, it is presumed that their rapport amongst that community should increase (Chilisa 2019, 236), but if a scholar is regularly altering the direction of their project, this process of rapport and trust-building between the two communities may be dampened. Shifting a research project as it has already started in an effort to scrape more data than was initially agreed upon could reinforces the distrust that many Indigenous communities feel towards researchers. This behavior may be particularly insulting to Native communities because they have historically experienced the wrath of the US Federal Government's shifting treaty policies (Neville & Anderson, 2013).

As described earlier, academics working to build networks within Native communities have to first acknowledge they are trying to interact with communities that have a long and sometimes toxic history with university-led research and extension (Daubenmier, 2008), and because of this, the burden of proving ones trustworthiness lies much more heavily on the scholar trying to gain entry rather than the community being approached. Native scholars even make the claim that research and action anthropology conducted in Native communities is useless to the Native communities being interacted with; such research may even end up reinforcing wrong stereotypes about Native people (Deloria, 1969). Ultimately, as described by Linda Smith, the relationship between a scholar and a Native collaborating community will be complicated (1999, 156).

Knowing when to back off

Modern-day agricultural Extension in Native communities

In many Native communities, scholars can be met by those who consider academia and its craft as irrelevant to Native well-being or potentially even unacceptable (Borofsky, 2019; Gaku & Carrier, 2015; Gaudet, 2014). There is literature that has even been published that has documented how university-trained scholars have inflicted damage within Native American communities through their research methods, which was been carried out with both transparent and non-transparent intentions on the part of the academic (Daubenmier, 2008; Simmons, 1985). With this stigma that follows university professionals as they step into Native American communities, any collaborative networks they may want to build between the university they represent and a Native community will be challenging.

Andreas Wittel (2000) describes gatekeepers as someone who can open (or close) the field for a researcher, play the position of a mediator between a researcher and a community, and work to make a scholars' interactions with a community start off on the right foot. Community gatekeepers may present themselves at different points during a research project despite a scholar's warm welcome by other community members, and these gatekeepers may or may not hold advanced degrees and be versed in academic language. When the Meskwaki community got word that we were interested in conducting both agronomic and ethnographic research amongst them, we were asked to have a meeting by the directors of two different departments within the Meskwaki administration. Even thought the meetings went well, the Meskwaki community ultimately never became formal collaborators with our project; they allowed anthropology scholars onto their Settlement for research purposes previously and still remember the interpersonal drama it caused within the Nation (Daubenmier, 2008).

Unfortunately, despite an agronomist's best intentions, there may come a time in their collaboration with Native communities that it may be best to step back, slow down, or perhaps even stop a planned extension project. This will often be communicated to the agronomist by the community, with different levels of intensity that can range from being outright ignored in email and phone call correspondences to being aggressively and loudly chastised in a public setting. It may be easy to overstep one's boundaries as an outsider with no experience in the community if a scholar does not readily have the assistance of a key collaborator that the community respects and this most especially can happen during in-person activities. During extended visits into communities and with particular families or individuals, knowing when to back off and give some space to a collaborator during the research is also essential. It may be easy to get caught up in the fever of a project going well. Still, it is prudent to remember that as an outsider, you are literally dependent upon the collaborators to engage with you; committing any major social faux pax like hanging out with a person viewed as toxic or untrustworthy in a community could damage the project.

Collaborative research etiquette

One way to help ease anxieties and suspicions towards university extension specialists who might be trying to engage Native Nations is by striving to make sure that extension is truly trying to work *collaboratively* with the Native people rather than just trying to dump university-level science knowledge on a community that may or may not have any interest in the topics being discussed. The Extension specialists should consider some key questions before attempting to contact the Native community in the early phases of the relationship process, as described by Smith (1999): 1) What knowledge will the community gain?; 2) What are some possible negative outcomes and how can they be eliminated?; and 3) What are some likely positive outcomes"? (226). Smith writes that these questions are important for a scholar to consider before even approaching minority communities because scholars should be working to understand their personal reasons to why they want to approach Indigenous communities, and who will benefit more from the interaction of Indigenous communities do choose to collaborate (226).

A truly collaborative project between an AES and a Native community will start being collaborative in the beginning phases, when the AES is working to build relationships within the communities they are interested in working with. While the Extension specialist may have a general area of interest that they want to work on with the Native community, the Extension specialist needs to remain flexible and open to critiques and criticisms of their proposals by members of the Native Nations they are interacting with. Tom Osborn writes about the historical 'blueprint approach' in development projects by extension specialists, which Osborne describes as the go-to behavior by extension specialists who go to a community with specifically defined and highlighted goals (1995, 5). This type of outreach event: "…constrains program development, limits abilities to respond effectively to changing conditions, and opportunities and learn from past experiences" (Osborn 1995, 5). Using the blueprint approach within Native communities may be in error because Native people may experience different issues affecting their gardens than growers using highly technological growing techniques with the goal of increasing yield. Native growers using Indigenous methodologies can experience different pests and diseases to different severities than do those using modern cropping practices, because many times they are using heirloom crop varieties and planting them using Indigenous methods. In our project, there were many collaborators with this project that grew food for their personal consumption, but only one or two actually sold the produce they grew. Entering the community with a predefined research agenda is rarely as helpful to a Native community as would creating research goals *with* the Native communities. Collaborating in the early phases may look like extensive communications with the Native community about their needs through email exchanges, phone calls, in-person meetings, and in some cases, webcam meetings. Engaging in these behaviors could help lead to a higher Native engagement with the project than a program developed solely by the Extension specialist and delivered to the community.

Depending on the extension scientist working in Native communities and the level of respect bestowed upon them by that collaborator community, there may be moments when members of the Native communities share significant cultural insight with the extension specialists. Some of these cultural viewpoints may even be rooted in ancestral knowledge and may radically depart from the worldviews held closely by university-trained scholars. For example, some of the collaborators in the communities associated with our project had cultural values that forbid the use of tillage techniques on the soil and instead preferred to plant seeds in organic matter on top the soil surface. Laura Manthe, an Oneida grower and member of the Ohelaku Corn Growing Co-op, has chosen to let weeds grow between her rows of white corn because she notices that the weeds soak up excess moisture. The problem of the differences between a university agronomist's worldview and those of Native communities is best summed up by Bagele Chilisa (2019): "As Western-educated people who use Western-defined categories of analysis, we are not in a position to acknowledge the explanation of other realities" (109). Aside from academic disciplines such as anthropology that are specifically trained in thinking about the differences in worldviews and perceptions of other cultures, the vast majority of scientists are intellectually siloed within the published literature of their field. Knowledge systems and practices that exist beyond those walls may be deemed as less credible than those that do.

An example of how a situation could arise between an agronomist and Native community members is the conceptualization of plants and animals as human relatives that many Native communities into their culture. This belief system understands all living things as having a spirit that must be respected because it represents a key component within their worldview, as do all living (and some non-biologically living) things (Harkin & Lewis 2007, 215; R. Kimmer 2013, 121-126). Referring to the different plants within the corn, bean, and squash intercropping methods as *sisters* to one another is a representation of this worldview that treats plants as family members. Some Native American have even been recorded as referring to their corn plants with the term mother, while many Native American communities refer to soil as Mother Earth (Greendeer, 2020; B. Heart & Larkin, 1996; Kosola, 2020) or Grandmother Earth (J. Buffalo, 2020; S. Buffalo, 2020). Bear Heart, Native American shaman from the Muskogee-Creek Nation, even referred to the wind as his mother (1996).

Ultimately there may be times in the initial stages of relationship building between the collaborating community and the AES where the specialist is noticeably affected by interacting with a culture that views life forms differently than is taught in mainstream society. Within our own project, we had to learn to accept that there were limitations to the amount of data we were going to be able to collect from the seeds in the produce that we grew. Our collaborators respect seeds and plants as non-human relatives, similar to concepts described by Kimmerer (2013). Because of the close relationship some of our collaborators had with their seeds, the overall research team made the decision to not proceed with any seed-destructing analyses. To them, destroying plant seeds was both disrespectful and unnecessary. Native American people respecting plant life and seeds as actual living beings with agency may bring with it a level of responsibility (Whyte et al., 2016). The destructive analysis we had wanted to conduct on the seeds from our crops was scuttled and replaced with a less invasive analysis on the flesh of some of our crops. Before we were able to obtain permission to conduct these tests, we were asked to provide the project Advisory Board a detailed description as to how our analysis would benefit the overall project. Doing this allowed the collaborators the ability to understand more fully what our intentions were with our experiments on the culturally significant seeds and provided them the opportunity to decide whether or not they felt those experiments were appropriate.

Native American soil knowledge and university soil science

In contrast to university agronomic science, which typifies plants, soils, and other biotic life as variables to be controlled and examined, many Native growers using Indigenous methods instead consider the plants they grow and collect as *medicine,* described by Bond-Hikatubbi (2019), Kimmerer (2013), and many others (Cora, 2001; Frisbie et al., 2018; Gould, 2018). An agronomist may use indicators of soil health that can be examined through different chemical analyses done in a laboratory, but Native growers sometimes instead use their senses to gather more tactile and easily observable indicators. Lois Stevens, a member of the Oneida Nation, describes an ideal soil for growing food as being characterized by having a "wormy smell" (2020). To her, worms are a definitive indicator species of healthy soil. According to the Meskwaki Nation Red Earth Garden Farm Manager Grant Shadden (2020), the appearance and texture of high-quality soil should be like chocolate cake. According to Ho-Chunk Nation member Jessika Greendeer, a different way to judge the health of a soil is to observe the wild plants that are growing in a space because the different wild plant species that are already present in a space can give a grower a detailed level of insight into increasing the relative fitness of the soil that supports them (2020). Agronomists may rely more on an outside expert's analysis of the relative health of their garden soils, while Native growers using Indigenous methods may instead prefer using their own sense of judgement on whether a soil is healthy or not.

While giving an industrial farmer or horticulturalist a detailed soil analysis of their property may be a considerable token of friendship and a quick way to secure future connections between the researcher and grower, some Native people maintaining backyard garden plots that collaborated with this project did not view a science-lab soil analysis in the same way. As part of our relationship building process and to help our collaborators maximize their garden potentials, we offered to take soil samples from any gardener that wanted us to, with many growers even asking us to soil samples from multiple garden spaces they maintain in their back yards. Some gardens were very large and were planted with tractor equipment, while others were very small and only occupied a 3ft x 3ft space. The soil samples were collected from the growers and then delivered to a soil lab company that is popular with agronomists working with commodity crop farmers. After receiving the results from the soil lab, I was then charged with writing up nutrient recommendations specific to each garden, which were based off recommendations that would be prescribed for industrial corn and soybean farmers.

Throughout the project, a few growers thanked us for the soil test results and nutrient recommendations we wrote up for each of their gardens and described to us how they made future cropping decisions based on what we provided them. Hank Miller runs the Biology Department at the Nebraska Indian Community College in Santee Nebraska, and he asked for cover crop recommendations when receiving his soil test results, as did Marlon Skenadore who manages the Oneida food pantry. But the majority of the home gardeners were less engaged with the results from the soil tests than we expected because the results were likely not as useful to them.

Most the collaborator growers affiliated with this project are using their backyard gardens to grow particular food items of cultural and personal importance rather than for selling their produce in a marketplace. In many of the gardens, a percentage of the of the harvest was actually allocated towards ceremonial uses in some capacity. Vast scholarly literature has been published about different Native Nations, including the ones collaborating with the ISU 3SI Project, which describes the communities referring to the plants they grow and their overall gardens as sacred (Gould, 2018; Kimmerer, 2013; Miewald, 1995; Moodie, 1991; Whyte, 2016). As described by John Buffalo during his interview, one's garden is a direct representation of how that gardener lives their life: an overgrown and weedy garden indicates that the gardener has things going on at home that they need to cut out. Most all of the growers had harvest yields from their home gardens that they found satisfactory enough to not voice concerns about, and the vast majority were not aware of the micro and macro nutrient deficiencies present in their garden soils until I told them they were dealing with one. This soil science knowledge I cast towards the collaborators may have been perceived as intrusive considering the remedies I was prescribing for their garden soils were based off soil nutrient recommendations made for industrial row crop agriculturalist, who many times are farming tens to hundreds of acres. Instead of collaborating more with the horticulturalists on the team to determine nutrient recommendations for backyard fruit and vegetable growers, who may not necessarily have the equipment or the skillset to manage their gardens like a row crop farmer, I and my mentor used nutrient recommendations that we would regularly prescribe for commodity crop farmers. Because there were many gardens I wrote recommendations, it saved time to use cropping practices that I was familiar with rather than try and learn new methods. Doing so though may have actually worked against our team's intentions and made our soil science less relatable to the collaborators.

While I was not intending to critique anyone's gardening practices, the type of advice I was offering to them ran akin to what Bagele Chilisa refers to when she describes problems contained within research conducted towards minority ethnicity communities: "…imperialism…privileges the first world position as knower and relegates the third world to the position of an Other who are learners (2019, 20). With the team's emphasis on teaching the collaborators our understanding of soil science and agronomic practices, alerting them to what was wrong with their cropping systems according to our scientific standards, and then telling them how they should be fixing their cropping systems using our methods, we very well may have been reinforcing those stereotypes Chilisa mentions. Months after I processed the soil samples from our outings in the Summer of 2019 and collected and wrote up nutrient recommendations for each grower, I engaged one of the collaborators during a community visit and asked them what they did with the soil lab results and if they altered their cropping practices because of them. The collaborator responded: "I didn't understand the results, so I threw them away. It was too scientific for me". In that moment, the collaborator, who was highly educated, was telling us that we might have strayed from our intended goals of helping backyard gardeners by using language and methods that did not apply to them and likely many others. Renita Marshall describes small farm operations that are led by minority-ethnicity agriculturalists as being: "…operated by individuals with different knowledge bases" (2012, 3), describing a major hurdle that an AES should consider when collaborating with Native communities. While an AES may hold a worldview that is based off published literature, minority ethnicity agriculturalists may instead value knowledge from different sources more. A lot of gardening knowledge within the collaborating communities is passed from one generation to the next by being physically present with one another and orally communicating together, while academia is based off of written text and broad universal techniques.

An example of this clash of mindsets is how we instructed our collaborators to fix the pH levels in their gardens. For AES, prescribing a certain amount of lbs. per acre of lime or potash, like we did, may be an acceptable recommendation to an industrial-scale midwestern agriculturalist who uses heavy machinery to plant and harvest their crops, but to a backyard ancestral-variety food grower, these type of soil nutrient recommendations seem out of place. Characteristics such as cation exchange capacity and salt extractable nitrate are concepts not specifically targeted within most (if any) traditional ecological knowledge systems, so when I tried to vocalize how the home gardeners could alter their soil pH or cation exchange capacity by adding different inorganic substances to the soil, that message may not have been received as I hoped it would.

Most likely, my error in creating the soil nutrient recommendations for each garden was in how I communicated soil health information back to them; rather than me testing the soil health within their gardens using their methods, I used my own set of soil health parameters that didn't necessarily apply to those I was working to help. Instead of collaborating with each grower about what they wanted the soil nutrient recommendations to look like, for the sake of time, I used a one-size fits all approach and gave each grower recommendations based on the agronomic literature supporting industrial agricultural practices and varieties, as my discipline taught. It may have benefited my collaborators more if I would have use more Indigenous focused methods, described by scholars working alongside Indigenous African American communities as: "…methods that may not be conventional with White populations, and identify collaboration by allowing the community to participate and provide input during all stages of the research process" (Baugh & Guion 2007, 7). Had I invested more energy into figuring out what the gardeners would do with the results before I took the soil samples, I suspect I those soil test analyses would have been more valuable.

Workshops and Extension events

One challenge an agronomist may face while interacting with Native communities and trying to organize community educational workshops is low turnout. This can occur both during in-person events and during online workshops, as we learned during the Covid-19 pandemic. There may ultimately be no one singular reason for a low and the reasons for lack of engagement by collaborating communities may be varied. Francis Nyamnjoh, a scholar who worked with Indigenous communities in Africa, encountered resistance to his work by individuals in the communities he interacted with. He described the issues he was experiencing as being caused by a lack of familiarity between the two groups: "…the call to have more engagement between a still mostly white anthropology and "African voices" tends to be countered with the view that there just aren't many Africans with sufficiently high-level anthropological training" (2012, 25). Native communities may feel less inclined to act kindly and engage with others that they have no experience with or can relate to. Linda Smith describes the importance of individual familiarity within Native communities, and recommends that scholars who are trying to build networks and trust within Indigenous communities, turn up regularly at culturally significant events to develop rapport over time (1999). Individuals within collaborating Native American communities may even feel as if AES work could be "…detrimental to their own language, culture, and identity", according to work by Joe St. Charles and Magda Constantino (2000, 57). If it is at all possible, working to get individuals from within collaborating communities may be beneficial to an AES working to help teach Native communities agronomic practices.

