CORN IN THE UPPER MIDWEST: FARMERS' PERCEPTIONS AND STRATEGIES FOR MANAGING ON-FARM GENETIC DIVERSITY

by

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Abstract

Debates about the genetic diversity of cultivated crops have riled the scientific community. While there is growing scholarship on measuring genetic diversity among crop types in the United States, less research focuses on measuring on-farm genetic diversity. More specifically, there is a clear and distinct lack of research measuring on-farm genetic diversity in U.S. corn (*Zea mays*) today. The literature shows that three common inbreds, B73, Mo17, and A632, are present in the parental background of an alarming percentage of commercial hybrids commercially available (Coffman et al., 2019; Mikel & Dudley, 2006; Smith, 1988; van Heerwaarden, Hufford, & Ross-Ibarra, 2012). With approximately 90 million acres of field corn planted in the U.S. annually, it's imperative to understand the genetic diversity of the varieties most grown in farmers' fields. Restrictive intellectual property policies largely prohibit farmers and researchers from knowing specific genetic backgrounds of field corn hybrids. Given the majority of corn producers in the Upper Midwest do not have access to genetic background information of the seed they purchase, what are their perspectives and strategies for managing on-farm genetic diversity in their corn crop? I conducted twenty exploratory interviews with corn growers throughout Illinois, Iowa, Michigan, Minnesota, and Wisconsin, about their farming practices, and perceptions and strategies for managing diversity on their corn acreage. Interviewees had a wide range of farm size and practices. This data is not generalizable, but salient points provide better understanding of farmers' roles and perceptions about on-farm genetic diversity. These include measuring surface level diversity by planting multiple varieties each year, issues of seed relabeling, importance of relationships with seed dealers in making variety selection decisions, and perceptions that other farmers are not managing on-farm diversity in corn. The data and analysis show a need for further research about the options farmers have in making decisions about their on-farm genetic diversity and the role of seed companies in managing germplasm diversity in the marketplace.

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Chapter 1. Introduction

It hasn't always been like this. Though a drive through Iowa today with a view of corn uniform in height and stature as far as the eye can see, peppered with squat white windowless hog buildings makes it hard to imagine what it was before or could be again.

Today ninety percent of the global human population's food energy relies on just fifteen crops. Three crops make up two-thirds of that, including corn, wheat, and rice (Food and Agriculture Organization [FAO], 2015). There have been strong trends toward narrowing crop species diversity in the United States over the last thirty years (Aguilar et al., 2015). This trend and reliance on monoculture cropping systems is particularly acute in the case of U.S. corn production.

Monoculture is a cropping system wherein a farmer cultivates a single crop over an extensive area. Annually, approximately 90 million acres of corn are planted in the U.S., representing about 28 percent of the annual principle crop acres (approximately 302 million) according to the USDA's National Agriculture Statistics Service. These acres are largely concentrated in the Upper Midwest region, where over 48 million acres of corn were harvested in 2017 (United States Department of Agriculture [USDA], 2018). This region includes Illinois, Indiana, Iowa, Michigan, Minnesota, Nebraska, North Dakota, South Dakota, Ohio, and Wisconsin. Three major markets absorb corn in the region: animal feed, ethanol production, and industrial uses. A small amount is used for direct human consumption. (Capehart & Proper, 2019).

"Corn is King" in the Upper Midwest (Roesch-McNally, Arbuckle, and Tyndall, 2018) and blankets much of the agricultural landscape. And its "queen" is unarguably soybean (Hatfield, Cruse, & Tomer, 2013). A staggering seventy percent of the region's cropland is planted to a corn-soybean rotation or continuous corn (USDA, 2018). These farmers are answering former Secretary of Agriculture Earl Butz's famous 1970s call to "get big or get out" and federal policies continue to provide the course.

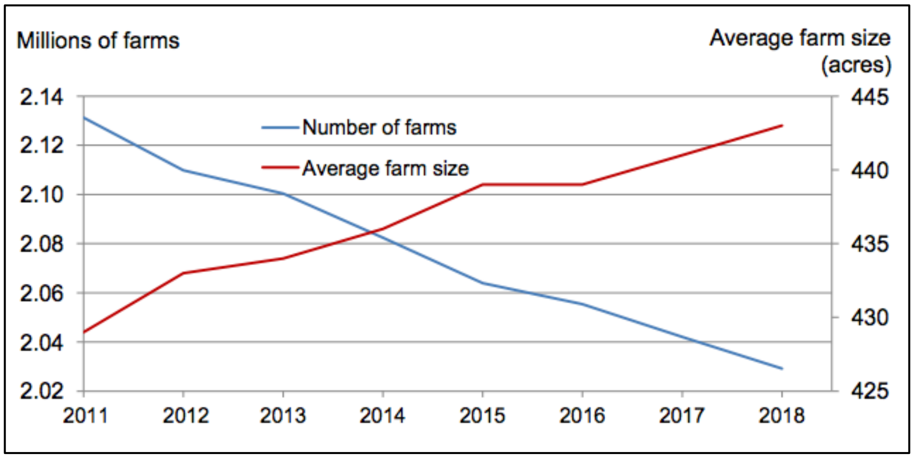

Figure 1. Number of U.S. farms and average farm size from 2011 through 2018. From: United States Department of Agriculture, 2019.

