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A framework to guide future farming research with Indigenous communities

Tribal Food Systems Research Fellowship

FIRST NATIONS DEVELOPMENT INSTITUTE

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Abstract

We present a framework to guide applied research with Indigenous Peoples. Indigenous cropping systems are relevant to scientifically addressing many of the shortcomings and problems regarding current cropping systems. Indigenous food sovereignty movements are currently preserving and expanding their cropping system food ways. The knowledge underlying these efforts is not static but dynamic, incorporating contemporary tools in ever changing environments. We highlight four principles of Indigenous farming that are reflected in both practice and cultural traditions: polycultures, seed-keeping, sustainability, and community. These principles have been pivotal to the primary author's doctoral research as they collaborate with Indigenous communities in Wisconsin to trial organic farming practices that utilize their traditional values and knowledge. We encourage more applied research in farming and natural sciences that uphold Indigenous ways of knowing as equal to Western science through collaborating with Indigenous Peoples. Researchers should be aware of the implications of research in Indigenous communities, involving the cultural boundaries associated with crops and seeds, which are often not regulated and thus warrant protection. As Western science seeks to find sustainable alternatives to current farming norms, as seen in other areas of land management, we encourage creating shared learning environments between researchers and Indigenous Peoples to foster relevant and equitable outcomes for farming practices.

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Indigenous foods, framework, extension, traditional ecological knowledge, organic, scientific collaborations

Introduction

There have been efforts within Western science to acknowledge and integrate Indigenous perspectives and knowledge systems. Relevance of these efforts has steadily been growing in the natural sciences, as we continue to redefine our relationships with land and the underlying natural processes/resources (Berkes et al., 1994; Menzies, 2006). For example, Western science has begun working to understand the role of Indigenous fire management, helping governmental agencies maintain landscapes, control more destructive and unpredictable fires, and further forestry research (Nikolakis & Roberts, 2020; Wynecoop et al., 2019). Coastal Indigenous Peoples have been integral to research in monitoring and managing fisheries and marine populations (Capistrano & Charles, 2012; Menzies, 2006; A. J. Reid et al., 2021). Indigenous practices and knowledge are currently discussed with regard to stewardship of fauna populations though hunting and conservation efforts (Souther et al., 2023). It is important to note the circumstances underlying reconciliations of knowledge, that Indigenous management practices were suppressed by colonization and subsequent government policies for centuries as a tactic to further remove Indigenous Peoples from their lands, cultural practices, and traditional foods.

Indigenous farming has not seen enough attention to influence mainstream practices. Research about Indigenous farming is presented through historical and theoretical lenses and rarely, if ever, applies current Indigenous food practices in practical research (Doolittle, 1992; Kapayou et al., 2023; Lewandowski, 1987; Mt. Pleasant, 2011, 2015; Mt. Pleasant & Burt, 2010). Compared to modern mechanized farming, Western science makes unfounded and less researched assumptions that traditional or Indigenous farming practices are inefficient and impractical (Acharya et al., 2020; Rahman et al., 2011). Moreover, a complex mesh of political and economic factors upholds the current farming system to impede change, in individual policy or more systemic, while also weakening the line between research and application (Bowman & Zilberman, 2013; Prokopy et al., 2019), further inhibiting support for adoption of Indigenous methods and institutional recognition of these practices (Johnson et al., 2021). Only recently has there been direct contribution from Indigenous farming practices in an applied manner (Kapayou et al., 2023).

In this applied theory essay, we will describe the principles of Indigenous farming and their significance for Indigenous cultures in North America. We will present a framework to guide Western farming research, which encompasses many fields of natural sciences, on how to better integrate this knowledge and science through research collaborations. We then discuss this framework in the context of the primary author's doctoral research, driven by an Indigenous perspective.