Low participation rates by a collaborating community may occur when events are held in-person, but this can be especially troublesome when an AES tries to network and deliver workshops or education events through a computer screen as we had to. The travel-crippling Covid-19 pandemic experienced worldwide forced us to engage with the collaborators virtually- through webcam and email- from March 1st, 2020, to May 15th, 2021. During early outings to the collaborator communities, we were advised that the best way to bring in community members to an educational workshop or event was to bring in food for everybody to eat, and many conversations between the research team and the collaborators occurred over the course a meal. Nancy Souisa describes the importance of sharing food together: "In the 'eating together' activity, people come together not only to enjoy the meal but also exchange ideas and experiences. It becomes a space to share more than food. Meals also feeds the relationship" (2018, 8). In these situations, we experienced moments that bonded us together and these helped build and strengthen interpersonal connections between us. Offering and receiving food reflects a sense of community (Quandt et al., 2001). During our virtual workshops, however, the prospect of bringing food is non-existent. Aspirations we had of increasing individual engagement with our project within the collaborating communities may have been blunted because we were not able to interact with our collaborators in culturally appropriate ways, such as sharing meals together.

Conclusion

Agricultural extension has remained relatively structured since its inception. How it is accepted in Native communities in modern times is a product of the agricultural education that Native American people experienced through the colonization process. University agricultural Extension specialists who are trying to better focus their extension efforts for Native communities may benefit from enlisting the help of a cultural anthropologist, who may better have the tools to understand the needs and demands of different communities. Because social interactions and conversations about growing crops within Native communities may function differently than they do in mainstream industrial agriculture circles, a university AES should not expect the same acceptance of their trade in both social circles. Native American communities across the American Midwest region are growing food items and crops for the market economy, but there is not a large percentage of them growing at an industrial scale. AES that are accustomed to interacting with mainstream farmers for agricultural extension and research may make missteps while attempting to interact with Native food growers, and these missteps could harm the acceptance of them and other AES in the future or decrease the success of the project due to the engagement and interest by the Native community.

Using an anthropological lens to examine the AES and Native relationships can be beneficial to those working to help Native people learn how to improve the yields in their cropping system because these two different cultures operate on different worldviews. Creating a reciprocally beneficial relationship between AES and Native communities may require enlisting the help of different disciplines than are normally associated with Extension events directed at mainstream agriculturalist. Native people have interacted with AES and agricultural instructors for generations, all claiming their techniques are the best. Interestingly though, Native people have been experiencing the increasing ecological damage caused by industrial agricultural processes and the sciences that support it since the 1960s, as recounted by John Buffalo (2020). If Native communities choose to allow AES into their communities to teach food growing techniques, it would be beneficial for the AES to strive for collaboration at all stages of the research design and implementation by building relationships and networks within the communities where open dialogue can occur. Using anthropological methods to better understand the needs and wants of Native communities may be more beneficial than dumping agronomic lessons on them.

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CHAPTER 4. CONSEQUENCES OF A MODERNIZED RELATIONSIHP BETWEEN NATIVE PEOPLE AND SOIL

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Abstract

Native American people of the Midwest prior to colonialism would have daily interactions with soil to meet their nutrient needs, and their cultures appreciated the Natural world in a way that placed their communities in a state of deference to Earth[3] rather than one of dominance. An acknowledged relationship between Native people and Earth was structured along concepts of reciprocity and humbleness. This paper examines how current Native people from five different communities in the American Midwest view soil as it fits within their culture, as well as the self-described benefits they have experiences through regularly interacting with soil by gardening for food. Native people statistically suffer from dietary diseases and diseases of despair at rates significantly higher than their non-Native neighbors. The pressures of modernization within relationships between Native American people and the soil may be currently causing them to suffer negative physical and mental health effects. Through interviews and by acting as a participant observer during gardening activities, I was able to gain both etic and emic perspectives related to the importance of Earth in different Native communities and cultures.

[3] earth: the entity from which all life originates from.

Introduction

Throughout the course of history until approximately the last 200 years, most people have engaged in regular physical contact with Earth through practices such as hunting, gardening, and gathering resources needed for survival. Through recent societal advancements in technology and science, very few people need to actively engage with Earth to survive, and many people invest little sweat equity in harvesting the daily food they eat. Instead of actively getting one's hands exposed to Earth through food gathering activities such as gardening and hunting, many commit their time to making money for a financial incentive that they then use to purchase commercially grown food. Many people have a weak biocultural connection to the food they eat because that relationship doesn't go beyond the experience of the market economy. Erik Gomez-Baggethun et al., connect the term *bioculture* with traditional knowledge, Indigenous practices, and the capacity of small-scale societies to connect their livelihoods with the conservation of biodiversity in their territories (2013). Sadly, practically all of these components are lost when one works for a financial profit to purchase their food items in the globalized market economy. While this behavior of working a job to buy produce rather than growing one's own food might be the norm within the United States, it is not a universal experience throughout all communities or households.

Certain collaborators in the ISU Three Sisters Intercropping Project are members of Native Nations in the Upper Great Lakes, and they interact with their food through a different worldview. It is based on the observations of their ancestors and is built upon acts of appreciation directed by humans towards Earth to show gratitude for providing subsistence to families from one generation to the next. This ancestral way of life values Native peoples interacting with landscapes in a way that strives to ensure future generations may have equal opportunities at natural resource assets, and stresses how a profound sense of respect and humbleness is necessary when interacting with Earth in order to continue receiving her blessings. This acknowledged relationship based on the human-Earth dependency is clearly articulated in the interactions they have with their gardens. These are spaces where their cultures acknowledge their direct relationship with the Earth and transmit their cultural knowledge from one generation to the next.

Over the summers of 2019 and 2020, I interviewed community members from five Native American communities of the American Midwest region to hear their perspectives on the relationship between humans, soil, and plants. The focus of my questions during these interviews centered on how individuals interacted with Earth and how they viewed Earth within their culture, but a recurring theme emerged during these interviews that linked the self-reported feelings of mental well-being in the Native American people I interviewed and the amount of time they spent interacting with soil through gardening activities. Some interviewees had gone through phases in their life where they were not regularly interacting with the Earth or participating in activities related to food gardening with family. They described feelings of incompleteness associated with those periods and some were experiencing physical and mental health issues or were battling different types of substance abuse. Some interviewees then went on to explain in detail the life-altering changes they felt after they began getting their hands dirty with friends and family and connecting with their community's Indigenous methods of food gardening. At the same time as their relationship with Earth increasing, they were experiencing an increase in their feelings of wellbeing. So much so, that some were able to give up their substance abuse while others lessened their need for prescriptions to treat their anxiety or depression.

This chapter organizes observations and interview data collected during a portion of the

ISU Three Sisters project in order to contextualize the benefits of well-being that the interviewees reported from interacting with the Earth.

Methods

This research was conducted as part of a multidisciplinary project at Iowa State University, called the Three Sisters Intercropping Project. The project's overarching goal is to work collaboratively with five different Native communities located near Iowa State University to support food sovereignty efforts through gardening. The component of this project that I am affiliated with seeks to share knowledge about increasing soil health to help them be successful gardeners. I spent multiple weeks during the summer of 2019 and 2021 traveling to the Oneida Nation near Green Bay, Wisconsin the Santee Sioux Nation and the Omaha Nation located along the northwestern edge of Nebraska, the Meskwaki Nation, located in central Iowa and a food growing co-op serving the Native American community in the Minneapolis-St. Paul metro called Dream of Wild Health. The purpose of these trips was to engage the community members with helpful tips on increasing the health of their garden soils, and to learn from them how they interacted with Earth. I asked select people from each community who were knowledgeable about their cultural cropping practices to be interviewed for me to gain a deeper understanding of how they contextualize soil as a necessary resource. Because Native American people have been agriculturalists across the Midwest and Upper Great Lakes region of the United States for hundreds of years before colonialism, those that are growing food using Indigenous methods have a perspective on sustainable cropping practices and the human-to-Earth relationship that are insightful.

Attacks on Indigenous Understandings of Soil

Generations of violent and forced cultural assimilation of Native American peoples by the United States Federal Government, as well as the leagues of missionaries from different religious groups that occupied key positions of power in the early stages of colonialism in the Americas, has dramatically impacted the ancestral and pre-colonial Native American. Tactics such as the forced removal of Native American people from their homelands to areas miles and sometimes hundreds of miles away and then forcibly confining them on Reservations, effectively worked to strip them of the enviro-cultural knowledge and autonomy that they and their ancestors had built to sustain their communities over generations (Nesper & Schlender, 2007; Neville & Anderson, 2013). Then, once the vast majority of Native people had been confined to Reservations through tactics that included violence (Bowes, 2014), many Native children from the communities were taken from their homes and placed into Church and Federal Government run Indian Boarding Schools (Firkus, 2010; Ricciardelli, 1963).

Victoria Haskins and Margaret Jacobs describe how government officials actively broke the cultural bonds of Native American children by using off-reservation boarding schools (2002), with the school instructors actively working to eliminate the Native youth's worldview about the Natural World and their environment. Rather than the pupils learning to view Earth and its features as entities that needed to be revered and profoundly respected as they may have learned in their home communities, Native youth were instead taught Christian scriptures about human's superiority over landscapes and the animals associated with it such as Genesis 1:26: "…male and female He created them. Then God blessed them, and God said to them, 'Be fruitful and multiply; fill the Earth and subdue it; have dominion over the fish of the sea, over the birds of the air, and over every living thing that moves on the Earth'". According to Drew Leder, professor of philosophy at Loyola University, these concepts play into beliefs of anthropocentrism and "human beings as the pinnacle of nature and/or having unique supernatural significance (2012, 78). This way of thinking is a radical departure from viewing and interacting with plants as relatives as can be found in many Indigenous cultures (Frisbie et al., 2018; Kimmerer, 2013; Wall & Masayesva, 2004; Wilson, 1917). Ultimately, the US Government's goal at this time was to forcefully assimilate Native American people into the Euro-American culture and market economy by stripping them of their Indigenous lifeways, including many of their of interacting with the Earth and its resources (Firkus, 2010).

One subject that was of particular interest by the school teachers to inform Native youth about was the concept succinctly summed up by John Foster as "capitalist agriculture" (2000, 20), which is the idea that the sole purpose of growing crops is for their sale in a commodity market. Through the mindset that supports capitalist agriculture, private property rights and its associated commodification of landscapes rules supreme, and these ambitions are protected and defended at least partially by the state (McCarthy & Prudham 2004, 276). To support colonial initiatives of capitalist agriculture in the Americas, the United States Federal government would use the concepts of private property and land ownership to craft written agreements between them and Native communities to acquire their land (Neville, 2013). Native communities once had relationships with landscapes that have now been stripped from them through forced education and concepts of private land ownership.

Native peoples of the American Midwest before colonialism had cultural worldviews about growing food that caused them to value discipline and self-control, as seen in the food storage pits in archeological sites located in Sutherland, Iowa (Whittaker et al., 2015). These large pits indicate that they were growing large amounts of produce for use at a later time, rather than for immediate consumption. The site was occupied for three centuries around year 1200 CE (Whittaker et al., 2015), and Native people at this time were not growing crops for transactions in market economy nor did they use grain for animal husbandry; the produce being stored in the pits was going to be used for human consumption and would require the discipline to not eat the entire harvest immediately.

For their survival, Native people viewed their interactions with the Earth as a collaboration, and this relationship that demanded offerings was what help them experience the weather conditions that they needed to grow crops and survive from one season to the next (B. Heart & Larkin, 1996). Buffalo Bird Woman describes her family as wanting to nurture their growing corn plants so much that they would sing to them as they tended them daily (Wilson, 1917). Doing this may have helped at least partially alleviate concerns the grower could have had about the growing season. John Buffalo, member of the Meskwaki Nation in central Iowa, describe the caretaker position Earth has over humans as one in which Earth provides humans the necessities for survival *in abundance* (2020). Linda Clemmons, professor of History at Illinois State University, describes the Native people of the 1700 and 1800s living in the area of Northern Illinois as surviving because: "…they based their subsistence patterns on the seasons, following a cyclical round of hunting, gathering, cultivating crops, and sugar-making (2003). This worldview carried by Native American people puts them in a state of deference to Earth and its natural process rather than one where humans are inherently superior. The collaboration between some Native American cultures and natural resources is based on reciprocity and operates in a way that both parties benefit.

Capitalist agriculture on the other hand, is focused on financial profits through the extraction of annual resources from the landscape by methods of exploitation (Spaargaren & Mol, 1992). As described by Marx, capitalist agriculture is: "…a progress in the art, not only of robbing the worker, but of robbing the soil" (1867, 637). Capitalist agriculture is not based on worldviews of humbleness or reciprocity with Earth for providing food products, instead capitalist agriculture is a mindset where humans dominate the landscape and manage it in a way that the landowner profits financially from the crop harvests. Key features of this crop production method include the maximization of crop yields in a given space, and with as little human input per plant as necessary during the growing season. Within the boarding schools, the youth were taught the methods to grow the commodity crops that support capitalist markets such as wheat, oats and hay (Ricciardelli, 1963). The Native pupils were also informed that the sedentary life required to maintain commodity crops was considered by the boarding school teachers to be a superior way of life than that which was affiliated with the pupil's ancestors (Firkus, 2010).

Traditional cropping practices that were practiced by Native people prior to this point in history included planting crops along bodies of water rather than out on the open plains (Delabarre & Wilder, 1920), planting a large diversity of crops (Gartner 2003, 43), and praying to the Great Spirit before planting and after harvesting (Bear Heart, 1996). Rather than being exposed to their home community cultural practices, the youth were instead taught to disregard those ancestral ways of thinking and interacting with the environment and to replace them with Euro-American values and a dependence on the market economy. Despite the financial burden associated with running the boarding schools to train Native youth in the agricultural methods and lifeways of European society, much of the commodity farm training would be essentially useless for many of the youth when they returned to their Reservations communities. While some Native American children chose to attend the boarding schools specifically to learn how to farm (Booth, 2005), other children were forced to learn how to farm while attending the boarding school because the schoolteachers had the children work as a labor force for Euro American farmers in the area Creating a farm efficient enough to compete in the agricultural markets required a substantial amount of start-up capital to purchase and maintain farm implements and draft animals, seed, fertilizer, and barns to store all the equipment, and vast amounts of capital was not something Native people historically were in the position to accumulate. Often it was not even culturally appropriate to accumulate large amounts of capital. In addition, even if they were somehow able to secure farm machinery, many of the lands selected by the United States Federal Government for reservations were situated on poor quality soils that settler farmers did not want for themselves (Miewald, 1995).

Ancestral soil connections

Soil is intimately linked to Indigenous cultural teachings, so much so that some origin stories held by Native communities describe a small handful of Earth as the foundation from which all plant life on Turtle Island (North America) originated from (Kimmerer, 2013; McGregor, 2004) According to multiple Oneida members, this small handful of Earth retrieved from the bottom of the ocean by a muskrat was danced upon by Sky Woman, and her dancing spread the Earth across the entire back of a generous turtle, which gave humans a place to live (Manthe, 2020; Webster, 2020). Marlon Skenandore, manager of the Oneida Emergency Food Pantry, describes one of Earth's appearances within Oneida cultural stories as a material that the Creator used to form the first humans using different colored clay; the Creator then scattered those figures around the planet while, which is considered the reason why people have different shades of skin around the world. This is interesting as Meskwaki Nation Ancestral Farm Manager and holder of a wide array of traditional cultural knowledge for his community, Luke Kapayou, also describes the first humans as being shaped by the Creator out of a handful of Earth. Earth plays a foundational feature in the cultural stories held by each of the collaborator communities.

Within the collaborating Native communities, soil is used in different culturally significant annual rituals and ceremonies. An example of this is soil teaching children how to behave around members of the opposite sex as part of the Rites of Passage ceremonies in the Oneida Nation, as described by Oneida Food Pantry Manager, Marlon Skenadore in 2020. In this important teaching ritual for both male and female Oneida youth, they are instructed to work with each other to build and plant what was referred to as a Mother Earth Garden. Skenadore and another Oneida Nation interviewee, Dr. Becky Webster, Assistant Professor of American Indian Studies at the University of Minnesota, were both asked about the ceremony during their interviews, and both described the process as having the males in the group being in charge of moving and shaping the Earth into the form of a woman while being instructed in proper etiquette in interactions with women, and having the females be in charge of sowing the seeds into the woman-shaped garden formed by the males while respecting the laborious work that the males had to do to create the garden (Skenadore, 2020; Webster, 2020). The instructors of the exercise recite their Nation's origin story as the young people shape the body of Sky Woman, a culturally significant feature within their Nation's oral history. This garden teaches the youth their cultural gender roles and to respect the other gender for their qualities and differences. In this setting, Earth is more than just a substance that holds up a crop plant for its eventual harvest and sale, Earth actually helps support and guide this culturally important ritual experience within the Oneida culture. Earth in effect, acts as material that bonds humans, and plants, together.