Getting big is precisely what is occurring in U.S. agriculture today. Consolidation throughout the sector is deepening and producing a landscape with increasing farm size and decreasing number of farms [Figure 1] (USDA, 2019). Corn and soybeans are the two major drivers of the U.S. agricultural economy (Roesch-McNally et al., 2018) and are factors in consolidation trends throughout the agricultural sector.

1.1. Making of a Monoculture: Corn as Far as the Eye Can See

The image below [Figure 2] offers a glimpse into the diverse cropping systems of Iowa's past and the extreme change in landscape that occurred over a relatively short time period. The image on the left shows a 9-square-mile aerial image of an Iowa farmscape in 1953 with several crops planted (Keller & Brummer, 2002). Each shaded block is a crop in the field and taken together the patchwork of shades shows a diverse system. These blocks are likely corn, winter wheat, oats, pasture, hay or pasture, and soybean. The image on the right of the same landscape in 1999 shows a starkly different story. The sections labeled “C” are corn and those labeled “B” are soybeans. What was once a landscape of five or six crops is now predominately two: corn and soybean. The red Xs indicates abandoned farmsteads (Keller & Brummer, 2002).

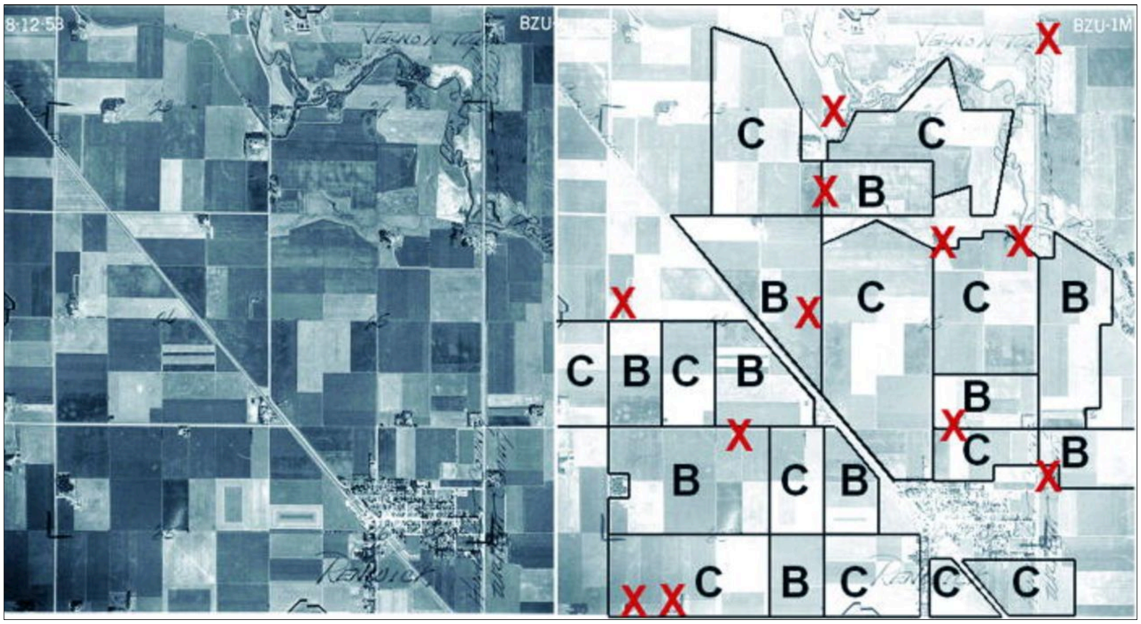

Figure 2. Cropping system change snapshot in Humboldt County, Iowa. From: Keller & Brummer, 2002.

The importance of measuring and preserving biodiversity for resilient ecosystems and food security is echoed throughout all sectors of agriculture – in farmers’ fields, in seed banks, among policy writers, and within seed companies. DuPont, now Corteva, one of the largest agricultural chemical and seed companies in the world which is often criticized for its role in the industrial agriculture system that perpetuates monocultures, had a position statement on biodiversity on their website (DuPont, 2013).