Principles of Indigenous Farming and Their Cultural Significance

Currently, Indigenous farming is an expanding effort coinciding with other movements of Indigenous food sovereignty, defined as Indigenous Peoples controlling and maintaining traditional food systems to feed their communities with culturally relevant foods (Coté, 2016). According to the 2017 U.S. Department of Agriculture census of agriculture, approximately 80,000 farms are owned by Indigenous Peoples and there are 60,000 producers; both numbers increased 7–10% from the 2012 census (USDA National Agricultural Statistics Service [USDA NASS], 2017). These numbers represent agriculture as a whole: 75% of the farms specialize in livestock production and only the remaining 25% are crop focused (USDA NASS, 2017). While Indigenous farming exists and has continued to proliferate through Indigenous people maintaining their connection to their land and cultural traditions, as of now the definition of Indigenous farming is only distinct from the modern definition of farming (cultivation of land and growing of crops) as meaning performed by Indigenous Peoples. We feel, however, that the Indigenous worldview that centers a deep and sacred connection to the land deserves to be emphasized, although it may seem broad. Growing crops is

fundamental to knowledge of the environment and our connection to it (Pesantubbee & Zogry, 2021), "Traditional Ecological Knowledge" (TEK), defined as a "cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission" (Berkes, 2018, p. 8). In this essay, we take a broader view of TEK as encompassing multiple domains of Indigenous experience and simply refer to it as Indigenous knowledge (Berkes et al., 2000).

In North America, Indigenous Peoples from different cultures farmed in a diverse range of environments that required various strategies and practices (Hurt, 1987). What allows these traditions to continue across generations are the ties Indigenous Peoples have to the land along with the connection to cultural knowledge they uphold. Connection to the land is interwoven into traditional farming, which emphasizes manual labor such as planting, weeding, and harvesting by hand. We identify four principles of Indigenous farming that are consistent with both historical and contemporary practices along with actual Indigenous worldviews of land stewardship. These principles of polyculture, seed-keeping, sustainability, and community are integral to cultural traditions and offer alternative ways of thinking about many questions and concerns Western scientists have about current colonial-rooted farming practices. Such research should be guided by Indigenous farming practices, informed by Indigenous worldviews, and improved by traditions before post-colonial conventional agriculture. The four principles are important for the subsequent framework we will discuss.

Polycultures

Many crops domesticated in Central and North America are integral to culture and foodways today. Important staples such as corn, beans, and squash are grown by many Indigenous cultures in environments across North America. The common practice known as The Three Sisters, growing corn, beans, and squash together because they nourish and support each other, is a prominent example of companion planting, or polyculture, which has guided farming practices in many cultures. Benefits of polycultures include diverse diet, and current research validates their long-term sustainability (Mt. Pleasant, 2016). Not every culture practices companion planting, or polyculture, exactly the same way as there are variations of the Three Sisters (Mt. Pleasant & Burt, 2010). Historical accounts also describe companion planting practiced as spatial crop diversity, planting mixed fields and not relying upon a strict monoculture crop (Fritz, 2019; Hurt, 1987). There is strong archeological evidence that Indigenous ancestors domesticated and grew vast, diverse crops (Fritz, 2019). Polycultures represent a fundamental difference between Indigenous farming and current colonial-rooted monocultures. Western science has discovered the correlation between the diversity of plant communities and their productivity, a concept researchers want to transition into mainstream farming (Mariotte et al., 2018; Tilman, 2020). Indigenous Peoples proliferated plant communities, rather than post-colonial conventional farming that integrates plant communities in a reductionist practice. A plethora of research shows how polycultures can be more successful than monocultures in terms of productivity and yield (Vandermeer, 1989). Although not all current Indigenous cropping efforts include polyculture consistently, or they may rely on monoculture practices, their values and utility are often engrained alongside traditional methods. Indigenous cropping systems offer a manipulatable system that can help researchers disentangle the ecological factors that influence the success of polycultures. We argue that understanding these systems is relevant to current research on better optimizing diverse cropping systems to meet the needs of a growing population while relying on ecology to reduce reliance on external inputs.