Many Native collaborators interviewed distinctly remember their first childhood experiences with gardening and soil, and these experiences seemed to most especially remind them of their family members that were with them at that particular moment in time (J. Buffalo, 2020; L. Kapayou, 2020; Skenadore, 2020; Stevens, 2020). When interviewed, Skenadore described the times his mom and his daughter were together working the Earth with him in his mom's garden as very emotionally important memories to him, and he wanted to work towards having more moments in the garden together again with them in the future. Luke Kapayou, ancestral farm manager for the Meskwaki Nation, talked in his interview about how one of his earliest childhood memories was following his uncle for a year while his uncle drove a tractor to plant their crops. John Buffalo, tribal historic preservation director for the Meskwaki Nation, recalls his first experiences playing in Earth was with his mom in their family garden. John described these moments as times when he learned from both her and from his observations of their garden (Buffalo 2020). Many interviewees described emotional experiences when revisiting Earth within old garden plots that they and their families had interacted with in previous growing season and these spaces held memories that they found personally significant in their lives.

Benefits from an active relationship with Earth

Studies have shown that by having regular interactions with Earth such as gardening, individuals may take in microbes from the natural world that could be positively impacting how their body functions. Research conducted by Megan Clapp et. al., found overwhelming evidence showing that the microbiota within the human gut has profound impacts on the mental health of an individual, with the capability of causing issues such as anxiety, depressive disorders, autism, and schizophrenia (2017, 131). Having interactions with different microbes found in nature by activities such as walking has implications on the functioning of human gut processes, and according to work by Craig Liddicoat et al., the relationship between humans and the microbiota they interact with throughout their life has the potential to affect human: "…bodily development, mood, and stress responses" (2016, 1023). Those that restrict the diversity of microbes they expose themselves by not enjoying the natural world through regular interactions may be setting themselves up for states of depression or anxiety.

During his interview, John Buffalo described how the smell of certain soils associated with floodwaters from the Iowa River on the Meskwaki Settlement are associated with so many memories of his childhood that he will sometimes go spend time in the area near where he grew up to revisit that smell that is highly specific to what J. Buffalo describes as his "bioregion". John defined his bioregion as the immediate area on the Meskwaki Settlement where he lived his entire childhood and some of his early adulthood. The term bioregion is first credited in the literature by Roman Catholic priest, Raimon Panikkar, who described it as a homogenous territorial area where all biota are linked to a culture in a harmonious embrace (1995). Bioregions are comparable in size to watersheds as described by one of the founders of the Sudbury Valley School, Daniel Greenburg (2021). By repeatedly exposing himself to Earth microbes wafting in the air within the smells of the Iowa River mud, John Buffalo may have been unintentionally using soil in a way that benefits his physical health at the same time he enhanced his mental health he experienced by visiting those odors. Researchers have explored the growing sterility of modern life and its disconnectedness with the natural world where we humans originally developed , with a growing body of literature suggesting that our decreasing interactions with microbes found in the wild may very well be contributing to the rising cases of "…allergic, auto-immune, and chronic inflammatory diseases…occurring across developed nations in recent decades…" (Liddicoat et al., 2016).

The positive health benefits from working Earth through subsistence gardening extend beyond the microbial level though. In fact, gardening can also improve a grower's cardiovascular health too. Work conducted by Allyson Holbrock found that regular moderately-intensive gardening sessions can be all the physical activity necessary to reduce the chance of premature death in those that are at risk of mortality from inactivity (2009, 55). Gardening and getting dirty provide a grower with healthy produce harvested under conditions they are acutely aware of, but gardening can also counteract feelings of day-to-day stress, and boosts self-reported health scores (Grinde & Patil 2009, 2335). Work by Amy Shaw et. al. found that the majority of respondents to their survey disclosed an innate connection with nature with no known cause as to the reason (2013). Eric Brymer et al. describe non-human nature has having the capacity to: "…1) restore mental fatigue, 2) trigger deep reflections, 3) provide an opportunity for nurturing, and 4) rekindle innate connections" (2010, 1). The boost to physical health from Native American food growers who regularly engage with soil is significant and multifaceted.

Another way that engaging with soil through gardening boosts human health is by acting as a foundational substance that helps promote interpersonal bonding (Sempik et al., 2003). Healthy soil gives Native people a space to grow produce with others, which is then in turn harvested and prepared for meal dishes that are then shared with others. Many of the interviewees remembered and spoke about their first memories in a garden, being able to easily recall which family members were present with them at that time. Becky Webster described in her interview how the White Corn Growing Co-op she is a part of is multigenerational and includes children and elders: "So I think in one case we have a picture of four generations of one family in the barn husking corn together. It's really awesome to see all these different people at different stages" (2020). The common theme uniting all the generations in the picture is Earth that is supporting the seeds that they plant; the more attention they give to improving the health of their soil, the better their cropping systems will perform and the better memories they may create in that space.

Jessika Greendeer interacted with soil to grow the food that she used to feed the attendees at her father's memorial ceremony (2020) and interviewee Lois Stevens talked about her appreciation of the gardening she and her "Quaran-team" were able to engage in, which helped all of them relieve some of their pandemic-induced stress in a socially distant way (2020). Here soil was used to create personally healing moments as well as act as a way for growers to escape the dangers associated with the Covid-19 pandemic. There were food shortages across the country and mental health issues radically increased during the pandemic; individuals having a pre-existing relationship with a garden soil may have benefitted from it.

Activating one's relationship with Earth through activities such as food gardening can not only work to help individuals feel connected to one another by bringing acquaintances together, food gardening can also work to spur and build up the relationship between the Native gardener and their spirituality. Native gardeners that were interviewed would often refer to Earth as either Mother Earth or Grandmother Earth (Buffalo, 2020; Manthe, 2020), and Jesikka Greendeer described a cultural taboo in her community against spitting on the Earth (2020). Understanding Earth as the ultimate provider of life can give comfort to someone needing a bit of guidance or reassurance in a time of need and help them feel less alone in the world. This is important because, as described by the World Health Organization, feelings of social isolation can be highly detrimental to one's sense of wellbeing (2019). A garden is described as a mother figure by Robin Wall Kimmerer (2013), who hopes that her children tending a garden in the future will help them through times when she is no longer available. Within different Native communities, the act of gardening itself is a way to connect with spiritual forces that may be able to uplift individuals needing assistance.

Prior to the 1800s, Native peoples would have had very regular interactions with Earth as they lived through their day-to-day activities, and when one considers their seasonal movement patterns of foraging and hunting wild game, their lifeways of building semi-permanent homes using forest products, animal hides, and clods of Earth in some cases, creating pottery out of clays, and regularly building fires to heat their homes and cook, it is easy to see how they would also have interacted with a diverse array of soils located in different positions across a landscape. Silty loam soils are common along rivers and streams where many Native communities were growing crops, padus sandy loam soils are located in the forested areas of Wisconsin, and Valentine fine sand soils with moderate slopes are found across the plains of Nebraska (Websoilsurvey, 2022). Upper Midwest Native Nations, such as the Ho-Chunk and Meskwaki, changed their dwelling sites based on the seasons and the foodstuffs that could be found at those times (Buffalo, 2013; Firkus, 2010). Their seasonally based migratory lifestyle and the bare-Earth structures they lived in would therefore have allowed them to interact with a large swath of different types of Earth as they moved into other areas at different times of the year to participate in subsistence activities such as foraging and hunting.

Another way Native people were exposing themselves to vastly different soils in their day-to-day lives is through the food they consumed. Many animals that were hunted by Native people, such as buffalo and deer, can travel 10s of miles a day, and consuming the flesh from those animals would have exposed those hunters and their families to the soil supporting the vegetation eaten by the deer and buffalo. Foraged and hunted food items were sourced from and nourished by different soils found across the American landscape. Current research suggests Native people may have benefited from consuming foodstuffs procured from multiple and distant regions throughout their entire lifetime, because eating only from one localized landscape can sometimes lead to human health issues caused by micronutrient deficiencies (Oliver, 1997). Prior to the colonialization of the Americas, generations of Native peoples were accustomed to frequent exposure to an array of microbially diverse Earth. Under these circumstances, it is not a stretch to say that Native peoples' gut microbiota may have evolved to interact with a multitude of different types of Earth.

A modernized human and soil relationship also has significant cultural implications for the Native collaborators interacting with our project. As interactions with Earth decrease, especially among many living in urban and sub-urban communities, the amount of time many Native people can dedicate to learning cultural stories and ceremonies around gardening shrinks along with it. Cultural values and thoughts about the need for reciprocal relationships between humans and non-humans taught during the act of gardening are much less easy to experience when Native people have to trade their free time for a financial profit to pay bills in order to survive.

An important observation from this project is seeing how an enduring and continued intergenerational relationship with a garden helps retain cultural values and thoughts within a particular Native community. An example of this is the Green Corn Festival organized in part by Laura Manthe and Becky Webster of the Oneida Nation. They gathered their friends and family together annually to preserve part of their corn harvest for the year and to share stories while enjoying each other's company. The spaces these families grow their corn on every year are sites where different songs, rituals, and stories about Oneida ancestors are passed down to descendants, helping to preserve the cultural knowledge within that community. Rather than succumbing to the mentality supporting the capitalistic market economy where 'time equals money', these families are using their time to directly interact with the soil to grow food to feed each other. The dense social fabric created by the shared labor in the garden may help inspire individuals to feel as if they are an active and valued member within a cohesive unit.

A Deeper Dig into Native Cultural Connections to Soil

Cousins John and Shelley Buffalo, both cultural knowledge holders in the Meskwaki Nation, a community that calls itself *People of the Red Earth*, referred to Earth in their interview with the phrase "Grandmother Earth". It is common for Native people to interact with their grandmotherly figures in a humble and compassionate manner and even elevate their status in the community to that of a respected *Elder*. Elders in Native communities are understood to hold a particular amount of cultural wisdom (Chilisa 2019, 238; Kimmerer 2013, 121; Perdue & Green 2010, 34), and ecological knowledge (Harkin & Lewis 2007, 41; Nabhan 1989, 189). Because of this, Elders are an intensely appreciated and honored segment of the community. When John and Shelley referred to the Earth as 'Grandmother', it placed themselves in a position of deference to Earth rather than a state of dominance.

When interviewed about how she would define soil and what it meant to her, Jessika Greendeer replied, "Soil to me is…you know, just an alias for the Earth. You know, in Indigenous perspective…looking at the Earth as our Mother…" (2020). In these cases, Native people are describing their interactions with Earth that they may have through their gardening activities as a direct interaction with the nurturing and providing entity that all life arises from. This Earth conceptualization is recognized as the substance from which all-natural materials originate, including people, as described by Skenadore, who said the Creator used different colored Earth to create the different skin tones of people found around the world. This type of worldview carried by Native people frames humans as a dependent of Earth because it is the source of our life. Shelley Buffalo describes this nurturing component of Earth: "You know, the Earth provides everything we need. In abundance. And we're losing all that at such an incredible rate, because, you know people have been severed from their relationship with the land" (2020). This description of a human plus Earth existence alludes to a relationship that may have its own set of responsibilities that need to be abided by.

Shelley Kosola alluded responsibilities that humans have towards Earth during her interview: "…soil is responsible for life, and if we don't take care of it, we're not gonna have the type of life that we need to create healthy environments" (2020). Understanding that Earth has the capacity to work against humanity's interests if the human and soil relationship is neglected provides a sense of urgency to act in Shelly's quote. Interestingly, Grant Shadden described during his interview that he witnessed life changes that can quickly occur when a crop grower begins to act environmentally responsible with their relationship towards Earth when he was employed in Africa working to help Indigenous peoples there improve their quality of life.

Prior to him helping bring back permaculture practices to their community, individuals were living in extreme poverty because they did not produce enough crop each harvest to sell in the local market. After getting some of the growers to think more about building the health of the Earth, they were able to harvest enough to support their food needs and also had a salable surplus. Grant stated: "Some of the students were sending their kids to school for the first time, because they employed these practices, because they doubled their production of maize. And now they actually had money for medicine, for school fees. And it was just because they took care of the soil. Right. And the soil took care of them…" (2020). A healthy relationship with Earth may benefit food growers by having long-term multi-pronged positive impacts.

Published works by scholars from fields such as psychology and philosophy have written about the benefits to human wellness from regular interactions with Earth like those that can be had through the act of gardening (Deloria, 1994; Jung, 2008; Watts, 2003). Research by Eric Brymer found that many people feel that increased exposure to the natural world and views of green spaces during their day-to-day life enhances their feelings of well-being (2010).

Interacting with soil through acts like gardening has been known to be beneficial to human health for so long that the first hospitals in Europe contained gardens because hospital staff saw improvements in patient healing times when patients would visit the gardens regularly (Grinde & Patil, 2009). It has even been recorded that the famous Native American war leader Crazy Horse felt that Earth contained such a powerful source of energy that he would stand with no shoes or socks on over bare Earth for hours every day because he felt recharged by doing so (B. Heart & Larkin, 1996). The connection between different Native American cultures and Earth is layered deep and contains levels of intricacies, in addition to acting as the substance that supports Indigenous gardening activities.

One other way an ongoing and continued relationship with Earth in Native communities benefits individuals is in the way it acts to preserve bodies of cultural knowledge about gardening. Take, for instance, the Rites of Passage ceremony, conducted by the Oneida Nation in both the New York and Wisconsin areas, and a point for exciting conversations during Marlon Skenadore and Becky Webster's interview. Specific gardening ceremonies were becoming rarer on the Oneida Reservation in Wisconsin, and it wasn't until a recent surge in food sovereignty efforts in their Nation was it realized what was at risk of being lost. After beginning collaborative efforts between Oneida in New York and Oneida in Wisconsin, particular ceremonies that were culturally significant were once again conducted again in both communities. Skenadore, the head of the Oneida Food Pantry and someone who witnessed the Rites of Passage ceremony firsthand, described it succinctly: "The whole ceremony was beautiful…I don't know, it kinda just…hangs with you". Due to the effects of modernization on generations of Native people and lands, it is harder for Native people have the relationship with Earth that their ancestors have. This impacts their ability to preserve cultural knowledge that pertain to Earth, in particular cultural knowledge that focuses on Indigenous crop production methods. The impacts of modernization on Native American people's relationship with the Earth may be far and wide reaching.

Conclusion

The Native American communities that collaborate with us on the Three Sisters Intercropping Project have a culturally defined view of their relationship with Earth as one that places it into a caretaker-type position within their lives. For the interviewees associated with this project who once actively interacted with Earth through activities like food gardening and then were forced to pull back on these behaviors through different life circumstances, they described experiencing feelings of malaise, anxiety, and even depression. As these Native people began to reignite their relationship with Earth and actively interact with it alongside their friends and family, they experienced powerful emotions that enabled them to feel mentally and physically more secure and content. For some collaborators who were taking prescription medicines or self-medicating through drug and alcohol use, reigniting this human-Earth relationship was what they needed to discontinue their need for these substances.

As people who live on top of the Earth, we are all subject to the forces of nature that including weather phenomena and climate change. Social scientist F. Sutton defines modernization as a: "…predominance of universalistic, specific, and achievement-oriented norms; a high degree of mobility and an open-class system based on achievement" (1963, 71), and it is important to note that he makes no references to human interactions with Earth in his description. It is easy for those living in modern industrialized countries to forget that we are a ward *of* the Earth, as the amount of time average people living in cities directly interact with the "wild" outdoors has been shrinking, all happening while rates of psychiatric issues have been increasing through time (Liddicoat et al. 2016). Bringing people together through regular interactions with Earth by gardening has the proven potential to help individuals recover from trauma (Helphand, 2019; Marcus, 2006; McCormick, 1995; Stigsdotter & Grahn, 2002). Inspiring Native people who may be suffering from substance or psychiatric disorders to engage with Earth through activities such as food gardening should be considered as a tool to aid in their treatment.

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CHAPTER 5. THE IMPACT OF INTERCROPPING MAIZE, BEANS, AND SQUASH (THREE SISTERS) ON SOIL FERTILITY AND HEALTH

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5.1. Abstract

Intercropping practices--like maize (*Zea mays*), bean (*Phaseolus vulgaris*), and squash (*Cucurbita spp.)*, being planted in close proximity called the “Three Sisters” (3SI) --have been documented to have positive effects on the soil compared to single crop plots. However, few studies have directly compared the Three Sisters to single crops. Soil biogeochemical properties of 3SI in the Upper Midwest were compared to maize, bean, and squash single crop plots in central Iowa with the hypothesis being that the 3SI method would result in higher value for indicators of soil health at the conclusion of each growing season. Soil samples and incubated organic materials were collected from a certified-organic managed research garden composed of Webster-clay and Clarian loam soils. Soils collected from 3SI treatment plots showed that this practice generally affected the soil by extracting up to 53% more salt extractable N in the top 15 cm of the soil surface than the average of the single crop plots, as well as decomposing birch wood strips at rates 43% higher. The effects of 3SI on the soil varied intra-annually with the varying weather phenomena for each growing season a contributing factor. Increased microbial activity associated with the rhizodeposits from the different crop types in the 3SI may result in a cropping system that is more efficient at nutrient uptake

5.2 Introduction

Commercial farming operations in the United States are an economic engine for the country, contributing over 1 trillion dollars to the U.S. gross domestic product in 2020 (Agriculture, 2020), and spans over 363 M ha footprint across North America (USDA, 2020). According to the USDA 83% of that area devoted to agricultural production is managed using methods known by farmers and scientists as single-species row cropping (USDA, 2020.) This single crop specialization as a farming technique is the product of multiple different agronomic disciplines working together such, as herbicide science, plant genetics, and mechanical design, to create an industrial cropping system that hardly resembles a natural ecological system. Sustainable agriculturalists and have long recognized the consequences on the environment from this large scale cropping practice, which range from the off-field movement of chemical pesticides and fertilizers (Sataloff et al., 2009; Sjoberg, 1976), soil erosion and waterway sedimentation issues (Helmers et al., 2012; Noe et al., 2020), diminished areas for wildlife habitat (Secchi et al., 2008), and a measurable loss in soil organic matter (Tamang, 1993). Modern industrial agricultural is arguably on an unsustainable trajectory and should be adapted to counteract its negative ecological effects (Carlisle et al., 2019). But that begs the question, what would a more sustainable agricultural system look like?