A recent study by Aguilar et al. (2015) illustrates strong trends toward narrowing crop species diversity in the U.S. from 1978 to 2012. It shows that crop diversity and reliance on monoculture production is particularly acute in the case of U.S. corn production in the Upper Midwest. Despite alarms about the risks associated with narrowed diversity, Upper Midwest farmers continue to practice monoculture. Some farmers are fighting to diversify their landscape and markets while others continue the status quo despite the warnings from researchers and scientists. Why is this? There are multiple interrelated factors underpinning the corn monoculture in U.S. agriculture. To better understand this, we must tease out the factors that produce this landscape.

Upper Midwest farmers working to diversify the landscape are, like the markets they serve, rare. They are working on a landscape and a market bound to monoculture. They are present none-the-less, increasing plant species and within-species diversity on their fields. Roesch-McNally, Arbuckle, and Tyndall (2018) illustrate several barriers to diversified cropping systems in the Upper Midwest, including the predominance of corn on the landscape, lack of markets, loss of livestock from the farming system in the region, and high cost of land.

Over the last thirty years the Upper Midwest region has radically transformed (Roesch-McNally et al., 2018). A driving factor in this transformation is federal policies incentivizing farmers to invest in a production-oriented agricultural system that rely on intensive production, heavy inputs, and commodity markets. The result is what Carolan and Stewart (2016) define as the “high yield production regime” (p. 82). Policies and federal subsidies are intended to support farmers and lessen financial risk. However, policies that support one particular species have inevitably reduced crop biodiversity (Di Falco & Perrings, 2005; Hatfield, Cruse, & Tomer, 2013).

The 2015 study by Aguilar, et al. looked at changes in crop species diversity in the U.S. from 1978 through 2012. Their work shows a trend towards decreased crop diversity. It also shows that the Midwest contains the lowest amount of crop diversity in the country. Their findings suggest that changes in cropland diversity have not been linear. Upper Midwest cropland did not go from very diverse to very narrow in one straight line. Instead their data indicates that while crop diversity is clearly trending towards a homogenized landscape, it has ebbed and flowed throughout regions [Figure 3] (Aguilar et al., 2015). This suggests that farmers' decisions on what to plant are not the only factor developing the landscape. Instead capital is entering and exiting the area based on federal farm programs, corporate investments, and market opportunities, as well as farmers' decisions. The production of corn monoculture is multi-faceted and the Aguilar et al., (2015) findings of ebb and flow in diversity richness on the landscape reflect this.

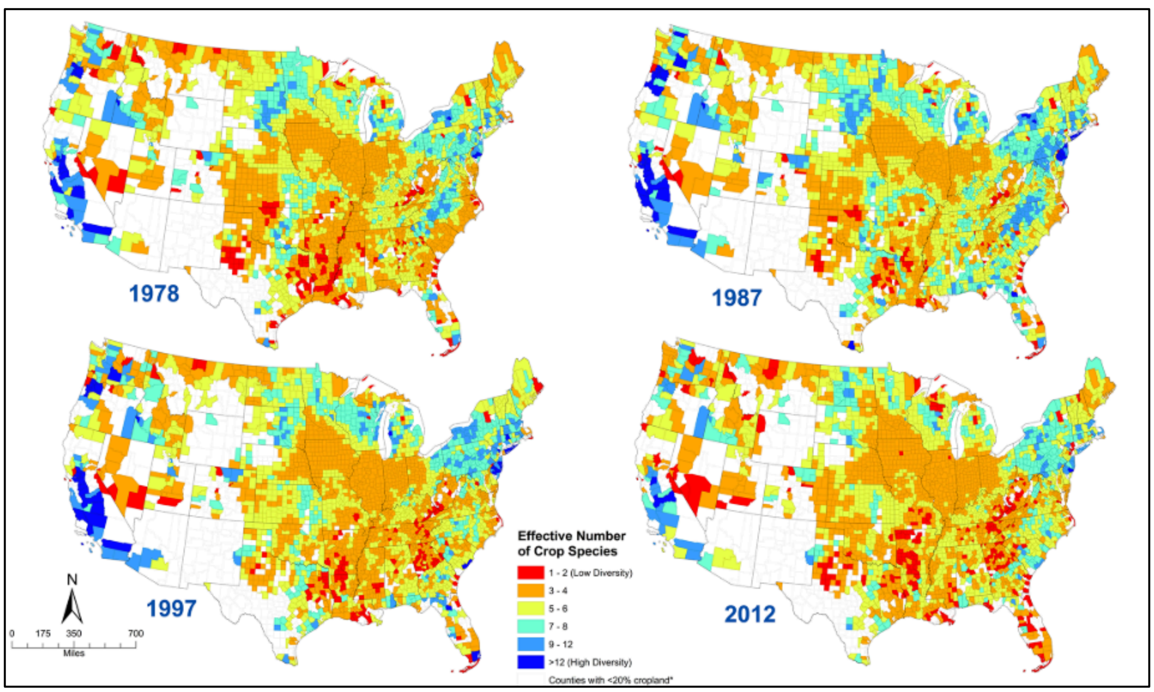

Figure 3. Snapshots of changes in crop diversity on U.S. cropland: 1978, 1987, 1997, and 2012. Crop diversity is the narrowest in the Upper Midwest though changes have not been linear. From: Aguilar et al., 2015.