Seed-keeping

Seed-keeping preserves genetic diversity through growing and passing on seeds and the underlying knowledge from generation to generation (Hill, 2017). These efforts have also been called "rematriation," which emphasizes the role of women in Indigenous societies in preserving traditions and knowledge (Herrighty & Hill, 2024). Through sharing and gifting seeds, genetic diversity is intentionally preserved by facilitating mixing seeds within a variety to maintain diversity and prevent cross-

pollination. Preservation of Indigenous varieties may have also allowed unique phenotypes to continue, contrasting with the genetic diversity of current conventional crops lost through decades of breeding that prioritized yield or size. Crop research now investigates the heirloom and wild ancestors of crops for traits lost such as nutrition, resistance to disease, interactions with microbial partners, and ability to withstand harsher climates (Chen et al., 2015; Kumar et al., 2020; Newton et al., 2011; Pérez-Jaramillo et al., 2016; Zsögön et al., 2018).

There are Indigenous concerns about potential corporate malfeasance and academic misconduct involving long-stewarded traditional heirloom seed varieties. Research and genetic modification of heirloom seed varieties without the informed consent or prior knowledge afforded to traditional seed-keepers is known as biopiracy (Reid, 2009). There is little to no regulation and protection for ownership or stewardship of these seeds at any level of government, both tribal and federal. There have been local and international efforts, but nothing consistent across Indigenous North America (McCune, 2018).

Indigenous Peoples exercising the right to food sovereignty tend to resist the ideas of Western ownership that allows people or entities to own living organisms, considering living organisms to be kin. A seed could easily end up in the hands of researchers or even companies just through informal means of passing ownership such as gifting. This situation gives no incentive for researchers to follow regulations or create measures to protect Indigenous seeds. Without regulation, there could be subsequent research on these crops that is not sanctioned by the Indigenous owners. Attempting to mine the data and knowledge stewarded by Indigenous Peoples would be unethical without providing them informed consent or agreement. This is why we emphasize collaborative efforts that build relationships and trust. A seed is only part of a whole system, made up of its genetic material, the Indigenous Peoples who have cultivated them for centuries, and the land that provides for their existence. Seed research requires input from the Indigenous Peoples who have stewarded them for centuries along with the very land they cultivate (Herrighty & Hill, 2024; Nazarea, 2005). Research should be cautious and documented to ensure equitable outcomes for the Indigenous Peoples involved. Incorporating Indigenous values and practices more aligned with traditional ways could help democratize farming practices and instill relationship-based collaborations between Indigenous Peoples and researchers that could help to reverse centuries of harm.

Sustainability

A common thread that connects Indigenous people of the past to the future is land stewardship. We develop an understanding of our cultural knowledge through land stewardship; it becomes one's duty to preserve our environment to ensure future generations can further cultural knowledge. The goal of Indigenous farming is to create a balance that sustains land to ensure that future generations can grow crops and continue cultural knowledge. Indigenous Peoples have been in witness to the pollution and land degradation consequent to genocide and removal of stewardship. Certain cultural practices have become largely inaccessible and a large body of cultural knowledge has been lost. Indigenous Peoples in North America are subsequently at the forefront of many environmental movements as they understand that much of their cultural identity continues to be at stake. Like other people of color, they find themselves among the most affected by negative environmental outcomes (Fernández-Llamazares et al., 2020).

We emphasize these points to support the idea that Indigenous people who farm will tend to align themselves with sustainable practices and options. Explorers and early colonists noted that Indigenous Peoples were not afflicted with land problems such as soil fatigue and erosion—major issues for today's farmers (Doolittle, 1992; Hurt, 1987; Mt. Pleasant, 2011). Practices such as controlled burnings and soil structures like mounds and ridges altered the landscape, and crop rotation allowed for optimal nutrient cycling and less intensive cultivation of land. Tillage done by hand did not have the same negative effects as large-scale machinery tillage. In the experience of the primary author's research on the norms of contemporary Indigenous growers, chemical inputs such as herbicides and

especially pesticides are avoided. The primary author also notes that land farmed by Indigenous Peoples with a history of non-Indigenous cultivation often requires major investments to rebuild soil fertility to better support sustainable and productive farming. A significant research effort would be to establish long-term management plans for utilizing fertilizers, a current necessity that could be mitigated through sustainable practices such as cover crops. Many of these practices align with what Western colonized farming defines as organic, sustainable, or conservational. These sustainable alternatives naturally coincide with the Indigenous farming ethos and would be fertile ground for future collaborations. Many Indigenous growers mirror Western ideas of sustainability and are experimenting with some contemporary tools while being wary of others that are seen as harmful. We believe Indigenous voices should be uplifted in sustainable farming as the goals and outcomes align.