5.2.1 Traditional ecological knowledge (TEK) and intercropping

Indigenous communities around the world have been using cropping practices developed and refined over generations, which supplement foraged food. Contrary to the growing practices of most modern agriculturalists, a central theme of Indigenous cropping methodologies is planting and maintaining biodiverse cropping stands rather than single cropping; in essence, mimicking the type of biological diversity already found in nature (Hart, 2008). As described by Berkes et. al., Indigenous communities pervasively have a worldview that values a “community of beings” (2000, 1259), which appreciates complex interactions between humans and all living things. Because each plant within a biodiverse cropping system will respond to disease, weather patterns, and insect pressures in unique ways, intercropping provides a sort of insurance that the grower will be able to harvest something out of their subsistence gardens.

A prime example of the type intercropping practiced by Indigenous communities is commonly referred to as the Three Sisters (3SI) (Mt.Pleasant, 2016). This method of subsistence gardening has been practiced by Native people in the Americas for at least 7000 years (Landon 2008, 113), and is a polyculture consisting of maize (*Zea mays L.*), squash (*Cucurbita L.*), and common beans (*Phaseolus vulgaris L.*), grown together in the same space during the same growing season. Previous research on 3SI have shown: numerous complementary effects within the aboveground architecture of each plant species in the system (Raviele & Lovis, 2014), increased root volume density, nutrient uptake, and sometimes greater individual crop yields (Zhang et al., 2014a); and greater caloric production per unit of area compared to single crop stands (Herrighty et al., 2021; Mt.Pleasant, 2016). Researchers investigating the *milpa* system, Central America's version of 3SI, have shown polycultures can have radically changing microbial communities in their root zones through different points in the growing season, potentially (Rebollar et al., 2017), potentially affecting how those root systems are able to mobilize nutrients for their uptake However, as of late, there has not been much exploratory research into the effects upon the soil from Native American 3SI agriculture when compared to a similarly managed single crop stand, using modern scientific methods.

5.2.2 Community science and soil health measurements

Community science is described as a: "…collaboration between professional scientists or experts and volunteers who are amateurs or just interested participants" (Fan and Chen, 2019, 183). Community science activates a greater network of individuals than may be possible within University research projects (Van Eck, 2022), and the data they collect may be highly site specific and potentially more relevant to their individual needs (Paci & Krebs, 2003; Pauli et al., 2016). Giving community scientists easy-to-observe measurements of soil health that they can use to gauge the changing health of their cropping system allows a community to build levels of autonomy that they might not receive through more commercialized hierarchal type arrangements. Simple to conduct do-it-yourself (DIY) tests such as measuring the decomposition of household materials like popsicle sticks, tea bags, and cotton strips can give an interested grower significant insight into the approximate nutrient availability and microbial activity within a soil (McClaugherty et al., 1985), Earthworm population counts within the soil of a cropping system can indicate how well that soil should be expected to retain water after precipitation events or if the plot is being excessively tilled (Andriuzzi et al., 2015; Stroud, 2019), and analyzing the aggregate stability of a plot can help a grower know characteristics about the amount of organic matter and erosion resistance of their system (Herrick et al., 2001). Combining different types of soil health analysis may then give a community scientist a broad perspective of the health of their soil or cropping system, while also being economical and interactive.

Examining how 3SI affects the soil and comparing it to the effects from single cropping by using tests developed for community scientists, and modern scientific methods, will put us in a better position to give weight to the arguments posed by Native growers about why they grow the 3SI. We are interested in learning how Native cropping practices differ from single cropping practices and working to understand if Native horticultural methods are more or less ecologically sound than single cropping in regard to soil health.

Questions guiding this research include: 1) How does 3SI using traditional Native American techniques and varieties affect soils compared to single crop stands of the same varieties. I hypothesize that 3SI will increase soil biological activity and general soil health compared to single cropping. The 3SI will increase concentration of immobile plant-available nutrients (e.g., phosphorus and potassium) but decrease mobile plant-available nutrients (e.g., nitrate and sulfate). I hypothesize this is due to interspecies interactions between crops and soil microorganisms that will release more plant-available nutrients in the rhizosphere, but the increased root proliferation and coverage will increase uptake and use of mobile nutrients that would otherwise be lost via leaching or gaseous losses (Zhang et al., 2014).

5.3. Methods and materials

5.3.1. Field site and experimental design

The experiment was conducted during the 2020 and 2021 growing seasons at the Iowa State University Horticulture Research Station, located in Story County, Iowa (42°06'27.4"N 93°35'03.8"W). The site held an organic certification, and we used organic approved methodologies during the entirety of the research experiment to maintain that certification. The historical mean annual temperature for the garden site is 9.98 °C, and the mean annual precipitation for the site is 895.85 mm (Iowa State University, 2020). The research garden received 281 mm of precipitation during 2020 and 337.82 mm of precipitation during the 2021 growing season. The soil was predominantly Webster clay loam and Clarion loam. Baseline, static soil properties are shown in Table 5.1.

Table 0.1. Ancillary background, or baseline, static soil properties measured during the 2021 growing season

Soil Property (units)	Mean ± Standard Deviation
Sand (%)	26.7 ± .8
Silt (%)	31.2± 5.6
Clay (%)	34 ± 2.6
pH (unitless)	6.8 ± .16

Soil organic matter (%)	2.8 ± .4
Bulk density (g cm^3)	1.2 ± .1
Cation exchange capacity (meq 100 g^{-1})	16.2 ± 1.7

At the beginning of the 2020 growing season, the site was tilled using a Tiller Hiller implement to create a field of 16 parallel east to west oriented ridges. Using hand tools, 16 distinct and equally spaced garden mounds were created per research plot (Fig. 1). A series of 4 mounds by 4 mounds represented a research plot, and there was a total of 16 plots in the garden. These mounds were resistant to erosion and were only rebuilt at the beginning of the 2021 growing season, and all mounds were reused from one year to the next. Each mound measured roughly 20 cm tall by 35 cm wide at its base, and the size of each mound was consistent throughout the entire garden.

We used a randomized block design, with intercropping or single cropping the 3-Sisters within each block as our testable treatment effect. There were four research blocks, and each block containing four plots that were either: single crop bean, single crop maize, single crop squash, or maize+bean+squash growing simultaneously (Figure 5.1). All plots were equal in size (6.1 m x 6.1 m), and the overall research garden measured 29 m x 24.4 m with the long leg of the garden following a North-South trajectory. Each plot within the garden was irrigated similarly with drip tape irrigation at a rate of 674.8 GPH when the garden manager deemed necessary.

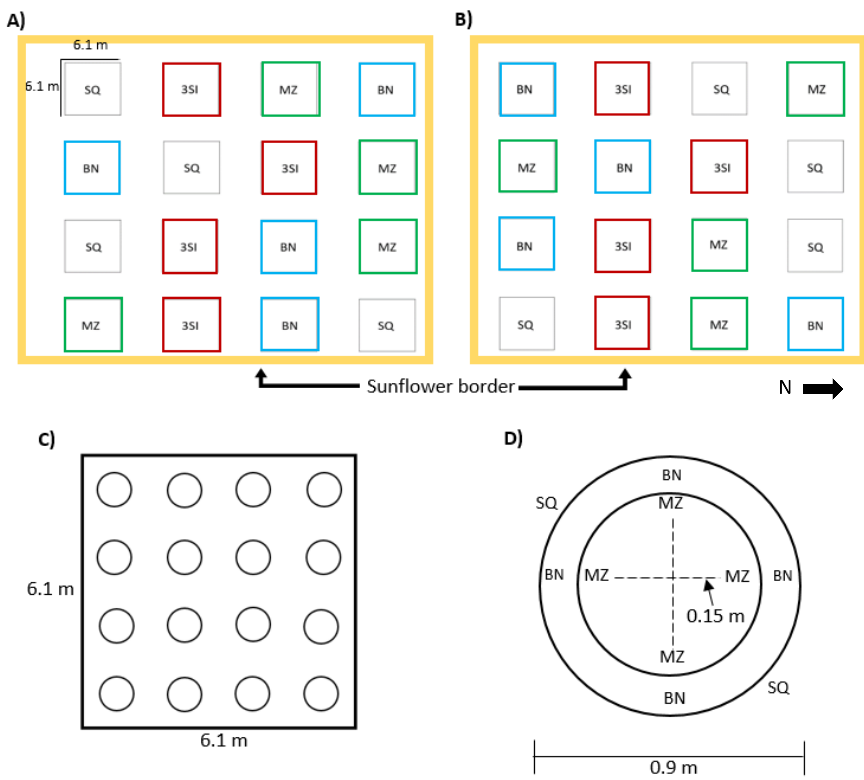


Figure 0.1 Experimental design of the Iowa State University Three Sisters Intercropping experiment. A) Year 2020 experimental layout with plot treatments. B) Year 2021 experimental layout with plot treatments. C) Within-plot diagram showing layout of 16 mounds. D) Within-mound diagram showing seed placement in a 3SI mound.

5.3.2. Seeding rates and timing

All seeds used for this project were chosen based on their demand by Native communities collaborating with the overall research project for rematriation purposes. For the 2020 growing season, all seed placements and the number of seeds of planted within each mound remained consistent between the Three Sisters plots and the single crop plots (Table 5.2). On June 4th, four Turtle Mountain White corn seeds were placed into the mound, on July 8th Hidatsa bean transplants were deployed and the Algonquin Long Pie squash was germinated indoors and transplanted into the garden on July 12th. We shifted our seeding dates for the 2021 growing season to account for weather patterns that we were experiencing that growing season and planted our maize seeds into the mounds on May 1st, the bean seeds were planted June 1st, and the squash seeds were planted June 15th (Table 5.2).

Table 0.2 Crop varieties and seeding and transplanting dates for 2020, 2021 growing season

Growing Season	Crop	Variety Used	Date Directly Seeding in Field	Date Transplant Was Seeded	Date Transplant was Placed in Field
2020	Maize	Turtle Mountain White	4 June	-	-
	Beans	Hidatsa		28 June	8 July
	Squash	Algonquin long pie pumpkin		2 July	12 July
2021	Maize	Turtle Mountain White	13 May	-	-
	Beans	Hidatsa	1 June	-	-
	Squash	Algonquin long pie pumpkin	15 June	-	-

5.3.3. Soil sampling and processing

Representative soil samples were taken from each research plot prior to planting at the beginning of the 2020 and 2021 growing seasons to determine early season plant-available nutrient concentrations. Four soil cores (2 cm diameter, 15 cm deep) from within the four center mounds of were collected each research plot, and then composited by sieving (2mm) the samples. These samples were analyzed for soil organic matter, pH, and other plant available nutrients.

A second composite soil samples (6.35 cm diameter and 15 cm deep) were collected from all 16 mounds and composited at the end of the growing season to determine the effect of 3SI and single cropping on soil biology, plant-available nutrients, and other parameters. Composite soils were stored in a cooler with icepacks while in the field until arriving at the laboratory. There, the fresh soil was fresh sieved with an 8 mm sieve to homogenize entire sample, then a sub-sample was collected for aggregate stability tests. The remaining sample was sieved to 2 mm and stored at 4 ℃ until microbial biomass and organic C and N extractions were conducted.

5.3.4. Laboratory Soil Sample Analyses for 2020 and 2021

Soil samples were immediately delivered to AgSource Laboratories in Ellsworth Iowa after the sampling date. Soil analyses conducted by them and reflected in the soil data included: macro and micronutrients, CEC, and Soil CO_2 Respiration.

Using methods described by Vance et al., (1987), a chloroform fumigation-extraction in order to analyze the microbial biomass C and N. A 5 g of this sample was stored at 25°C for 24 hours with a covering to prevent light contamination, while another 5 g of the total soil sample was fumigated in a vacuum sealed desiccator jar with 30 mL of 99.9% chloroform for 24 hours. A 0.5M amount of potassium sulfate was used to extract both the fumigated and unfumigated samples in their own separate centrifuge tubes by shaking them on a reciprocal shaker at 150 rpm before. Afterwards, each sample was put into a centrifuge for 2 minutes at 2000 rpm to separate the solids from the supernatant before filtering the mixture through a Whatman no. 1 filter paper. I collected this filtered sample into scintillation vials and stored these at -20° C until I was ready to run them through a Shimadzu TOC-L analyzer (Shimadzu Corporation), to analyze the extracts for organic C and N. Prior to running the extracts through the machine, each sample was spiked with phosphoric acid to remove any carbonates.

I calculated microbial biomass by subtracting the values from the fumigated organic C and total dissolved N data, from the unfumigated sample data collected from the Shimaddzu TOC-L analyzer. I then by dividing this difference with a correction factor of 0.45 for MBC and 0.54 for MBN (Grace et al., 2006).

5.3.5. Simple, Inexpensive Do-it-Yourself Tests

At the end of the 2021 growing season, we used simple, inexpensive, DIY soil tests that paired with what our collaborating community scientists were measuring on their experiments (See Appendix). These soil tests were conducted using inexpensive and easy to obtain household items and were able to produce insightful data that was comparable to test conducted within modern soil science laboratories.

5.3.5.1. Bulk Density

Bulk density in each plot was measured using a methods described by (Doran & Mielke, 1984). A 7.62 cm X 7.62 cm PVC ring with a beveled edge on one side was pounded into one of the four center mounds using a 2x4 block of wood in each plot. I used a soil knife to extract the soil that was contained within the buried PVC rings and the entire volume of soil was placed into a labeled plastic bag for transport back to the soil lab. The soil samples from each plot were then dried in a microwave for 2 cycles of 8 minutes until they were completely dry. The samples were then weighed and recorded as grams / 347.57 cm^3.

5.3.5.2. Aggregate Stability

Aggregate stability was analyzed based on techniques described in (Kemper & Roseanu, 1986). Representative aggregates were taken from each plot, sieved down to 4mm, and dried in a microwave for 2 cycles at 7 minutes. A 10 g sample of dried sample from each plot was placed into a confectionary sugar hand sifter. The confectionary hand sifter was then gently submerged in a 500 ml beaker of water. The sample was left under the surface of the water for 8 minutes. After this, the soil sample was completely raised out of the water, held for 5 seconds, and then gently submerged the sample again for another 5 seconds. This cycle was repeated for a total of 5 repetitions. The entire soil remaining in the sifter was gently tapped out onto a Tupperware dish with any soil stuck in the sugar sifter forced out with a jet from a water bottle. This sample collected in the dish was then microwaved for two cycles at 7 minutes, until dry. The dried sample was then weighed to compare the percent remaining from the initial 10 g.

5.3.5.3. Water holding capacity

I measured water holding capacity (WHC) on <2 mm sieved soil using similar method to those described by the USDA. A Whatman #1 filter was folded into quadrants and placed into a funnel and ~20 grams of dried soil from each representative plot was placed into its own filter and funnel unit. Water was added to the filter and funnel until the soil sample was totally submerged. At this point, a piece of saran wrap was secured over the filter and wettened soil combo, and the entire unit was set aside to rest for 16 hours. All excess water was allowed to drain through the soil into a receptacle that held the filter+soil+funnel combo. After the rest period, the wettened soil remaining in the filter was weighed and this value was used to calculate the water holding capacity of the soil.

5.3.5.4. Decomposition potential

Analyzing the decomposition potential of each treatment within the garden allowed us to better understand how the 3SI cropping systems differ from single cropping in its effect upon the soil functions. This method is used to understand the relative health of a soil within a cropping system by other soil scientists (Middleton, 2019). The deployment of our decomposable household items occurred on July 1st, to help the research team locate each item easily during their retrieval and to help prevent damage to the actively growing plants within each mound. Perimeter mounds within each plot were assigned a number and then randomly selected to receive a decomposable household material for data collection. We then weighed 10 tea bags of each type after drying them for 24 hours at 55℃ to obtain an average value for each tea type for analysis purposes. In 6 of the perimeter mounds, a pair of Teavana-brand Earle grey tea and Mint green tea bags (Starbucks, Seattle, USA) were buried to be removed at different time points in the growing season (4, 7, 30, 60, or 95 d after burial). The cotton string associated with each tea bag was reinforced with an 11-inch piece of fishing line and a tape label was attached to the end to aid in retrieval and identification. The location of each tea bag and every decomposable item was also flagged to aid in retrieval. The tea bags were removed from the garden at their respective time points, placed into a labeled bag for transport back to the laboratory, dried for 24 hours at 55℃, and then we recorded their mass after removing the string and tag assembly. The tea bags from each rep removed at 95 d were dried for 24 h, the contents of each tea bag were placed into an individual pre-weighed crucible, and then placed in a muffle furnace at 530℃ for 12 hours. We considered the remaining ashes mineral soil contamination, and the weight of this ash was subtracted from the final tea weight to represent ash-free dry mass.