Planting one species on the landscape exposes farmers to biological and climatic risks, and negatively affects water quality (Hatfield, Cruse, & Tomer, 2013). The National Resources Conservation Service promotes crop rotation and crop diversification as a conservation practice to farmers. Agronomically, increasing plant diversity increases soil quantity and quality, water and air quality, and reduces pests and diseases (Gaudin, et al., 2015; Hatfield, Cruse, & Tomer, 2013; USDA, n.d.). Today farmers have the added struggle of increased intensity and frequency of weather events resulting from climate change. Projections suggest that corn and soybean yields will decline with the increasing temperatures, drought, and severe storms in the region (Gaudin, et al., 2015; Hatfield, Cruse, & Tomer, 2013; Melillo, Richmond, & Yohe, 2014).

But just how monoculture is the corn monoculture on the Upper Midwest landscape? We need to go another layer deeper in how we measure diversity, and that's within the crop species.

1.2 Open-Pollinated to Hybrid Corn: Trading Diversity for Predictability

The most pertinent categories for measuring genetic diversity in corn in the Upper Midwest are parental and regional (National Academy of Sciences, 1972). Parental diversity refers to the genetic background of the hybrid parents and their inbreds. Regional diversity considers how many different varieties of corn are being planted in a given area, e.g. across one farm, five farms, the state, watershed, region, et cetera (National Academy of Sciences, 1972).

U.S. regional diversity of on-farm corn acres drastically changed with the shift from open-pollinated to hybrid varieties (National Academy of Sciences, 1972). Prior to the broad adaption of hybrid corn in the 1930s and 1940s, farmers planted open-pollinated corn. According to Martin and Leonard (?), there were over 1,000 different corn cultivars grown throughout the U.S. in the early 1900s (1967). Early in developing hybrid corn, plant breeders selected popular open-pollinated varieties that were widely adapted to the region to develop inbred lines for hybridization. This original selection and self pollination of open-pollinated plants began a narrowing in genetic diversity that today's hybrid development is built upon (Ho, Kresovich, & Lamkey, 2005).

The first hybrid corns were developed and commercialized in the 1920s. These varieties were largely tailored to the Upper Midwest region though farmers were slow to adopt them, instead continuing to plant open-pollinated varieties (Wych, 1992). Anecdotally, severe droughts of 1934 and 1936 drove farmers to rapidly adopt corn hybrids because the plants performed well in the drought conditions. From then farmers' adoption of corn hybrids and industry growth grew exponentially in the 1930s and 1940s both in size and in regionality (Hallauer, Russell, & Lamkey, 1988; Wych, 1992). By 1960, ninety percent of U.S. corn was planted to hybrids (Bruns, 2017).

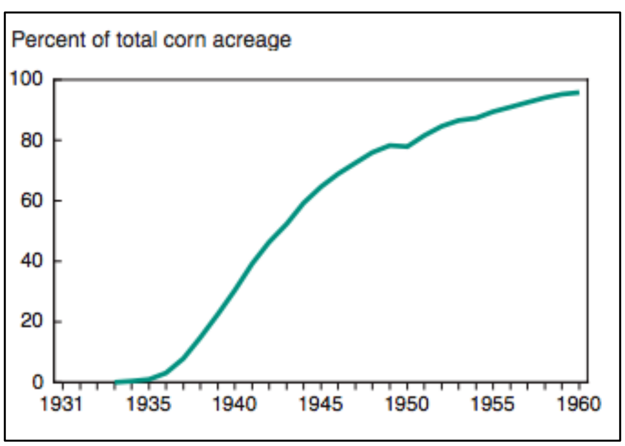

Figure 4. Adoption of hybrid corn in the U.S. from 1931 to 1960. Farmers were slow to adopt hybrid corn seed when it was first commercialized in the 1920s. From: Fernandez-Cornejo, 2004.

The early benefits of hybrid corn to farmers were uniformity and standability. The uniformity and standability of hybrids allowed for easier mechanical harvestability and paved the way for large-scale mechanized harvesting. Uniformity also provided more predictability in plant behavior and yield. This uniformity also allowed breeders more predictability in progeny performance, aiding in inbred and hybrid corn development (Duvick, 1975; Fernandez-Cornejo, 2004; Goldman, 2000; Wallace & Brown, 1988; Wych, 1998).