Community

Practices such as seed-keeping, planting, weeding, and harvesting are tied to cultural knowledge. Colonial-rooted farming sees manual labor as inefficient, but overlooks the knowledge sharing that happens during these traditional practices. Much of the labor in Indigenous farming systems is still done by hand by multitudes of people, the foundation of traditional farming. Current literature on Indigenous food sovereignty emphasizes the health benefits from not just healthy foods, but from physical farm (Jernigan et al., 2023). Farming smaller acreages would make incorporating manual labor in practices such as planting, harvesting, and weeding possible while facilitating the associated cultural knowledge. According to the 2017 USDA census, the percentage of Indigenous-owned farms of 1–10 acres is 25%, almost double the national average (13%). (USDA NASS, 2017). This trend has been confirmed from personal experiences and in the literature on current Indigenous farming (Johnson et al., 2021). Growing acreages of 1–10 acres would become more feasible with multiple people and/or a community effort utilizing manual labor along with farming machinery.

Although we hesitate to generalize about all Indigenous cultures in North America, we cannot ignore the role women have in many cultures that revolve around seed-keeping and crop domestication (Blue Bird Jernigan et al., 2021; Fritz, 2019; Herrighty & Hill, 2024). In the USDA 2017 census, 44% of Indigenous producers are women, notably higher than the 36% of American producers that are women (USDA NASS, 2017). This trend is relevant because it indicates the important role of Indigenous women within communities and foods systems. It is important to note that working in agriculture is already demanding physically and mentally. Women are often also faced with already disproportionate and unpaid domestic labor; ignoring how women's labor is integral to the system would only further perpetuate the effect that the unpaid and unrecorded labor of women lends to bad health outcomes (Seedat & Rondon, 2021). Indigenous women are leading most food and seed sovereignty efforts today, a stark contrast to post-colonial white male-dominated farming (Pilgeram et al., 2020). We must acknowledge that there are Black Indigenous people, and Black American farmers who have an unbroken lineage of land stewardship sharing a sacred connection to the land evolved through farming, seed-keeping and historical crop domestication (Ruffin, 2010). In fact, there are similarities between this framework and principles in the agroecology of African American cropping systems (Densu, 2010). There are also similarities in the struggles for land access, funding, and representation against systemic racism that still affect BIPOC farmers today (Buechler, 2022; Carpenter, 2012). Traditionally, farming is a community effort, which many food sovereignty movements emphasize as there are benefits ranging from culture revitalization to positive health outcomes. Research should understand the community aspects of these collaborations, when relevant, and address the needs and questions of communities and growers.

A Framework for Future Crop Research

We present a framework consisting of the four principles of Indigenous farming: polycultures, seed-keeping, minimal impact on land, and community. The purpose of the framework is to guide applied farming research asking quantitative ques-

tions, which can pertain to many fields such as plant sciences, microbiology, soil sciences, and environmental sciences (Table 1). The four principles may not apply to every Indigenous cropping system, but one or more principles will be relevant and/or reflected in cultural traditions that need to be sustained. The principles allow researchers to be aware of traditional practices and the associated cultural boundaries and expectations of Indigenous farming. We define cultural boundaries in this paper in the context of relationship-building and participation in Indigenous food system, in this case, to understand Indigenous cultures and the activities that reinforce the relationship to agriculture. The principles we previously defined as the framework act as cultural boundaries for scientists to respect and integrate within their research.

When conducting research that will be working with Indigenous Peoples either to preserve or expand Indigenous cropping systems, these principles can guide researchers. For example, research on methods utilizing pesticides and herbicides may not likely align with the goals of Indigenous farmers. And if researchers want to grow traditional seed varieties on campus or at a research station, there are ethical considerations needed alongside discussion with Indigenous Peoples to obtain informed consent. If researchers have these principles in mind when building relationships, there can be more direct discussions and planning for collaboration and research. Researchers will not have to spend time in a back-and-forth with Indigenous Peoples attempting to understand why their research is not relevant to the needs of Indigenous Peoples. Research must become a social endeavor because growing food in Indigenous communities is a social endeavor. In contrast to previous methods such as community-based or action participatory research, this framework is a different practical application, creating scientific partnerships as opposed to studying Indigenous people as passive subjects. This framework reinforces research *with* Indigenous Peoples rather than research about and partly informed by Indigenous Peoples.