Strips of birch (*Betula spp.*) have been used to understand the decomposition potential of the fungal community underneath different cropping systems by soil researchers (Hobbie et al., 2006; Middleton, 2019). After weighing 16 birch popsicle sticks to obtain an average, we wrapped a popsicle stick for every plot in a fashioned screen mesh envelope and buried it vertically into a pre-selected garden mound. Care was taken to ensure each popsicle stick was completely buried underneath the soil surface, and the length of burial was 95 days. After retrieval, the birch popsicle sticks were taken back to the laboratory, dried at 50℃ for 24 hours, and then weighed to test for mass loss after any soil attached to each stick was removed.

Sixteen pieces of bleached white cotton handkerchiefs were cut into equal size strips (3 cm x 6 cm) and then weighed to obtain an average value. The strips were wrapped in a stapled together screen-mesh to aid in the retrieval of the unit after 60 days of burial. After retrieval, the units were placed into a labeled gallon-size bag for transportation back to the laboratory where they were dried at 40°C for 24 hours. After drying, I carefully opened each stapled unit over a brown plastic sheet to contrast the white colored cotton while I used forceps to separate the cotton shards from the plastic screen and collecting them into a dish for weighing and analyzing percent mass loss.

5.3.5.5. Earthworm abundance

Earthworms can be an excellent indicator of the general health of the soil underneath a cropping system (Stroud, 2019). After constructing a 17.8 cm x 17.8 cm rigid frame in the shape of a square, the frame was then taken to one of the four center mounds plots in each plot at the research garden. Using the frame as a guide, a cube of soil was carefully excavated from the mound that measured 17.78 cm x 17.78 cm x 17.78 cm. All soil removed from this volume of soil (5620 cm^3) was placed onto a nearby tarp to be sifted through by hand to count the number of Earthworms present.

5.3.5.6. Gravimetric water content

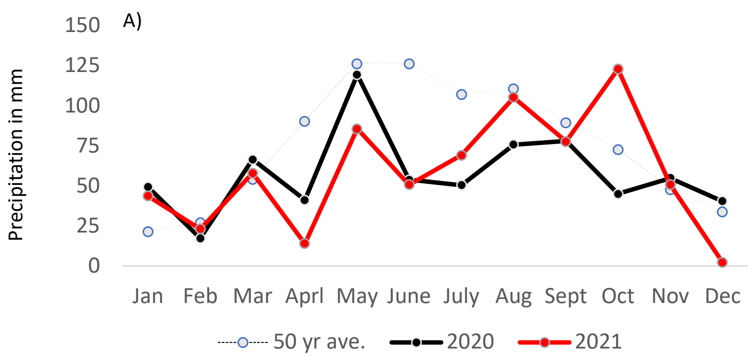
Soil samples from each plot were collected from a depth of 15 cm and deposited into a labeled gallon baggy for transporting back to the lab. Each sample was sieved down to 2 mm to remove all non-soil substances and to homogenize the sample. Then, 15 g of each sample was weighed and placed into a tin before being placed into an oven at 50 °C for 24 hours to completely remove any remaining moisture in the soil. Each sample was then reweighed, and the difference between the fresh weights and dry weights of each individual sample was divided by the weight of the fresh soil sample to calculate the gravimetric water content percent.

5.3.6 Statistical analysis

I analyzed all data using add-on tools within Excel software (Microsoft 2022), with the goal of determining if there was statistically significant difference between the parameters from 3SI and single cropping. To compare 3SI and single cropping with a balanced ANOVA, the single cropped values were averaged across the block before the ANOVA analysis and comparison of means. For example, plant-available nitrate under single crop maize, beans, and squash in Block 1 (Fig. 5.2) were averaged for one single crop nitrate value for the block. Once averaged, I conducted a one-way ANOVA test to determine significant difference between 3SI and single crop mean. The 3SI treatment effects were deemed either marginally significant, significant, or highly significant, with α-values of 0.1, .01, or .001, respectively.

5.4. Results

The length of the growing season varied between the two years with the weather for that specific year being the driving factor as to the number of growing degree days available. A derecho wind event struck the garden on August 10, 2020, effectively ending that growing season because all of our corn crops were flattened. The 2021 growing season was not affected by a derecho, but instead was afflicted with multiple different disease pathogens which reduced the overall health of our squash and maize plants. The site was under drought conditions for the majority of the 2020 growing season and the entirety of the 2021 growing season, but the temperatures in both growing seasons were similar and within the 50-year average highs and lows (Figure 5.3).



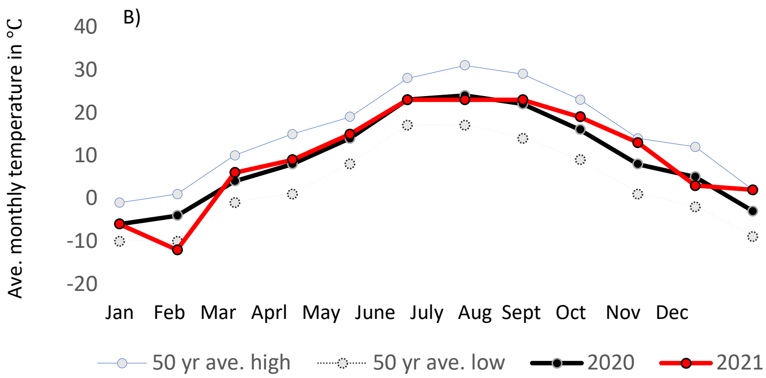


Figure 0.2 Climate data associated with the research garden over the 2020 and 2021 growing seasons. A) Site precipitation recorded monthly in mm, hashed gray line indicate 50 yr average, black lines indicate the 2020 growing season and red lines indicate 2021 growing seasons. B) Average monthly temperature in ℃, light gray indicates 50 yr ave. monthly low, blue line indicates 50 yr ave. monthly high

5.4.1. Analysis of Soil Biological Activity

Intercropping the 3SI together did have significant effects on multiple soil nutrient properties when compared to the average of soil values found underneath our single crop plots. A common way to estimate of the microbial biomass of a soil is by measuring its CO_2 respiration

(Oldfield et al., 2020), and data collected during both the 2020 and 2021 growing season showed that the average CO_2 respiration in the 3SI plots was higher than the combined average of the single crop plot for both years (24% and 18% respectively) (Fig. 5.3 and Table 5.3). . Because of the species diversity contained within a 3SI garden, different plant root exudates are being deposited into the soil and potentially priming the microbiota processes helping to boost their activity (Kumar et al., 2016), while single crop plots only benefit from the root exudates from a single species.

Proper plant selection in an intercropping system is characterized as having the potential of an increased utilization of soil nutrients within the cropping system (Duan et al., 2019), and this concept was supported by the data we collected. Although it was not a statistically significant difference, salt extractable nitrate was decreased by 54% under the 3SI intercropped plots when compared to the single crop plots for the 2020 growing season, and this trend followed through into the 2021 season when we observed a 9% decrease in the average of the 3SI plots compared to the average of the single crop plots (Fig. 5.3 and Table 5.3). Postma and Lynch described the differing root architecture between each plant species in a 3SI cropping system as being the cause of enhanced N uptake within their research (2012), and this complimentary effect at the root level between each plant within an intercropped 3SI system leading to enhanced nutrient uptake was also found in research conducted by Zhang et al., (2014).

Analysis of the microbial biomass carbon data from 2020 revealed a non-significant ($P>.05$) difference between the average value of mg C kg soil^{-1} found in the 3SI plots (239mg) when compared to the average of the single crop plots (252 mg) for a difference of 5%, with the maize treatments having the highest value at 263 mg (Fig. 5.3 and Table 5.3). This non-significant trend continued into the 2021 growing season, where the average of the 3SI plots produced a reading of 226 mg C kg soil^{-1} and the average of the single crop plots elicited a value of 197 mg C kg soil^{-1} for a difference of 14%.

The ratio of microbial biomass carbon to nitrogen ratio was analyzed over both years, with no significant difference between the 3SI treatments and the average of the single crops ($P>.05$). In both years, soils under the maize treatments had a more than a 30% lower MBC to MBN ratio than the soils under the 3SI treatments. Squash treatments had the highest recorded MBC to MBN ratio compared to all other treatments over both growing seasons (Fig. 5.3 and Table 5.3).

Extractable sulfate, measured in mg S kg soil^{-1}, was not significantly different underneath the 3SI plots when compared to the average of each individual single crop plots in both the 2020 and 2021 growing seasons. When compared against the average of the single crop plots during each growing season, soil samples collected from the 3SI plots averaged 19.5% higher during 2020 and 7.5 percent higher during 2021.

Extractable potassium, measured in mg K kg soil^{-1}, was not significantly different under the 3SI plots in 2020 but it was in 2021. When compared to the average of the single crop plots during each growing season, soil samples collected from the 3SI plots averaged 1% higher during 2020 and 27.4 percent higher in 2021.

Analysis of microbial biomass nitrogen over both years showed no significant difference between the 3SI plots when compared to the single crop treatments, although the average of the single crop plots was 24.5% higher than the average of the 3SI treatments for the first growing season. The 2nd growing season was characterized by the average of the 3SI plots having 3% higher levels of MBN than the average of the single crop plots.

Salt extractable organic carbon, (SEOC) measured in C kg soil^{-1}, was found to not be significantly different in the 3SI plots when compared to the single crop plots in any growing season, and the average of the 3SI plots was only 5% higher than the average of the single crop plots in both the 2020 and 2021 growing seasons (Fig. 5.3 and Table 5.3). Interestingly, the levels of SEOC in all the soil samples dropped by roughly 28.7% from the end of the 2020 growing season to the end of the 2021 season

5.4.3 Soil Physical and Biological Community Science Tests

5.4.3.1 Bulk Density

The bulk density values of all single crops were averaged together and compared to the average of the 3SI plots (1.45g/cm^3, and 1.39 g/cm^3 respectively), which showed 3SI having a 6% average lower bulk density than that of the single crops. The highest average bulk density was found in the corn single crop plots, which averaged 1.32 g/cm^3, and the bean plots had the lowest average bulk density at 1.22 g/cm^3 (Table 5.3).

5.4.3.2 Aggregate Stability

The percent aggregate stability average between the single crop plots and the average of the 3SI plots only differed by 1%. Maize plots had the highest percent aggregate stability at 14%, all other single crop plots had an average 12%, and the 3SI plots averaged 13% aggregate stability (Table 5.3).

5.4.3.3 Litter decomposition

5.4.3.3.1 Cotton swatch

The average mass loss in the cotton swatches buried within the 3SI intercropping plots was 20% higher than the average of the single crop plots (Figure 5.3), but the percent mass loss in the 3SI plots was very comparable to the average values obtained within the maize single crop treatments. Similarly, the average percent mass loss of the cotton swatch within the single crop bean treatments was nearly identical to the average percent mass loss found within the squash single crop plots (64.0% and 64.5% respectively). These two observations point to the maize species as being the dominant crop within the 3SI system with regard to cotton decomposition. ANOVA analysis on the decomposition data showed a significant treatment effect (Table 5.3).

5.4.3.3.2 Birch wood

The strips of birch wood decomposed with different rates in each plot when compared to the decomposition rates found with the cotton swatches. The 3SI intercropping system actually performed 18% less efficiently at decomposing the birch strips when compared to the average of the single crop plots, with an average percent mass loss of 15% for the 3SI systems and the single crops averaging 28.5% mass loss. Similar to the data retrieved from the decomposition of the cotton swatch, the presence of maize within the treatment was the prime variable into how much decomposition of the birch stick would occur. The birch strip percent mass loss was highest underneath the maize single crop treatment and lowest underneath the 3SI intercropped treatment (42.8% and 15.7% respectively). Squash treatments averaged 17.5% mass loss while bean treatments averaged 25.3% mass loss. An ANOVA analysis on the birch strip decomposition rates showed significant difference between the different treatments ($p<.0001$).

5.4.3.3.3 Green and Black Tea

The decomposition rate of the black and green tea was analyzed by only using the ash weight of the tea bag contents at 95 days and comparing them to the ash weight of unburied and tea bag contents. Despite the differences we found in soil respiration rates between the 3SI treatments compared to the single crop treatments, the decomposition rates of the tea bags buried for 95 days was nearly identical in all plots and across both tea types (Table 5.3). ANOVA analysis on the tea composition data showed no significant differences between the treatments (Table 5.3).

5.4.3.4 Earthworm Abundance

Earthworms have been referred to as ecosystem engineers because of their known effect upon a landscape (Stroud, 2019), and their presence or non-presence can be used as an indicator to judge the relative fitness of a soil. Earthworm population counts of a representative mound from each plot were taken on October 1st and October 2nd during the 2021 growing season. Three Sisters mounds averaged 47 Earthworms per cubic meter while single crop mounds averaged 49 Earthworms per cubic meter. Variability in population counts within each treatment was high, with some plots having significantly higher Earthworm populations than others of the same treatment type. The single crop squash plots on average had 56 Earthworms per cubic meter, corn plots had 51 Earthworms per cubic meter, and the bean plots had on average 41 Earthworms per cubic meter. An ANOVA analysis on the Earthworm data indicated no significant differences between the treatment (Table 5.3).

5.4.3.5 Gravimetric Water content

Knowing a soil's percent gravimetric water content can give a grower a good understanding about the possible amount of soil moisture that can be stored within their cropping system (Ni et al., 2017). Within this research project, the percent gravimetric water content was not significantly different in any of the treatments during both growing seasons (Table 5.3). It should be noted that the gravimetric water content within the samples was substantially in the 2021 growing season compared to 2020, but this variation could be attributed to watering schedules and weather patterns.

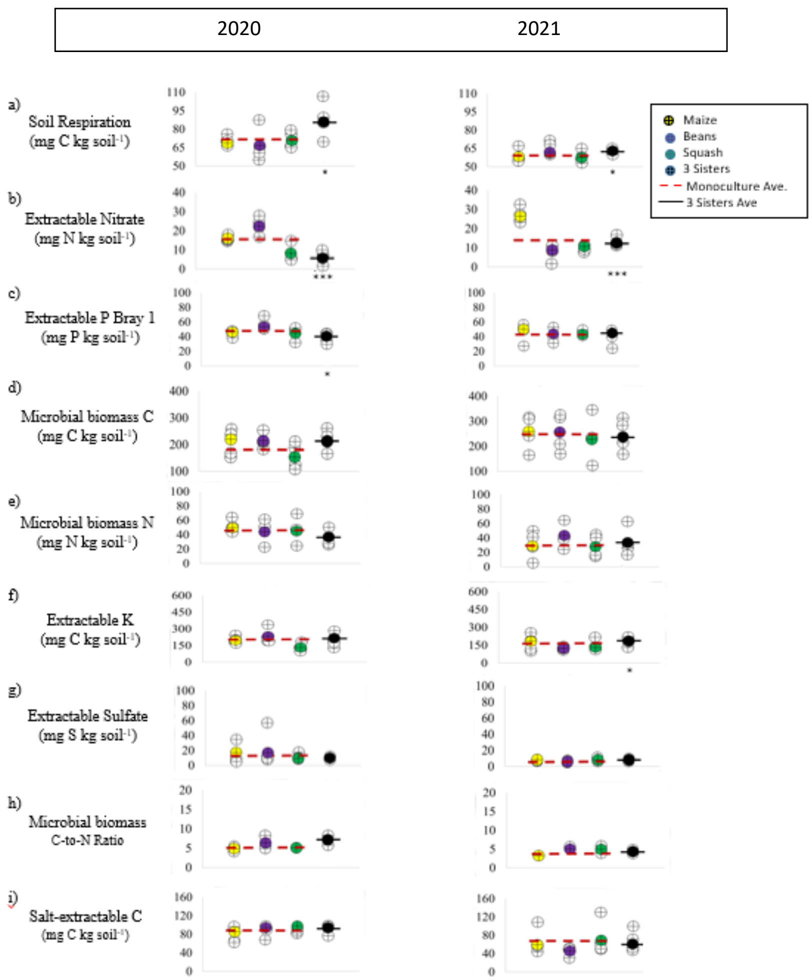


Figure 0.3 Soil properties measured on 15 August 2020, and 1 October 2021 at the Iowa State University Three Sisters intercropping Research Experiment (ISU-3SI). a) 24 h soil respiration with air-dried, rewet soils, Soil respiration, b) Salt extractable nitrate, c) soil test phosphorus with Bray P1 extraction, d) microbial biomass C extracted with chloroform-fumigation extraction, e) soil test potassium with Mehlich III extraction, f) microbial biomass N extracted with chloroform-fumigation extraction, g) soil test sulfur with phosphate extraction, h) microbial biomass C-to-N ratio, i) salt-extractable organic C. Replicates for each treatment shown with open circles (n=4), and significant differences between Monoculture vs Three Sisters intercropping (M+B+C) indicated by asterisks (*<0.1. **<.01, ***<.001).