Hybrids are the progeny of crossing inbreds, or "parents." Plant breeders develop an inbred by the iterative process of self-pollinating individual plants from a variable population and selecting among the progeny. The selected progeny are self-pollinated and the process is repeated for five or six generations of self-pollination, until homozygosity is achieved. The progeny of this new inbred are both homozygous, meaning there is no genetic variation within the individual, and homogeneous, meaning that all plants in the population are genetically identical (Hallauer, Russell, & Lamkey, 1988; Hughes & Henson, 1957; Shull, 1909; Shull, 1910; Wallace & Brown, 1988). Unlike open-pollinated varieties, F_1 hybrids are genetically uniform because they share the same inbred parents. Genetic diversity in a region is also tied to the number of different types of hybrids grown by farmers in a geographic range (National Academy of Sciences, 1972). Narrowed on-farm diversity opens farmers up to varied environmental and economic risks, and a narrowed genetic base puts the crop at risk to new pathogens and insects (National Academy of Sciences, 1972).

1.3 Southern Corn Leaf Blight Epidemic: Case in Point

U.S. corn growers in the 1970s experienced firsthand the risks that come along with monoculture cropping and on-farm genetic vulnerability. In 1970 and 1971 nearly 15 percent of U.S. corn was destroyed by an epidemic of southern corn leaf blight (*Bipolaris maydis*). Some growers reported losing their entire crop and growers in the Midwest averaged a loss of 30 to 50 percent of their corn crop. The economic impact was a loss of ~$1 billion or the equivalent of ~$6 billion today (Bruns, 2017), devastating to the agricultural community.

The epidemic was the result of corn monoculture on the landscape coupled with narrow genetic diversity in corn seed. A new strain of southern corn leaf blight flourished on a landscape blanketed with hybrid corn containing the Texas male sterility (*cms*-T) cytoplasm. *Cms* is caused by a natural mutation in the chloroplast genome, thus cytoplasmic, that causes male sterility in plants with T cytoplasm. While likely known among campesinos for some time, U.S. plant breeders first described plants with the mutation in Mexico in the early 1900s (Bruns, 2017). Plant breeders and researchers in the U.S. looked for ways to utilize the male sterility mutation for easier hybrid corn seed production.

A single corn plant contains both male flowers (that produce pollen containing sperm) clustered in the tassel and female flowers (each containing one egg) on the ears. Modern single cross hybrid corn seed is produced using two genetically different inbred parents – an inbred designated as the male and an inbred designated as the female are cross-pollinated and the progeny is an F_1 hybrid. Normally, both parents produce fertile anthers and eggs. Prior to *cms*-T hybrid seed corn companies would detassel (remove the tassel which produces pollen) the female plants to so the females could not pollinate themselves. Instead all the eggs on the female ears would be fertilized by the sperm from the male plants. Only seed from the female rows would be harvested and sold as seed. This method ensured the resulting seed would be the proper cross (Levings, 1993; Rogers and Edwardson, 1952). Detasseling is a laborious process both in function and in time spent. Plant breeders developed a process to breed *cms*-T (male sterility) into female parents which resulted in a plant producing tassels that did not produce functional pollen. Such plants were unable to pollinate themselves or plants nearby and did not need to be detasseled manually (Rogers & Edwardson, 1952). This simplification of production led hybrid seed corn companies to widely adopt the practice (Bruns, 2017).

In 1970 between seventy and ninety percent of U.S. hybrid corn contained *cms*-T. That year a relatively new strain of southern corn leaf blight entered the U.S. and the climate was perfect for the growth of the pathogen and widespread infection. The presence of *cms*-T made the plant extremely susceptible to the new pathogen strain (Bruns, 2017). Researchers, seed companies, and farmers may not have been able to predict the devastating impacts of this particular vulnerability or the weather conditions that allowed for widespread infection. But they could have predicted the risk of monoculture cropping coupled with narrowed and uniform corn genetics.

Cms-T offered hybrid corn seed producers efficiency and decreased costs of production. The rational decision in a capitalist system was of course to adopt the technology widely (Kloppenburg, 2004; Magdoff, 2015). This created a large geographic area planted to corn varieties susceptible to the southern corn leaf blight. Economically speaking the epidemic was the result of capital producing monoculture on the landscape and the landscape producing capital.

In some ways the epidemic also generated economic opportunities for corn hybrid seed companies and redistributed capital geographically. The following year hybrid seed corn prices increased because the supply of inbred lines not containing *cms*-T was low and demand was high. Some companies bolstered their supply by producing seed for non *cms*-T hybrids that winter in Hawaii, Florida, the Caribbean, and Central and South America. Companies also imported non *cms*-T seed from eastern Europe. The imported seeds were not particularly well adapted to the Midwest and did not produce good yields the following year (Ullstrup, 1972).