Introducing a framework for research on Indigenous cropping systems is important because there is currently little guidance or regulation by institutions. Any current regulation works in tandem with regulations on research with humans. For example, Kapayou et al. (2023) investigated the Three Sisters effect on soils at different sites with Indigenous partners across the Midwest. The research team created an advisory board to guide their work on the Iowa State University campus

Table 1. Framework for Indigenous Farming

	Principles of Indigenous Farming			
	Polyculture	**Seed-keeping**	**Sustainability**	**Community**
Definition	Indigenous Peoples often grew various crops spatially together. These practices have continued and allow opportunities to trial other forms of contemporary polycultures.	The intentional preservation of traditional seed genetics over generations. These crops are sacred and require permission and oversight from their stewards.	Sacred connection to land through stewardship. Indigenous Peoples are often at the forefront of environmental movements and practices.	Indigenous Peoples working together to preserve traditional food systems. Often there is an emphasis on manual labor- heavy practices connected to cultural traditions.
Recommended application for research	How do diverse cropping systems (traditional or contemporary) function and what ecological principles drive success?	Can these ethically sourced crop varieties guide breeding practices and foster important crop traits?	How can we better monitor and optimize sustainable outcomes with alternative farming practices?	How to help preserve and maintain Indigenous food systems that are linked to many cultural, economic, and environmental outcomes?

To facilitate all principles in research, there need to be:

- Formal agreements or regulation (MOUs, IRBs, etc.)
- Acknowledgment of historical power dynamics and institution's current relationship with Indigenous Peoples
- Data sovereignty to ensure that Indigenous Peoples have ownership and say in how data is published and further distributed

and subsequent on-farm experiments run by their Indigenous partners (Kapayou et al., 2023). Concurrent with these efforts there were ethnographic studies conducted through interviews, that had to be cleared from their Institutional Review Board (IRB), in order to better understand perspectives on Indigenous foodways held by their research partners (Kapayou et al., 2023). IRBs represent an institutional regulation meant to protect human research subjects and the researcher. Another regulation is the Institutional Animal Care and Use Committee (IACUC), which does the same for animal research. The regulation for plant research, however, is mainly implemented when working with plant diseases or genetically engineered plants to ensure containment (Miller et al., 2009; Wolt & Wolf, 2018). This is representative of the Western colonial-rooted view of plants as organisms for which ethical protections are generally unnecessary, which directly clashes with many Indigenous worldviews that uphold plants as kin. There has been discussion at the international level about the methodology for utilizing sources of biodiversity such as plants for research, but such discussion have not occurred in the U.S. with Indigenous people (David, 2018). Researchers trained in natural sciences tend to be strictly quantitative and often lack training in the ethics or historical implications of their work.

To emphasize the stewardship of Indigenous lands, we encourage efforts to participate in the community, which can take the form of on-farm research. This facilitates protecting seed genetics and cooperating with supportive cultural traditions, and helps researchers gauge first-hand the capacity and needs of the Indigenous growers. Observations that stem from actual environment and management practices can benefit research. Consistency in observations hold more scientific weight than if performed in a more controlled environment away from the Indigenous community. In the case of agricultural research, these observations lead directly to practical agronomic outcomes while laying the groundwork for future research that can better untangle mechanisms in a more controlled environment. Such insightful data can help facilitate sharing of knowledge between Western science and Indigenous community efforts.