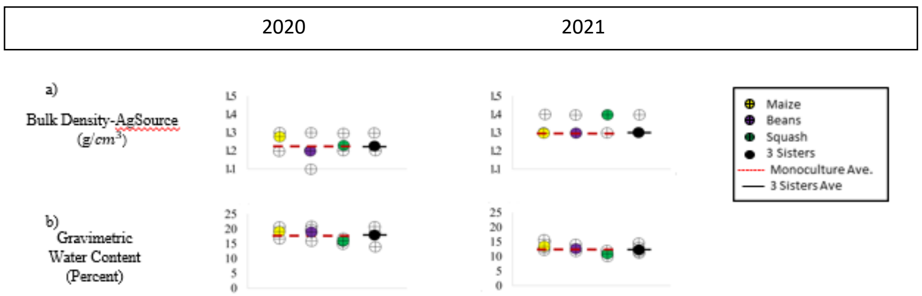


Figure 5.4 Soil properties measured on 15 August 2020 and 1 October 2021 at the Iowa State University Three Sisters intercropping project. a) bulk density, b) gravimetric water content cotton. Replicates for each treatment shown with open circles (n=4), and significant differences between single cropping vs Three Sisters intercropping (M+B+C) indicated by asterisks (*<.1, **.01, ***<.001).

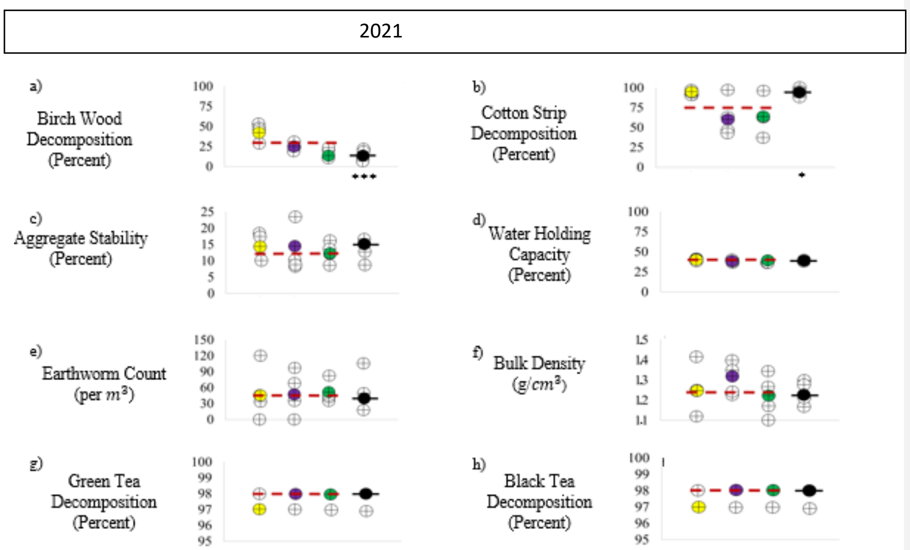


Figure 0.5 Soil properties measured on 15 August 2020, and 1 October 2021 at the Iowa State University Three Sisters intercropping Research Experiment (ISU-3SI). a) birch wood decomposition percent after 95 D, b) cotton strip decomposition after 65 D, c) aggregate stability (percent), d) water holding capacity (percent), e) earthworm count (per m^3), f) bulk density (g/cm^3), g) Green Tea Decomposition after 95 D, h) Black Tea Decomposition (percent) after 95 D. Replicates for each treatment shown with open circles (n=4), and significant differences between Monoculture vs Three Sisters intercropping (M+B+C) indicated by asterisks (*<0.1. **<.01, ***<.001).

Table 0.3 ANOVA results comparing Three Sisters intercropping to average of single cropping

	2020		2021	
Analysis	% Difference from Monoculture	P-value	% Difference from Monoculture	P-value
Soil Respiration (CO2 Burst)	19.5	.09	6.3	.08
Salt-extractable nitrate N	-53	**.0001**	-13	**2.00E-05**
Salt-extractable Carbon C	5.4	.75	5.8	.56
Extractable Phosphorus P -Bray 1	-17.5	.06	8.6	.54
Microbial Biomass Carbon	-2.3	.97	13.1	.23
Extractable Potassium K	1	.16	27.4	**.05**
Microbial Biomass Nitrogen N	-24.4	.7	2.3	.45
Extractable Sulfate S	-64	.55	0	**.04**
Microbial Biomass C to N Ratio	21.4	**.04**	2.2	.57
Gravimetric Water Content	3	.16	8.6	.54
Green Tea Rate of Decomposition	n/a	n/a	-5	.56
Black Tea Rate of Decomposition	n/a	n/a	-9.6	.67
Birch Wood Rate of Decomposition	n/a	n/a	-43.8	**.0019**
Earthworm Population Counts	n/a	n/a	-11.3	.99
Water Holding Capacity	n/a	n/a	-11.3	.99
Aggregate Stability	n/a	n/a	13	.97
Bulk Density McDaniel Lab	n/a	n/a	-1.9	.52

5.5 Discussion

The 3SI did alter soil biology and fertility compared to single cropping of maize, bean, or squash, but due to the limitation of this study, we were only able to observe this trend for 2 growing seasons. Nitrate uptake was significantly higher within the Three Sisters treatments during the first year, but this effect was substantially more subdued the 2nd year. Soil data varied widely from year to year, with weather patterns likely having some effects on the data we collected.

Depending on the soil characteristic being measured, the Three Sisters intercropping system does appear to have a dominant crop species effect. For example, maize single crop plots were more efficient at decomposing cotton in our research blocks indicated by higher decomposition values than both the squash single crop plots and bean single crop plots. Agriculturalists may need to understand how plant systems respond to one another in order to make informed decisions about how best to design sustainable agricultural systems. Because intercropping has the capability to enhance microbial activity when compared to single crop plots, it may represent an agricultural method that is more efficient about up taking added soil nutrient amendments.

Intercropping the 3SI had significantly different effects upon the soil than the effects found under single cropping. Postma and Lynch describe the 3SI system as benefitting from a form of niche partitioning in the soil by different crops, which leads to a synergism of nutrient uptake which they attribute to 'soil exploration competition' in the rooting zone (2012, 528). Nutrient loss to the environment from industrial cropping systems in the form of N fertilizer, is presently a serious threat to our aquatic ecosystems as well as our drinking water (Ehrmann & Ritz, 2013; Hawkins, 2019; Mt.Pleasant, 2015), with some researchers claiming that up to 60% of applied N fertilizer is lost to the landscape is lost to the environment (Jackson, 2008, 28). Our research gives weight to the argument that intercropping has ecosystem benefits when compared to the effects of single cropping, which in itself may show that intercropping is a more resource-use efficient method of growing food items.

Intercropping the 3SI had no statistically significant difference on soil physical properties when compared to the soil effects caused by single cropping, which included analysis of water holding capacity, aggregate stability, and bulk density. Aside from the Earthworm population counts which yielded no significant difference between the treatments (Table 5.3), the soil effects from 3SI agriculture were much more noticeable when we began to explore biological effects from the different treatments. The 3SI method incorporates a heightened diversity within the soil microbial community in the cropping system because of the three different plant types grown, and current scientific literature describes benefits of this enhanced diversity as affecting: "…decomposition, nutrient cycling, and soil organic matter (SOM) dynamics (McDaniel et al., 2014).

5.5 Conclusion

Intercropping the Three Sisters had consistent effects on soil nitrate, decreasing it relative to sole cropping and increasing biological activity (as assessed by CO_2 Burst). Other effects were inconsistent, i.e. only occurred in one year, and may be explained by either the varieties used for the year or weather conditions. It is clear that intercropping with maize, beans and squash altered soil biology and fertility. Future research should explore using stable isotope tracers to study flow of nutrients between the intercropped sisters and soil.

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CHAPTER 6. GENERAL CONCLUSION

The intent of the research behind the creation of this thesis was to analyze the environmental impact of Three Sisters agriculture on soil health and to contextualize how soil fits within the culture of different Native nations of the upper Midwest region. Our research found ways to improve future AES collaborations with Native communities in a way that benefitted all engaged parties. Native American people once had vast amounts of cultural knowledge about vast spaces of Earth across the American Midwest, which was forcefully stripped from them through colonialism and modernization. There is vast literature supporting the claim that a healthy human and Earth relationship may have positive emotional and physical impacts. Regular interactions with Earth through gardening and cooking activities amongst family members has the capacity to heal individuals suffering from trauma, psychiatric issues, and substance abuse. The Three Sisters intercropping method was more efficient at extracting N from the ground than monocropping over the course of our two-year experiment and may be a more resistant food production method than monocropping in adverse growing conditions.

A common question about the agronomic implications of the Three Sisters cropping technique is how we can 'scale up' the practice to the levels more along the lines of Big Ag and incorporate different industrial machinery to speed up the maintenance of the plot. Unfortunately for industrial farmers, though, after analyzing how Three Sisters agriculture is maintained within the Native Nations that practice it, it is becoming increasingly apparent that intercropping the Three Sisters may not have a place within the industrialized commodity crop market *as it currently exists*.

Native food growers that were interviewed as part of this project were unabashedly attuned to the precarious relationship that they have with Earth--how as humans, we are at Earth's mercy for our mere existence. They feel there is a need to interact with Earth in an appreciative manner because Earth has the ability to respond to our actions. Capitalistic market economies operate on a different existential plane. It is one where the destruction of Nature's assets are justified in the pursuit of a financial profit. Described by Gert Spaargaren and Arthur Mol as the "treadmill of production", capitalistic market economies need to continuously grow and exploit their resources in order to remain in competitive (1992). This exploitative behavior runs counter to non-colonial cultures that may be more sustenance based, and, as described by Judy Iseke and Leisa Desmoulins, view Earth's features and humans as interconnected holistically (2015, 46).

Concerns such as the long-term survivability of a cropping system can be easily overlooked within modernized communities because of the ability most farmers have to secure inorganic fertilizers, pesticides, and irrigation implements. The public often misses the negative effects of large-scale farming operations on the environment because most people do not spend much time interacting with these spaces in their day to day lives. This phenomenon is described by Kari Norgaard as a risk society, where individuals in developed countries are not fully able to understand the risks of the world through their own interactions with it and instead rely on sciences and technology to communicate it to them (2018). Since so few people in our communities interact with rural farmers, let alone farm or grow food themselves, it is easy for the majority of people to operate in their day to day lives without understanding the ecological risks associated with industrialized cropping practices.

Because farming is an activity only conducted by a small segment of the population, the effects of Industrial cropping practices on soil health can also be missed. There is overwhelming evidence that shows biodiverse cropping systems are less intensive on the soil and can make more efficient use of available resources, which can often result in a higher yield per unit of land than monocrop systems. These higher yields in biodiverse cropping systems are especially measurable when a growing system is affected by adverse weather and disease outbreaks, as occurred within our research project (Herrighty et al., 2021). Unfortunately, without the monetary incentives afforded to monocrop farmers, who the US Federal Government subsidizes to plant large single species stands of commodity crops, Three Sisters agriculturalists are at an immediate financial disadvantage compared to their neighbors.

Three Sisters agriculture incorporates concepts that mainstream farmers may be able to examine to determine the levels of sustainable soil use within their cropping systems. Because intercropping companion crops vary in their maturity dates and differ in above and belowground architecture, this system could help farmers prepare themselves for the increasingly volatile and unpredictable weather conditions that we now experience, as happened during our 2020 growing season with the August 10th derecho. Compared to monocrop plots, our research showed that the Three Sisters were more effective at using the available N in the soil, had higher rates of salt extractable carbon, and had increased soil respiration rates, all characteristics of a healthier cropping system.

Mainstream Industrial farmers, academic agronomists, and extension specialists may benefit by learning from Native peoples about what a reciprocal relationship with Earth looks like and how this type of relationship can benefit both the environment and a food grower. Treating Earth respectfully and thinking about all living organisms as an interconnected unit is a radical departure from the domineering and exploitative relationship many profit-minded agriculturalists seem to live, despite the health effects from living such a high-stress lifestyle (Crawford, 2022; Wilson, 2022). When interviewees associated with this project referred to soil as Mother Earth (or Grandmother Earth), they revealed how deeply they respected their interactions with Nature and how beautiful it can be to embrace that relationship. Acknowledging that we are a dependent of Earth and are at the mercy of environmental weather patterns can help decrease the blame a farmer may feel when their season does not go according to plan. This perspective may help that grower feel more inspired to adopt agricultural techniques that help them think more about the long-term survivability of their soil resources rather than focus their concerns on the immediate financial profits they could make in a particular year.

To be successful, university agricultural extension specialists and academic researchers hoping to work within Native communities need to understand that this type of human-Earth awareness exists. As a result of the importance of this relationship between many Native people and their environment, research goals developed prior to approaching a Native community may have to be altered or altogether scrapped to build and maintain genuinely collaborative research. We allowed the collaborating Nations to guide our study and show us how their cropping systems affected the soil by forming an Advisory Board, where a representative from each of the communities was given the opportunity to voice their input on how they felt our project should be conducted. The goal of this board was to ensure that our research remained culturally sensitive and beneficial to the Native communities and growers. Spending time working alongside collaborating gardeners allowed us to understand better their needs and limitations in a way that could have been missed had those more involved moments not occurred.

Future soil research using Indigenous cropping methodologies

While this research project was arguably a thorough analysis of the Three Sisters intercropping practice, there are still avenues of scientific exploration that it could inspire. I was limited in my ability to physically network with larger groups of collaborators for over one year due to the COVID-19 pandemic. This hampered my ability to engage with more people and hear their thoughts on soil. Had I been able to travel freely without worries about contagion I would have been able to earn the trust of the collaborators by being present with them for milestones during the 2020 growing season. This could have encouraged collaborators to introduce me to other knowledgeable members within the communities, resulting in more interviews and soil test results. The pandemic-caused social distancing during the 2020 growing season may also have had some effect upon the level of community scientist engagement we were able to activate.

A highly insightful direction of scientific inquiry about the soil effects of Indigenous agricultural methods could be to examine the soil effects of Three Sisters managed using organic approved methods, and then compare them to the soil effects of monocrop maize, bean, and squash that are managed using commercial production methods. This large difference in crop management techniques may solicit valuable soil data useful to both Native communities and other entities who may be interested in the long-term impacts of cropping practices on the landscape.

Future ethnographic soil research in Non-Native communities

Listening to Native American worldviews as they relate to soil and its importance as a biological, cultural, and social resource could be more critically analyzed if there were a counter examination of the importance of soil within agricultural social circles outside of Native communities. Indigenous agricultural methods are viewed as a collaborative effort between the food grower and the Earth, while capitalist agriculture is a manifestation of human dominance over landscapes. Even when Western science demonstrates that capitalist agriculture There were mathematical formulas developed by the 1930s that could predict the amount of soil erosion within industrial cropping systems caused by rain events on sloped landscapes and areas without vegetation (Shaw, 1930), but even 80 plus years later, industrial agricultural farmers are still using farming practices that are having profoundly negative consequences on the ecosystems due to soil erosion from their fields (Amundson et al., 2015; Belmont et al., 2011; Tomer et al., 2013). Using resources to try and understand the social pressures that keep industrial farmers who directly interact with the largest spaces of soil in our communities from adopting cropping practices that result in less soil loss could be a benefit in conversations about ways to help clean up our ailing rivers and streams in the Midwest. Scaling out, it may also be beneficial to conduct ethnographic research amongst environmental policymakers and lawmakers who craft market influences that push industrial farmers to grow crops in the manner they do.

Another avenue of ethnopedology research that may be beneficial to examine in non-Native agricultural communities is the presumed responsibilities within the concept of land ownership. Because many Native American epistemologies view Earth as an entity unable to be owned by individuals, instead referring to Earth as Grandmother or Mother Earth as interviewee Johnathan Buffalo, Rebecca Webster, Shelley Buffalo, and Jesikka Greendeer did, this helps direct how members of different Native American communities feel they can act towards the Earth. If non-Native farmers could gain an understanding of this worldview, they would understand the importance of reciprocal relationships with Earth and of acting with the respect for Earth's ability to care or harm us. While industrialized commodity cropping practices have remained the norm in the American Midwest for 100 years, the worldview that their design is based upon does not have to remain stagnant. Adopting agricultural methods that work to build up health of ecosystems would be more sustainable in the long term than agricultural methods that are inherently extractive and toxic to the environment.

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Appendix

ISU Three Sisters Intercropping Project
Soil Health Kit Manual

By

Derrick Kapayou

and

Marshall McDaniel

Updated February 11th, 2021

TABLE OF CONTENTS

Introduction & Purpose of This Manual

This manual is to be used in conjunction with the components contained within the soil health kit and is a feature of the ISU 3-Sisters Intercropping Project (ISU-3SI; website here when available). The purpose of the soil health kit and this manual is to help our Native collaborator gardeners analyze different soil health characteristics their gardens or fields. Monitoring soil health using inexpensive, yet scientifically robust, methods is key to observing positive change in soil. We at ISU hope that this kit and the overall 3-Sisters Intercropping Project will establish "community science" engagement within Native communities, where the ISU team and community-scientist collaborators can learn from one another about sustainable vegetable/crop production and soil health. In addition to engaging community scientists, our other goals with the ISU-3SI are to assess the cultural, historical, and agricultural impact of growing the 3-Sisters in our collaborator communities, and to determine the agronomic effects of the 3SI system (maize, beans and squash) on soil health.