Researchers from multiple agricultural sectors demanded that lessons be learned to avoid repeated events in the future. Fresh on the heels of the epidemic A.J. Ullstrup (1972) of the Department of Botany and Plant Pathology at Purdue University wrote:

> Emerging and developing nations, especially those whose agriculture is dependent on only a few crops, will be wise to learn from the example of the SCLB [southern corn leaf blight] epidemics in the United States how important it is to diversify their agriculture and maintain adequate genetic (and cytoplasmic) diversity in their major crops. This is the first and most important lesson to be learned. Never again should a major cultivated species be molded into such uniformity that it is so universally vulnerable to attack by a pathogen, an insect, or environmental stress. Diversity must be maintained in both the genetic and cytoplasmic constitution of all important crop species. (p. 46).

That same year the National Academy of Science appointed a committee to focus on genetic vulnerability in U.S. crops which published the *Genetic Vulnerability of Major*

Crops report. The report confirms Ullsrup's concerns about the risk of narrow genetic base on the landscape (National Academy of Sciences, 1972) and identifies three major factors that led to narrowed diversity of corn on the landscape: farmers' abandonment of open-pollinated varieties for hybrids based on yield superiority; changes in technology; and methods used for hybrid corn seed production, i.e. *cms*-T (National Academy of Sciences, 1972).

The report also discusses the role of the Iowa Corn Yield Test in farmers choosing hybrids over open-pollinated varieties and the narrowing of diversity on the landscape. The first test was conducted in 1920 and compared yield rates of varieties that had been submitted by farmers throughout the state. Findings were published and showed significant differences in yields among the open-pollinated varieties tested. The authors cite this and similar yield tests conducted in other states as a probable factor in farmers choosing to plant varieties based on yield potential rather than on-farm diversity. Results also provided data about promising varieties for developing hybrids (National Academy of Sciences, 1972). The yield-motivated decisions by farmers to widely adopt hybrids, uniformity of production, and benefits of specialization were ways in which capital produced the corn monoculture on the Upper Midwest landscape in the early part of the 20^{th} century.

The rapid and widespread adoption of hybrid corn by U.S. farmers in the 1930s and 1940s provided seed companies two important commercial advantages, both of which were related to the biology of the technology (Fernandez-Cornejo, 2004). First is simply, that the progeny of F_1 plants are genetically different from the F_1 parent and from one another. This meant that farmers could not save seed and replant F_1 hybrids and achieve the same genetic expression the next season, allowing companies a baseline of proprietary control over the seed. The second advantage for companies was that the progeny were also lower yielding, meaning the yield advantages from hybrid decreased generation to generation. These together meant that farmers had to purchase seed each year (Fernandez-Cornejo, 2004).

The privatization of and restrictive intellectual property policies of the present-day seed industry make it challenging to know whether corn seed genetics are diverse enough to mitigate risk of a similar outbreak. Parental background in hybrid corn seed is highly proprietary and tightly held. Three common inbreds, B73, Mo17, and A632, are present in the parental background of an alarming percentage of commercial hybrids sold today (Coffman et al., 2019; Mikel & Dudley, 2006; Smith, 1988; van Heerwaarden, Hufford, & Ross-Ibarra, 2012). We also know that about 66 million acres of corn were planted when southern corn leaf blight hit in 1970 and today approximately 90 million acres are planted, largely in the Upper Midwest.

1.4 Research Motivations in Corn Internationally: Outside the Vacuum

Before I present research that has been conducted in the Upper Midwest that focuses on measuring genetic diversity in corn, I want to explore the research motivations for measuring on-farm genetic diversity outside of the U.S. In particular in Mexico because of the amount of research focused on this region and its relationship to corn. My interest in doing so is to understand if there are differences in research motivations and how this relates to the U.S. context of my research. Further, the approximately 90 million acres of corn produced in the U.S. annually does not exist in a vacuum, making it important to assess salient research justifications for measuring or monitoring on-farm genetic diversity in corn internationally.

Researchers are striving to track global trends in losses of crop species diversity to address concerns for the associated loss of ecological stability and global food security (Khoury et al., 2014). Less of this research focuses on measuring in species on-farm genetic diversity, in particularly in corn. The importance of corn to global food security cannot be understated. Recent estimations show that it provides "30% of food calories to approximately 4.5 billion people in 94 developing countries" (Bellon et al., 2018). Crop centers of domestication, such as corn in Mexico, serve as genetic reservoirs for the future of humanity (Bellon & Berthaud, 2004; Birol, Villalba, & Smale, 2009). Understanding the agricultural, biological, and social systems that underlay crop genetic diversity are important for assessing the role of farmers in on-farm diversity and crop evolution (Strombert et al., 2010; Bellon, Gotor & Caracciolo, 2015; Bellon, Dulloo, Sardos, Thormann, & Burdon, 2017; Bellon et al., 2018).