As with all research with Indigenous Peoples, there are ethical considerations and cultural boundaries that must be acknowledged and addressed. Western research, since its inception on Indigenous lands, has commanded a presence conducting research in order to analyze as well as to document beliefs and traditions (Smith, 2012). Research worked in conjunction with colonization, providing the inadequately developed narratives about Indigenous people with a credibility that only served to justify genocide and assimilation (Drawson et al., 2017; Smith, 2012; Wilson, 2008). As a response, the field of Indigenous Studies developed so as to shift the narrative back to Indigenous Peoples, through research conducted amongst themselves and by developing methodology for future research (Wilson, 2008). Due to the lack of Indigenous scholars in many fields of research, many ethical considerations and cultural boundaries were not even acknowledged and had to be developed. For example, in the fields of medical and genomic research, Indigenous researchers have sought to ethically diversify data pools with Indigenous Peoples (Boscarino et al., 2022; Claw et al., 2018; Tsosie & Claw, 2020; Tsosie et al., 2020). Much research on Indigenous Peoples had not been held to high cross-cultural ethical standards or led by Indigenous Peoples, leading to tension between researchers and Indigenous communities in general (Garrison, 2013; Smith, 2012). For this framework, we advise collaborating with the Indigenous perspective by situating Indigenous Peoples not as the subject, but rather as research partners in investigating natural processes and how to optimize farming practices. Collaboration should validate that Indigenous people have continued to practice traditional knowledge of farming methods that should be considered as worthwhile as conventional farming. They should also make note that at one time, pre-colonization, the Indigenous way of farming was the conventional farming of the land.

The four principles are relevant to the many issues and questions in modern colonial-rooted farming that Western science is attempting to address. The prominence of monocultures in conventional farming has had direct and indirect negative effects on environmental quality, leading to the perception that modern farming is not sustainable

(Hossain et al., 2020; Reay et al., 2012). Monocultures facilitate the use of herbicides, pesticides, heavy fertilization, and tillage that damage biodiversity. Prioritizing uniformity and yield through monocultures has reduced genetic diversity, causing loss of traits vital for nutrition and other ecological functions (Falke et al., 2013; Meyer & Purugganan, 2013). Researchers have long advocated for breaking the monoculture norm and increasing crop diversity through space (intercropping, interseeding cover crops) and time (cover cropping, rotations) (Mariotte et al., 2018; Tilman, 2020). The four principles of Indigenous farming provide insight into these issues with relevant data, oral histories, and perspectives all from the very same lands we farm today. Indigenous growers may be more open to trialing sustainable practices that need more data to be determined to apply on bigger scales. As climate change continues to put insurmountable pressure on cropping systems, we must utilize all tools to both reduce reliance on greenhouse gas-based solutions and create ecological resiliency.

This framework also seeks to address the power dynamics between research institutions and Indigenous Peoples. Race and equity has been an intensifying significant topic in academia; in the last five years discourse has been galvanized into action as a result of the COVID–19 pandemic, the George Floyd protests, and the current pushback on DEI initiatives (Dorn et al., 2020; Meikle & Morris, 2022). Racial inequity has also driven discussions about how research institutions have currently and historically interacted with Indigenous Peoples. For example, the roles of land-grant institutions, often at the cutting edge of agricultural research, have been interrogated as directly benefiting from the genocide and dispossession of Indigenous Peoples (Ahtone et al., 2024; McCoy et al., 2021). This forms a stark imbalance in the power dynamics that operate within the already tenuous relationships Indigenous Peoples have with scientific research. Research needs to also address the needs of Indigenous Peoples in the post-colonial state by understanding the underlying systemic obstacles against them, beginning with acknowledgement of these power dynamics. We find this especially relevant for progressive farming research, with Indigenous Peoples still struggling for both access to land and capacity and support to steward their lands. This framework emphasizes the sharing of knowledge, especially of data between Indigenous communities and research institutions.

The discussion of data sovereignty in Indigenous research often emphasizes protecting data relating to health, language, and other cultural knowledge (Marley, 2019; Rainie et al., 2017). This puts current research on Indigenous agriculture more on a trust basis, as there is little institutional incentive or infrastructure to make agreements regarding this type of research. Even simple and formal agreements such as memorandums of understanding (MOUs) are not presented as initial ideas from the administration of research institutions. We argue that institutions need to make a concerted effort to ethically source seeds in collaboration with Indigenous Peoples. The act of knowledge sharing, especially through gifting or sharing seeds, is fundamental to the Indigenous way of life. However, the unfortunate truth is that research institutions have broken the trust of Indigenous Peoples, to the point that they advocate more for protections and regulation of their knowledge and data (Garrison, 2013). As discussed before, crops and other natural resource data are not considered protected by regulation on both ends—research institutions and, often, Indigenous communities—so that research institutions need formal agreements that will honor the goals and wishes of Indigenous Peoples regarding their data. Some Indigenous nations do have their own IRBs that oversee all research, including on crops, but IRBs require resources and expertise not all nations can manage. We argue that it is best to place leading responsibility for IRBs on research institutions (Hull & Wilson, 2017).