Our primary goal is to help Native collaborators in providing healthy and culturally appropriate foods to their communities, while also creating a cross-cultural "living classroom" for cultural, historical, and scientific knowledge. We will also use the data we collect to inform conventional, industrialized agriculture, which relies heavily upon monoculture cropping systems and is shown to negatively impact soil health properties. Native American perspectives, and traditional ecological knowledge, of the agroecological benefits of intercropping over monocropping align with modern-day scientific observations. We would like to learn more about how growing the 3-Sisters, and intercropping in general, could help to diversify and improve productivity and environmental performance of modern monoculture agroecosystems.

General Supplies & Helpful Hints

General Supplies

- **Notebook** - to record measurements and observations on
- **Pencil or pen** – to record measurements and observations

OPTIONAL

- **Excel for PC or Mac Computer** – to record and do data calculations

Considerations & Helpful Hints

a) **Use your senses and record everything in notebook**
Make sure to use your senses to observe soil, current weather conditions, any details particular to your measurement, and record those in a notebook. They can be helpful to interpret results later.

b) **How many samples should I take?**
Greater replication of treatments or measurements is better. However, it comes at a cost of more time and resources in some cases. You have to decide how much time and resources to invest in your measurements. As professional scientists we usually replicate treatments randomly three to six times in a field

c) **Timing is everything**
The best time to conduct most of these measurements is right before planting or after harvest, due to normally favorable conditions to work with soil (i.e. not too dry or frozen). Whatever time you choose, be consistent and collect samples this time of year every year.

d) **More resources in the appendix of this document**
There is an itemized shopping list for the soil health kit (SHK) at the end of this manual. It may help you locate the items needed for the various tests if you do not already have these items.

e) **Consider sieving your soils**
This helps ensure soil samples are thoroughly mixed and is ideal for collecting precise and accurate data measurements from the tests performed.

f) **Read the directions of the test completely before beginning!**
It is best to understand each step of the test before conducting the analysis on your soil sample. This helps prevent unintended accidents which might require you to have to collect more soil samples.

g) **We are here to help**
Feel free to reach out to the ISU team if you have any questions about this manual or any of the tests!

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1. Earthworm Abundance and Midden Counts

based on (Stroud, 2019)

Earthworms have been shown to be an excellent indicator of soil health (Bender et al., 2016; Reganold et al., 1990; Stroud, 2019; Thrupp, 2000). Earthworm abundance and activity are generally increased with reduced tillage (Stroud, 2019), diversified crop rotations, (Finckh and Wolfe, 1997), addition of manure (Guttmann, 2005), use of cover crops (Bender et al., 2016), and other soil conservation practices (Drinkwater et al., 2016). Not only are Earthworms indicators of soil health, but they can also help contribute to soil health by creating soil pores that increase water infiltration storage (Magdoff and Van Es, 1993), and their activity can even increase microbial and plant growth (Kuzyakov et al., 2000).

Here we describe two methods for either measuring Earthworm abundance (counting Earthworm bodies), or activity (count *middens*). Counting Earthworm bodies will require the community scientist to physically handle each Earthworm in the area of interest while the Earthworm midden counts requires no worm handling. Choose whichever test you are most comfortable with!

Figure 4. Earthworm middens. a) close-up image of earthworm midden. Notice the pile of clumps. These piles average about 2 cm tall and 5 cm wide, with a burrow hole in found in near the pile center. More information available at (http://matoseuranta.it.helsinki.fi/instructions/sampling-methods). b) photo comparing the numbers of earthworm middens found in growing plots managed using conventional tillage methods versus growing plots managed using no-till methods. Notice the frequency of middens in the no-till system. More information can be found at (https://www.wisfarmer.com/story/news/2019/10/28/long-term-no-till-benefits-earthworms-leads-deeper-root-growth/2483949001/).

1.1. Earthworm Abundance - using pit excavation and hand sorting (based on Stroud, 2019)

Supplies needed

- **Garden fork or spade** - to turn soil
- **Meter stick -** to measure dimensions of soil pit
- **Ruler or measuring tape -** to measure exact size of pit
- **Small tarp or mat** - to put soil on top of
- **Pot or container with a lid** - to hold Earthworms for counting
- **Bottle of water** - to keep Earthworms from drying out

a) **Marking pit to excavate**. Using the ruler , measure out a square 18×18 cm (7×7") hole in the plot, from where you will dig to a depth of 18 cm (7"). Or in other words, you will excavate a 18×18×18 cm (7x7x7") soil cube.
b) **Digging**. With the garden fork or spade, remove and place all soil from this hole onto the small tarp or mat, which should be located close to the hole.
c) **Sort and collect Earthworms (and eggs)**. Gently sort through the excavated soil looking for Earthworms or Earthworm eggs. All Earthworms and eggs found should be put into the lidded container, with a small amount of water to keep them moist. Use the lid to prevent Earthworms from escaping before being counted. Spend no more than roughly 15 minutes on this step. Earthworm eggs can be placed into separate container.
d) **Count and describe.** Count the number of Earthworms and briefly describe their appearance, using the terms: small and red; pale or green; or plump and dark. Enter information into your notebook.
e) **Calculate abundance**. Calculation abundance by filling out the table below…

Table 1. Excel Data Sheet Template and Example Calculations for Earthworm Abundance

	A	B	C	D	E	F	G
1		# worms small and red	# worms plump and dark	Total # of Earthworms found in plot	Volume of soil excavated in plot (L x W x H)	Volume of soil converted from cm^3 to m^3 (100cm = 1m)	# Earthworms found per m^3
2	3-Sisters				5832cm^3	.5832m^3	=SUM(B1:D1)/F1
3	Maize				5832cm^3	.5832m^3	=SUM(B2:D2)/F2
4	Bean				5832cm^3	.5832m^3	=SUM(B3:D3)/F3
5	Squash				5832cm^3	.5832m^3	=SUM(B4:D4)/F4

Note: 5832 cm^3 comes from multiplying the Length X Width x Height of the soil you excavated!

1.2. Earthworm Midden Count – counting Earthworm burrows (based on Stroud et al., 2016)

Supplies needed

- **Tape measure** - to measure out area for scientific observation
- **Count clicker or notebook -** to keep track of midden counts

a) **Identify ideal location.** Choose a random, but representative location of your garden, field, or research plot.
b) **Study site prep.** Measure out a 1x1 m (3×3') quadrat onto the ground and set a timer for 5 minutes.
c) **Conducting scientific observation.** After starting the timer, carefully but quickly scan the soil surface within the quadrat looking for evidence of Earthworm middens (Figure 1). These look like small holes in the ground that are big enough for an Earthworm to squeeze through and can also take on an appearance similar to an anthill.
d) **Data collection.** Write down in your notebook the number of Earthworms found before moving onto the next plot.
e) **Further analysis.** Repeat steps a) through d), covering all plots in your research block. Make sure write down your observations.
f) **Activity level.** Calculate activity by filling in the table below

Other Helpful Resources

YouTube Video with J. Stroud - https://www.youtube.com/watch?v=bNxZqVtLPbs

Table 2. Excel Data Sheet Template and Example Calculations for Earthworm Midden Counts

	A	B	C	D	E	F
1	Treatment	Midden Count Replicate 1	Midden Count Replicate 2	Midden Count Replicate 3	Midden Count Replicate 4	Average Count of Earthworm Middens (#/m^{-2})
2	3-Sisters					= AVERAGE(B2:E2)
3	Maize					= AVERAGE(B3:E3)
4	Bean					= AVERAGE(B4:E4)
5	Squash					= AVERAGE(B5:E5)

2. Soil Bulk Density

based on (Doran and Mielke, 1984)

Soil bulk density is one of the most important characteristics of soil health. It is simply the mass of dry soil divided by the volume it occupies – typically expressed in the units of grams/cm^3. Soil bulk density affects water infiltration and storage of water (Council, 2010), root growth (Bennett et al., 2012), plant nutrient availability (USDA-NRCS, 2020), and even microorganism activity (Magdoff and Van Es, 1993).

Put most simply – the lower the bulk density the better. The lower the bulk density of a soil, the better that soil will be able to support animal, plant, insect, and microbial life in the soil. An average bulk density for general agriculture soils in the Midwest US is 1.3 g/cm^3. However, soil texture (or distribution of particle sizes) can regulate the bulk densities that plant growth begins to be hindered.

Supplies needed

- **PVC ring with beveled edge -** to measure an amount of soil
- **Wooden block -** for pounding the PVC ring into the ground
- **Mallet** - for pounding the PVC ring into the ground
- **Soil knife or old large screwdriver -** for removing soil from ring
- **One-gallon plastic bags (pre-weighed and labeled) -** to store soil (weight is W_{PB} for calculations)
- **2-place balance**, **with good precision -** for weighing the soil extracted with PVC ring

a) **Collect Soil Sample.** In each plot, pound the 7.62 cm diameter × 7.62 cm tall (3x3") PVC ring with a hammer and wooden block until the ring is level with the soil surface. The outer edges of the soil core can be removed with a knife. After extracting the ring with its intact core, empty the contents into a clean plastic bag. If you are doing more than one sample, make sure plastic bags are properly labeled.

b) **Dry soil.** *Microwave*: Empty the soil sample from the plastic bag into a microwave-safe dish. Place this dish into a microwave, and use 2 × 7 minutes cycles on HIGH power, or until soil is bone dry. *Oven*: turn oven on at 200 ºF and dry soils for 6-8 hours until soils look very dry. Let cool. Transfer the dry soil onto the scale and record the weight of the ***dry soil only***.

c) **Calculations.** Calculate bulk density of the soil sample by using the following formula:

   Value from Step b) / 21.21 cm^3

Example: 42 grams / 347.57 cm^3 -**Enter your information in the table below!**

d) ***<u>SEE INSTRUCTIONAL VIDEO ASSOCIATED WITH THIS TEST FOR MORE INFORMATION.</u>***

Table 3. Excel Data Sheet Template and Example Calculations for Soil Bulk Density

	A	B	C	D
1	Treatment	Weight of oven dry soil (g)	Volume of the PVC ring (cm^3)	Soil bulk density – g of soil /volume of PVC ring (g/cm^3)
2	3 Sisters		347.57 cm^3	= B2/C2 (g/cm^3)
3	Maize		347.57 cm^3	= B3/C3 (g/cm^3)
4	Squash		347.57 cm^3	= B4/C4 (g/cm^3)
5	Beans		347.57 cm^3	= B5/C5 (g/cm^3)

Note: 347.57 cm^3 is the volume of the PVC cylinder, and is calculated by squaring the radius, multiplying that by 3.14, and them multiplying that by the height of the cylinder. $V= (3.14) \times (r^2) \times H$

3. Decomposition

based on (Keuskamp et al., 2013)

Decomposition of organic material in soils is a complex physical and chemical process that is made possible through interactions between soil organisms, the physical environment, and the material being decomposed (Ehrmann and Ritz, 2013). Through the decomposition process, complex organic molecules from dead materials are broken down into simpler organic and inorganic molecules that are easily taken up by plant life (Magdoff and Van Es, 1993). Faster decomposition rates are indicators of healthy soil organisms (Duddigan et al., 2020), which help to boost crop productivity in that area.

Supplies needed

- **Green and rooibos teas in bag (1 each)** - to test as a decomposable
- **100% cotton handkerchief** - to test as a decomposable
- **Birch popsicle stick -** to test as a decomposable
- **Gardening hand trowel -** to bury and retrieve decomposable items
- **Flags (x4) -** to mark site of buried decomposable items
- **2-place balance with good precision** - for weighing the decomposable items after harvest

a) **Record initial weights.** Weigh each item to be buried in the garden (tea bags, cotton swatch, and popsicle stick). Record these values in the table provided.
b) **Identify ideal location.** Locate a suitable spot in the 3Sisters plot for the burial of all 4 items (teas, cotton, and popsicle stick). This spot will ideally be more in the center of the plot than towards the edges.
c) **Hole preparation.** Dig the holes for each item to be buried, using the diagram below to help guide the placement of each article. Using the hand trowel, dig a hole roughly 6.5 cm diameter and 9 cm deep (3x3.5”) for each of the tea bags, a slice roughly 16.5 cm deep (6.5”) for the popsicle stick, and a square roughly 15.25 cm wide X 15.25 cm long X 15.25 cm deep (6x6x6”) for the cotton handkerchief.
d) **Burying of items.** Bury the decomposable items using the soil removed from the hole, making sure to allow the flag on the fishing line attached to each item to be visible from the soil surface.
e) **Marking locations.** Mark the position of all for items with a flag, for easier locating at the end of the project.
f) **Helpful hint.** Take notes during this experience! If you have to deviate from this protocol, write down in your observation booklet what you did and why.
g) **Harvesting items**. Using the hand trowel, gently dig up the items buried and place each one it its own baggy for analysis. Try and dig up any and all pieces of the items, taking care to not leave any pieces in the soil.

When to harvest decomposable items!	- Cotton handkerchief	=	50-60 days after burial
	- Tea bags	=	50-60 days after burial
	- Popsicle sticks	=	90-100 days after burial

h) **Recording harvest weight**. After harvesting items from the garden, weigh them and record their values in the table provided.

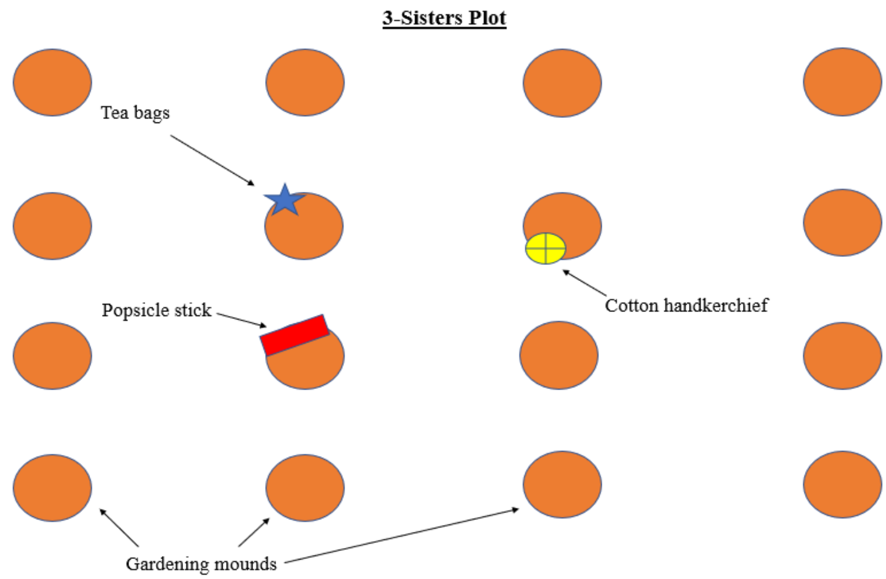


Figure 2. Site selection for burial of decomposable. Notice the sites for burial are in the mounds the center of the garden rather than the edges. Decomposables were buried in different gardening mounds for this demonstration because the mounds were too small to bury more than 1 item without intruding on the planting deck.

3-Sisters Research Block

Figure 3. Possible site selection schema for burial of decomposables. M=maize; B=bean; Sq= Squash; 3SI= 3-Sisters. Red bars indicate buried popsicle stick; Blue stars indicated buried tea bags; Yellow circles indicate buried cotton handkerchief. Notice each decomposable is located in each plot.

***NOTE. For more details about how to initially lay a research block, please see the 3SI Plot Layout document

Table 4. Excel Data Sheet Template and Example Calculations for Decomposition tests

	Grey Tea (preseason wt)	Grey Tea (postseason wt)	Green Tea (preseason wt)	Green Tea (post-season wt)	Popsicle stick (preseason wt)	Popsicle stick (post-season wt)	Cotton handkerchief (preseason wt)	Cotton handerchief (post-season wt)
Three Sisters	g	g	g	g	g	g	g	g
Maize	g	g	g	g	g	g	g	g
Bean	g	g	g	g	g	g	g	g
Squash	g	g	g	g	g	g	g	g

Table 5. Excel Data Sheet Template and Example Calculations for Decomposition tests

		A	B	C	D
		Popsicle Stick # days buried	Grey Tea # days buried	Green Tea # days buried	Cotton Handkerchief # days buried
A	Three Sisters				
B	Maize				
C	Bean				
D	Squash				

4. Aggregate Stability

based on (Herrick et al., 2001)

The slaking test is a type of measurement that analyzes the stability of dry soil aggregates after they have been wetted (Ehrmann and Ritz, 2013). Soil slaking is a feature that is impacted by the amount and quality of organic matter in a soil, and has use in determining a soil's water infiltration rate and erosion susceptibility (Bryan, 2000). Higher values obtained in a slaking test are correlated with healthier and more biologically active soil (Herrick et al., 2001).