1.4.1 Research in Mexico

Most major crops were domesticated between 10,000 and 4,000 years ago. In the case of corn, Neolithic people domesticated maize from its wild relative teosinte about 9,000 years ago in southern Mexico (Matsuoka et al., 2002). Farmers and gardeners selected new varieties as they moved corn north and south. The people selected varieties adapted to new environments, pest pressures, and human uses. They created strains adapted from what is now southern Canada to northern Argentina and from the lowland tropics to the high Andes resulting in a broad genetic base (Flint-Garcia, 2013).

In many domestic centers of origin, genetic diversity is at its highest concentration today. This is true for corn in Mexico, where smallholder farmers continue to select their local varieties for adaptation to changing climate, management, and uses. (Bellon et al., 2018) Thus creating a reservoir of broad genetic resource for ongoing agricultural needs. Nature is not static. Essentially campesinos – smallholder farmers managing family farms producing, at least partially, for self-consumption, relying mostly on family labor – select and maintain a corn genetic reservoir for the rest of the world (Bellon, Gotor, & Caracciolo, 2015). One of the most often stated research justifications for measuring and monitoring on-farm genetic diversity of corn in Mexico is the conservation of genetic resources for future breeding. Crop centers of biological diversity, such as Mexico in the case of corn, are essential resources for new germplasm.

Farmers and plant breeders need sources of rich with genetic diversity where they can find new germplasm to improve crop quality. They also need sources of germplasm to adapt to changing climates and production environments, and be resistant to biotic and abiotic stress (Smale, Bellon, & Aguirre Gómez, 1999; Birol, Villalba, & Smale, 2008). The need for ongoing breeding and the importance of conserving the genetic resources of corn as a resource for doing so is required for global food security (Badstue et al., 2007; Birol et al., 2008).

Campesinos in Mexico are the stewards of corn genetic resources today – the centers of ongoing evolution of the crop. According to Bellon et al. (2018), "*Campesinos* are heirs to, and trustees of, the largest genetic diversity of corn in the world, which they maintain in their agricultural systems today" (p. 2). The ongoing evolution of corn and the maintenance of landrace genetic diversity in Mexico take place largely in farmers' fields and through informal seed exchange that exists at the foundation of campesino agricultural systems (Bellon et al., 2018). There is a call among the research community for increased understanding of the dynamics of these farmer-to-farmer corn seed exchanges and its effects on gene flow and diversity (Badstue et al., 2007; Bellon, Dulloo, Sardos, Thormann, & Burdon, 2017; Bellon et al., 2018).

Smallholder farms, that is farms less than or equal to 5 hectares or slightly more than 12 acres, make up the largest land base of corn production in Mexico (Bellon et al., 2018) and campesinos are conserving its genetic diversity through their "informal" seed systems. These systems do not rely on annual seed purchases as an input, but rather on farmers saving and sharing seed year to year. Through this system, alleles are passed from generation to generation, "continuing the evolutionary processes that sustain and generate crop genetic diversity" (Bellon et al., 2018).

These informal seed systems are not only maintaining and preserving genetic diversity in corn but also adding to it. Bellon et al. (2018) illustrate that on-farm corn genetic diversity is at an all time high because of the scale at which campesinos are maintaining diversity. This highlights the irreplaceable role campesinos have in ongoing corn evolution as an *evosystem service*, defined as "the uses or services to humans that are produced from the evolutionary process" (Bellon et al., 2018).

Despite their importance, there is little research, understanding, or documentation of the role campesinos in maintaining corn genetic diversity and its evolution in Mexico. There is a loud call for more research to support these farmers in their on-farm conservation work, particularly in documenting their part in ongoing evolution and how it influences and creates genetic diversity needed for the future (Badstue et al., 2005, 2007;

Bellon et al., 2017). A deeper understanding of this process would also lead to better infrastructure and support for smallholder farmers practicing on-farm conservation. It is not just the seed that is passed from farmer to farmer and generation to generation, but along with it the traditional knowledge about the local varieties (Badstue et al., 2007; van Heerwaarden, Hufford, & Ross-Ibarra, 2012; Fenzi, Jarvis, Arias Reyes, Latournerie Moreno, & Tuxill, 2017; Bellon et al., 2018). The cultural and sociological dimensions are essential components of these informal seed systems and must be part of future research.