Framework in Practice of Primary Author's Doctoral Research and Methodologies

The primary author of this paper is currently a doctoral student at the University of Wisconsin-Madison in the department of plant pathology. In 2019 they began research collaborating with Ohe·láku (Among the Cornstalks), a farming co-op on the Oneida Reservation (Stevens & Brewer, 2019; Webster, 2023). Ohe·láku as a group is inter-

ested in incorporating organic practices alongside their traditional methods to improve soil health and reduce weed pressure as they expand their corn systems. Associated with soil health is their interest in how belowground microbes are influenced by their changes in management practices. To address their interest and needs, the primary author and his co-advisors, Dr. Erin Silva and Dr. Rick Lankau, developed a project in which different mixtures of cover crops were interseeded between the rows of the traditional White Corn; changes in the below-ground microbial community composition were observed. Although the primary author's research background is in quantitative analysis of plants and microbes, without initial experience conducting research with Indigenous communities, his own Indigenous background guides the direction of the research and relevant cultural awareness.

This interest in implementing interseeding into a long term and reduced-tillage management system created an intriguing intersection between contemporary practices and Indigenous knowledge. The Oneida people have a strong connection to the Three Sisters practice, but the manual labor and time needed to maintain a larger field of Three Sisters is not currently feasible due to time constraints and obligations of community members. Interseeding cover crops between rows of corn has been suggested in order to yield outcomes analogous to the Three Sisters traditions, such as weed suppression, lowered disease threats, and addition of organic matter to the soil similar to the intercropping practice of the Three Sisters. These outcomes emphasize the long-term sustainability goals of Ohe·láku in their efforts to heal soils on their lands while continuing their farming traditions. The focus on interseeding is combined with traditional practices such as hand harvesting, minimal tillage (with the goal of no-till), and disregard for pesticide and herbicide options. Ohe·láku has worked to adequately fertilize soils, from both conventional and organic sources, to ensure corn and cover crop productivity while adding nutrients to a soil drained from previous non-Indigenous stewardship via conventional farming practices. The downstream goal is to further reduce fertilizers and rely more on the cover crop benefits as a way to mitigate current regional issues with overfertilization and water pollution (Puckett, 1995).

The success and feedback from our initial years of relationship building has helped in expanding this work to other Indigenous food efforts in Wisconsin. Although these other efforts could not be implemented as experiments for the primary author's dissertation, they laid the groundwork for future efforts. The years of relationship building and connecting with different Indigenous partners allowed better gauging of the needs of Indigenous producers in Wisconsin and how the University of Wisconsin could support their efforts directly. Association with obtaining a doctoral degree gave an incentive for this research to continue for around five years despite ongoing events such as the COVID-19 pandemic. In the experience of the primary author, many Indigenous collaborations involving crop research before this project, and subsequent efforts, were often short-term and not well-documented within the academy. This revealed the ignorance about how scientifically relevant current Indigenous food systems are and how the university could work to help preserve and maintain them.

The primary author advocated for building trust between Indigenous Peoples and the University of Wisconsin, the need for which highlights the importance of this research. To address data sovereignty, the primary author is working with university administration to create a Memorandum of Understanding (MOU) that would allow Indigenous partners to own their data, share co-authorship on eventual publications, and ensure that samples and data collected are not used outside the scope of the project. Institutional regulation for this type of Indigenous crop research, focused solely on quantitative methods, is inadequate if it does not include some aspect of humans as part of the research questions. It is the first time the administration has considered anything like this, as there has not been any research project like this, and the hope is to set a precedent for future research. Since a MOU is a non-legal binding agreement, we the authors hope for required future agreements that protect Indigenous Peoples and ensure researchers and the university are aware of cultural boundaries. As this effort is already outside the scope of a plant

pathology doctoral student, we hope just that these efforts have at least established the idea among administration and other researchers.