Supplies Needed

- **Hand sieve (for powdered sugar or baking) -** used to hold soil sample in water bowl
- **Wide bowl deep enough to mostly submerge the sieve -** to analyze soil particle stability
- **5 grams of sieved to 4 mm and air-dried soil (roughly 30 days) -** for data collection purposes
- **Stopwatch (or phone app) -** important for keeping accurate track of time
- **Water to mostly fill wide bowl -** to analyze soil particle stability
- **Plastic squeeze water bottle (mostly full)** – to clean sieve of all soil

a) **Experiment preparation.** Fill the wide bowl with enough water to that there is only ½ inch of bowl left above the surface of the water.
b) **Wetting soil.** Put the 5-10 grams of air-dried >4mm soil into the hand sieve and dunk it underneath the surface of the water. Start the stopwatch and submerge the soil sample for 8 minutes.
c) **Performing experiment.** After step 2, raise the sieve out of the water for 5 second, and then completely dunked again 5 second. Repeat this step 4 times.
d) **Dry soil**. After the dunking process is completed, dump the soil remaining in the sieve into a microwavable-safe container. Flip the sieve over the microwaveable safe container and use the squirt bottle to lightly blast any soil remaining stuck to the sieve into the dish. *Microwave*: Place the container (measuring cup or plastic dish) in the microwave and use 2 × 7 minute cycles on HIGH power, or until soil is dry; *Oven*: turn oven on at 200 ºF and dry soils for 6-8 hours until soils look very dry. Let soil sample cool to room temp and to record the weight of the dry soil.
e) **Notetaking.** Record your observations in the table provided.
f) **Calculations.** Take the weight of the dry soil (POST DUNK) and divide it by the weight of the dry soil (PRE-DUNK). Take this result and multiply by 100 to get a % aggregate stability

   Ex. 45g / 50 g = .90 → .90 x 100 = 90% aggregate stability
g) ***SEE INSTRUCTIONAL VIDEO ASSOCIATED WITH THIS TEST FOR MORE INFORMATION.***

Table 6. Excel Data Sheet Template and Example Calculations for Aggregate Stability

	A	B	C	D
		Weight of soil pre- dunk (g)	Weight of soil post dunking and drying (g)	Percent Aggregate Stability ((B / C) x 100)
1	3SI			=(B1/C1)x100
2	Maize			=(B2/C2)x100
3	Bean			=(B3-C3)x100
4	Squash			=(B4-C4)x100

5. Water Holding Capacity

based on (Grace et al., 2006)

Water holding capacity measures the ability of a soil to hold onto and release moisture to growing plant life (Barrios and Trejo, 2003). Water holding capacity is majorly affected by the composition of a soil (percent sand, silt, and clay) (Tamang, 1993), as well as the percentage of organic matter in a soil (Oldfield et al., 2020). According to the USDA, a 1% increase in soil organic matter in a field can contribute to over 25,000 more gallons of water per acre available to plant life. Higher water holding capacity values are correlated with healthier growing systems (Kremen and Miles, 2012).

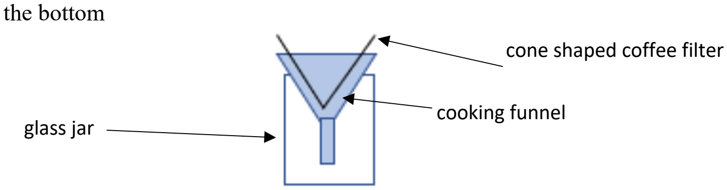
Supplies needed

- **Roughly 3 cups of soil -** from growing plot.
- **Home oven (or microwave)-** set at 200 degrees, used for drying soil sample
- **2-place scale with good precision -** used for weighing soil samples during analysis
- **Hand trowel -** for collecting soil sample
- **1-gallon plastic bag -** for containing soil samples after retrieving them from the plot
- **1 marker -** to label items when necessary
- **Funnel -** to hold coffee filter paper for analysis
- **Cone-shaped coffee filter -** to hold soil for water filtering and analysis
- **Sliced mushroom in glass jar (empty)-** to hold funnel
- **16 oz of water-** to conduct experiment

a) **Collecting soil samples.** Remove vegetation from the soil surface before using the hand trowel to scoop out approximately 3 cups of soil from the top 10 cm (4") of your research plot (garden). Place this into a one gallon plastic bag and label it according to the type of crop being grown in it. If possible, stir the soils in the bag to create an even mixture. Return to the lab and weigh out 20 grams of the homogenized soil mixture.

b) **Dry soil.** *Microwave*: Place the container with the soil in the microwave and use 2 × 7 minute cycles on HIGH power, or until soil is dry; OR *Oven*: turn oven on at 200 ºF and dry soils for 6-8 hours until soils look very dry. Let soil sample cool to room temp and to record the weight of the dry soil

c) **Wet filter.** Using the water, gently wet the coffee filter while it is still in the funnel. This can be done over a sink or Tupperware container to catch the excess. The filter paper needs to be totally saturated. Drain off any excess water and place the funnel + wet filter paper into the empty glass mushroom jar. (See schema below). Note how the jar keeps the tip of the funnel of the bottom



d) **Collecting data.** Place the assembled funnel and wet filter on the scale to weigh their combined weight. Record this value in the table below.
e) **Preparing equipment.** Place the wet coffee filter into the plastic baking funnel, then put these into the mushroom jar. Carefully pour the 20 grams of oven-dried soil on top of the wet filter paper inside the funnel.
f) **Conducting experiment**. Carefully and slowly, saturate the soil and until the water begins to drip through the funnel. At this point add a slight amount more water until the soil is slightly submerged about ¼- ½ inch. At this point, let the water drain through the funnel on its own to collect in the clear jar. *Cover the entire top of the funnel securely with a piece of plastic wrap and a rubber band*. Set the entire assembly aside for 6 hours.
g) **Data collection.** After waiting 6 hours, carefully remove the plastic wrap and rubber bands from the top of the funnel. Weigh the funnel + wet filter paper+ wet soil assembly and record this value in the table below.
h) **Calculations.** Subtract the weight of the wet filter + funnel, from the weight of the wet filter + 6-hour wet soil + funnel ((step g – step d)). You now have the mass of the wet soil.
FROM TABLE BELOW: D – C = mass wet soil (E)
i) **Calculations.** Subtract the weight of the dry soil (should be roughly 20 grams) from the mass of the wet soil, which was calculated in ((step h)). You now have the mass of the water *in* the soil.
FROM TABLE BELOW: E – B = mass water in soil (F)
j) **Calculations.** Take the mass of the water in the soil ((step i)) and divide it by the mass of the wet soil ((step h)). Multiply this answer by 100 to determine your water holding capacity (WHC).
FROM TABLE BELOW: (F / E) x 100 = water holding capacity (G)
k) ***SEE INSTRUCTIONAL VIDEO ASSOCIATED WITH THIS TEST FOR MORE INFORMATION***

Table 7. Excel Data Sheet Template and Example Calculations for Water Holding Capacity

	A	B	C	D	E	F	G
		Weight of dry soil (~20 g)	Weight of wet filter +funnel	Weight of wet filter + funnel + 6 hour wet soil	Mass of wet soil	Water Mass in soil	Water holding capacity
1	3SI				=D1-C1	=E1-B1	=(F1/E1) x 100
2	Maize				=D2-C2	=E2-B2	=(F2/E2) x 100
3	Bean				=D3-C3	=E3-B3	=(F3/E3) x 100
4	Squash				=D4-C4	=E4-B4	=(F4/E4) x 100

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LIST OF MATERIALS NEEDED

Use	Item	Cost	Location	Item Number
General Equipment	Electronic scale	$17.90	Walmart	888327679
	Notebook	$4.24	Walmart	16671273
	Plastic Bags (gallon) × 60	$7.79	Walmart	580592045
	Garden Sieve	$29.51	Walmart	282092141
1. Earthworms	Tape Measure	$4.71	Walmart	19398714
	Ziplock Containers	$1.95	Walmart	39444456
2. Bulk density	PVC Pipe	$13.87	Walmart	149527172
	Tarp	$6.95	Walmart	158580963
3. Decomposition	Gray Tea (pk of 24)	$11.07	Walmart	891805172
	Green Tea (pk of 24)	$10.48	Walmart	891805172
	Cotton Handkerchief	$9.87	Walmart	854127057
	Birch Popsicle Stick	$6.98	Walmart	101030428
	Garden Flags	$9.90	Walmart	339930721
	Gardening Trowel	$7.49	Walmart	16930220
4. Aggregate Stability	Hand Sieve	$5.29	Walmart	495885673
	Squeeze Bottle	$.98	Walmart	797794747
5.Water Holding Capacity	Plastic Funnel	$2.39	Walmart	896290952
	Cone-shaped coffee filter	$4.38	Walmart	10535001
	Empty glass jar or glass	$1.38	Walmart	55428222
	Saran Wrap	$2.98	Walmart	12442827

General Equipment

Electronic scale= $17.80

https://www.walmart.com/ip/ESYNIC-0-01g-500-Gram-Digital-Pocket-Scale-Portable-Weight-Scale-Food-Scale-LCD-Display-Electronic-For-Kitchen-Silver/888327679

1-Gallon plastic bags= $7.79

https://www.walmart.com/ip/Ziploc-Brand-Slider-Storage-Gallon-Bags-with-Power-Shield-Technology-60-Count/33338041

Garden sieve= $29.51

https://www.walmart.com/ip/Tierra-Garden-Garland-2-in-1-Sieve/282092141

Notebook= $4.24

https://www.walmart.com/ip/Five-Star-3-Subject-Wide-Ruled-Wirebound-Notebook-Color-Choice-Will-Vary-04119/16671273

1. **Earthworm and Midden Count**:

Vinyl tape measure= $4.71

https://www.walmart.com/ip/Singer-Vinyl-Tape-Measure-60-1-ea/19398714

Ziplock 2 count large rectangular containers= $1.95

https://www.walmart.com/ip/Ziploc-2-CT-Large-Rectangle-Container-36-oz-Each-One-Press-Seal-Plastic-Storage-Container/39444456

2. **Soil Bulk Density:**

Schedule 40 PVC Solid Pipe 3inch X 2ft Plain end= $13.87

https://www.walmart.com/ip/Charlotte-Pipe-Schedule-40-PVC-Solid-Pipe-3-in-Dia-2-ft-Plain-End-260-psi/149527172

Balance= $15.99

https://www.walmart.com/ip/Nutrition-Digital-Kitchen-Scale-500g-0-01g-Mini-Pocket-Jewelry-Cooking-Food-Scale-Backlit-LCD-Display-2-Trays-6-Units-Auto-Off-Tare-Stainless-Steel-B/340494387

Plastic Bags (gallon size)= $7.79

https://www.walmart.com/ip/Ziploc-Brand-Freezer-Gallon-Bags-with-Grip-n-Seal-Technology-60-Count/281042661

All-purpose tarp= $6.95

https://www.walmart.com/ip/ALL-PURPOSE-TARP-5X7-FINISHED-SIZE-4FT-8IN-X-6FT-6-IN/158580963

3. **Decomposition:**

Teavana Earl Gray Tea Bags (box of 24)= $11.07

https://www.walmart.com/ip/Teavana-SBK12416721-Modern-Earl-Grey-Tea-24-Box/891805172

Teavana Radiant Green Tea Bags (box of 24) = $10.48

https://www.walmart.com/ip/Teavana-SBK12434016-Jasmine-Citrus-Green-Tea-24-Box/377819310

Cotton handkerchief= $9.87

https://www.walmart.com/ip/Solid-White-Handkerchiefs-EEEKit-100-Soft-Cotton-Hankies-13-Pieces-Classic-Pure-Handkerchiefs-Men-Women-Kids-Square-Sheets-Gift-Mother-Father-Daughte/854127057

Birch popsicle stick= $6.98

https://www.walmart.com/ip/100-pcs-Natural-Wood-Popsicle-Sticks-Wooden-Craft-Sticks-Wax-4-1-2-x-3-8-New/101030428

Garden flags= $9.90

https://www.walmart.com/ip/25-Piece-Neon-Orange-Outdoor-Marking-Flags/339930721

Gardening hand trowel= $7.49

https://www.walmart.com/ip/Fiskars-FiberComp-Trowel-100S-Series/16930220

4. Slaking test:

60 mesh screen flour hand sieve= $5.29

https://www.walmart.com/ip/60-Mesh-Screen-Stainless-Steel-Flour-Sieve-Kitchen-Baking-Tools-Durable-Handheld-Screen-Mesh-Strainer-Oil-Strainer-Colander/495885673

Plastic Squeeze bottle= $.98

https://www.walmart.com/ip/Way-To-Celebrate-Squeeze-Bottles/797794747

5. Water holding capacity

Plastic funnel set= $2.39

https://www.walmart.com/ip/Plastic-Funnel-Set/896290952

Cone-shaped coffee filters= $4.38

https://www.walmart.com/ip/Melitta-4-Natural-Brown-Cone-Coffee-Filters-40-Ct/10535001

Empty glass jar= $1.38

https://www.walmart.com/ip/Great-Value-Organic-Whole-Mushrooms-7-oz/55428222

Saran Premium Wrap= $3.19

https://www.walmart.com/search/?query=saran%20wrap

MOBILE PHONE APPLICATIONS
for
GENERAL SOIL INFORMATION and DIY SOIL HEALTH MEASUREMENTS

Icon	Name of Mobile Phone Application	Measurement	Any Additional Hardware Needed	Link to App
	Worm Tracker	Earthworm abundance	None	https://play.google.com/store/apps/details?id=com.ualberta.edu.worms&hl=en_US&gl=US
	Tea Bag Index	Tea decomposition (biological activity)	Tea bags, trowel, 2-place balance	https://play.google.com/store/apps/details?id=com.spotteron.teabagindex&hl=en_US&gl=US
	Micro-BIOMETER	Soil microbial biomass estimate	Starter kit ($135)	https://play.google.com/store/apps/details?id=com.pes.microbiometer&hl=en_US&gl=US
	Nix Color Sensor	Estimate of soil organic matter content	Nix Color Sensor ($99)	https://play.google.com/store/apps/details?id=com.nix.nixsensor
	Slakes	Soil aggregate stability	Stand for phone, Petri dish, lamp	https://play.google.com/store/apps/details?id=slaker.sydneyuni.au.com.slaker&hl=en_US&gl=US
	Visual Evaluation of Soil Structure (VESS)	Description of soil structure	Shovel, white tote or tarp	https://play.google.com/store/apps/details?id=ch.hepia.vess&hl=en_US&gl=US
	LandPKS	Soil information (from SSURGO)	None needed to use, but to input data some materials are needed	https://play.google.com/store/apps/details?id=org.landpotential.lpks.landcover&hl=en_US&gl=US
	SoilWeb	Soil information (from SSURGO)	None	https://play.google.com/store/apps/details?id=com.casoilresourcelab.soilweb&hl=en_US&gl=US

Appendix B. Interview Questions

Interview questions:

1)How do you define soil?

2) Soil health is defined by the NRCS as the capacity of soil to function as a vital living system to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health. What part of parts of this statement most resonate with you and why or why not?
3) Would you share your thought about soil, its importance for you as a gardener and its cultural importance?
4) For you, what make a soil "good"?
5) If you garden or farm, what soil health promoting factors do you use and why?
6) How do you interact with soil everyday?
7) What ways is soil important to you beyond gardening?
8) Who taught you about your cultural ties to soil, and would you share what they taught you?
9) In what ways has soil been incorporated into your culture?
10) Are there soils on your tribal or ancestral lands that are particularly important to you and why?

Appendix C. IRB Approval

Detailed information about requirements for submitting modifications for exempt research can be found on our website. For modifications that require prior approval, an amendment to the most recent IRB application must be submitted in IRBManager. A determination of exemption or approval from the IRB must be granted before implementing the proposed changes.

Non-exempt research is subject to many regulatory requirements that must be addressed prior to implementation of the study. Conducting non-exempt research without IRB review and approval may constitute non-compliance with federal regulations and/or academic misconduct according to ISU policy.

Additionally:

- All research involving human participants must be submitted for IRB review. **Only the IRB or its designees may make the determination of exemption**, even if you conduct a study in the future that is exactly like this study.
- **Please inform the IRB if the Principal Investigator and/or Supervising Investigator end their role or involvement with the project** with sufficient time to allow an alternate PI/Supervising Investigator to assume oversight responsibility. Projects must have an eligible PI to remain open.
- **Immediately inform the IRB of (1) all serious and/or unexpected adverse experiences** involving risks to subjects or others; and (2) **any other unanticipated problems involving risks** to subjects or others.
- **Approval from other entities may also be needed.** For example, access to data from private records (e.g., student, medical, or employment records, etc.) that are protected by FERPA, HIPAA or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **An IRB determination of exemption in no way implies or guarantees that permission from these other entities will be granted.**
- Your research study may be subject to **post-approval monitoring by Iowa State University's Office for Responsible Research.** In some cases, it may also be subject to formal audit or inspection by federal agencies and study sponsors.
- Upon completion of the project, transfer of IRB oversight to another IRB, or departure of the PI and/or Supervising Investigator, please initiate a Project Closure in IRBManager to officially close the project. For information on instances when a study may be closed, please refer to the IRB Study Closure Policy.

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.

IRB 10/2019