The primary author's research is located at the University of Wisconsin-Madison, one of the land-grant institutions that benefited from the genocide and removal of Indigenous Peoples through land sales when they were created through the Morrill Act (Ahtone et al., 2024; McCoy et al., 2021). Even more heinous is the physical placement of the institution on an area known as Teejop to the Ho-Chunk people, where effigy mounds are found both intact and disturbed throughout the campus (Birmingham & Rosebrough, 2017; YoungBear-Tibbetts, 2009). This is a constant reminder for Indigenous Peoples on campus and gives more urgency to institutional efforts to reconcile these atrocities with Indigenous Peoples.

The goal of this research is to support Indigenous communities and their food sovereignty efforts, a restorative justice approach. We have provided financial support, resources, shared knowledge, and labor support through the research that has built stronger relationships between the university and Indigenous communities. As of the writing of this paper, there has been an increase in funding from a Sustainable Agricultural Systems Coordinated Agricultural Project. from the USDA at the University of Wisconsin-Madison that focuses directly on supporting Indigenous food systems. Part of the grant's goal is to increase the number of Indigenous graduate students working on Indigenous food systems at the University of Wisconsin-Madison, giving hope that current research will continue and more communities with various needs and research interests can be supported.

Concluding Thoughts and Future Questions

In this applied theory essay, we present a framework to guide applied farming research to collaborate with Indigenous people. The principles of Indigenous farming are polycultures, seed-keeping, minimal impacts on land, and community, all of which have a role in guiding research questions to be practical and culturally appropriate while addressing current challenges faced by Western science to make farming more sustainable. We want to cultivate applied scientific collaborations that directly address the needs and questions of Indigenous Peoples rather than theoretical approaches. We uphold the notion that the localized and experiential knowledge from Indigenous Peoples is equal to Western science. Phrases such as "we need to support and acknowledge Indigenous knowledge" tend to not encompass the idea of also supporting the Indigenous people themselves (Kimmerer & Artelle, 2024). This is because the knowledge held by Indigenous Peoples is often treated as a single independent entity. From the perspective of the secondary author, Western institutions absolve themselves from failing to include Indigenous people in more complete background research, not fostering shared collaboration, as well as continuing to perform as the pre-eminent authority for validation.

As Indigenous people, we are often asked how Western institutions can be better informed about Indigenous Peoples. The purpose of this framework is to provide an introduction to Indigenous farming practices and their cultural significance. We acknowledge that many researchers in the natural sciences are not trained to collaborate with marginalized communities or to understand the history of Indigenous North America peoples. By describing the principles and associated cultural boundaries, we hope to foster feasible and fruitful collaborations that tackle relevant scientific questions that can be answered by the principles of Indigenous cropping systems. Just as Indigenous scholars are trained in Western scientific methodology, we encourage Western researchers to learn more about ways of Indigenous science. In agriculture and natural science there currently are few Indigenous scholars, which is part of why these discussions and projects have not come to fruition. It is often left to the Indigenous scholars in these fields to advocate for such projects.

Scientific research has unlimited potential when combined with Indigenous knowledge. We recommend a model of informed scientific collaboration rather than a process that is one-sided and extractive. If scientists are indeed supportive of integrating all relevant knowledge into a functional paradigm, they should appreciate that Indigenous knowledge is a science with a more local and com-

munity-involved way of asking questions and solving problems. Mainstream science attempts to take an "unbiased" and objective position, whereas experience and unique perspectives directly inform Indigenous knowledge.

Science is challenged to understand how to transform current food systems while reversing many of the harmful trends created by scientific innovations, while navigating climate change to find more efficient and sustainable practices. What we are presenting here is another way of viewing the system to better unravel many the issues of our cropping systems. This can also be viewed as an new method of adding to our shared knowledge base to further scientific research. Collaboration and mutual education, joining the resources of scientific institutions and the sovereignty of Indigenous Peoples, can be a source of restorative justice for the land.

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