Some researchers argue that, while *ex situ* conservation is an important component of global food security, on-farm conservation is integral to ongoing evolution in corn and other crops (Bellon et al., 2017). Each time seeds are grown, selection for adaption for the immediate environment, pest pressures, and current uses occurs. Conversely, *ex situ* seeds are but a “frozen snapshot” (Bellon et al., 2017). This is a strong argument for the importance of on-farm conservation to the future of corn genetic diversity in Mexico.

As a global staple crop, corn in Mexico has been a major focus for crop improvement and new varieties (both hybrid and open-pollinated) are grown throughout the country today. The call from the research community to better understand how the introduction of new technologies might be impacting genetic resources was amplified when transgenic DNA was found in Mexican corn landraces. Quist and Chapela (2001) found introgressed transgenic DNA in corn landraces sampled from remote mountains in Oaxaca. While Mexico placed a ban on growing transgenic corn in 1998, data suggests that introgression events are somewhat common (Quist & Chapela, 2001). The report resulted in a widespread call from the research community to understand the implications of diffusion of transgenic DNA into traditional seed systems such as farmer-to-farmer seed sharing and the effects on genetic resources (Bellon & Berthaud, 2004; Birol, Villalba, & Smale, 2008; van Heerwaarden, Hufford, & Ross-Ibarra, 2012). Similar tests of landraces from the same area just four years after Quist and Chapela's report did not show the same results, sparking heavy debates in the research community (Soleri, Cleveland, & Aragón Cuevas, 2006).

There is consensus that transgenic DNA is present in some informal seed systems, regardless of whether introgression has occurred (Soleri, Cleveland, & Aragón Cuevas, 2006). Tests conducted by the Mexican government in 2002 confirmed the presence of transgenic DNA in landrace fields (Fitting, 2006). At that time, researchers began asking if and how particular transgenes might affect the fitness of introgressed landraces. Of particular concern was, do transgenes designed to withstand biotic and abiotic stresses, have a competitive advantage relative to traditional varieties and if so would they damage traditional seed systems (van Heerwaarden, Oretega Del Vecchyo, Alvarez-Buyyla, & Bellon, 2012)? There remains a need to assess the biological implications of transgenic genes in the crop's center of origin, domestication, and biological diversity (Fitting, 2006).

The presence of transgenic DNA in landraces in Mexico is in part a result of trade liberalization that launched with the North American Free Trade Agreement (NAFTA) in 1994. Researchers have also focused on the sociological implications of transgenes in Mexican corn landraces. There is concern in the research community that trade liberalization, migration, and lacking investment in smallholder Mexican farmers might be driving those stewarding genetic diversity from their land (Fitting, 2006; Soleri, Cleveland, & Aragón Cuevas, 2006).

NAFTA changed the existing agricultural tariff and import policies, and had direct effects on smallholder corn growers. The new trade policy allowed corn imports from the U.S. and drastically affected the price of corn in Mexico. Though policy makers planned a 15-year transition to the new tariff and import laws, changes were much more rapid (Nadal, 2000). "Between January 1994 and August 1996 domestic corn prices fell by 48%, thereby converging with the international market some twelve years earlier than provided for under NAFTA, and forcing Mexican corn producers into rapid adjustment" (Nadal, 2000). This was in part because at the time NAFTA was implemented, the Mexican government ignored the tariff quota that was planned for the transition and allowed all grain imports to come through tariff-free (Nadal, 2000).

This sparked researchers to ask how the larger context of the "neoliberal corn regime," might be affecting the social aspects of biodiversity. Elizabeth Fitting (2006) coined this term and defined it as "the series of recent policies associated with the ideology of neoliberal globalization, including NAFTA, which prioritize market liberalization, trade, agricultural "efficiency," and the reduction of state serves over domestic corn production." Genetic erosion in corn landraces may be imminent if traditional farmers are driven to off-farm employment and migration due to drastic changes in trade policies. This trend could result in a disruption of the knowledge transfer about corn production and the stewardship of genetic diversity from one generation to the next (Birol, Villalba, & Smale, 2008). The concern about implications on corn genetic diversity is due to the "extremely close interactions" between social diversity and genetic diversity, so that “genetic erosion takes place through the displacement of people and the destruction of social institutions that enable diversified production systems based on a wide variety of landraces” (Nadal 2000).

Despite the drastic tariff and import changes from NAFTA and the early concerns among the research community that the impacts on genetic diversity could be quick and severe, more recent studies show that smallholder corn producers continue to be present on the landscape. Orozco-Ramírez and Astier (2017) looked at additional processes in Mexico that may be leading to genetic erosion, including modernization in agriculture, importation of cheap corn, changes in regional crop cultivation, and social conflicts, among others. Their data suggests that the richness of diversity has stayed constant over the past 10 years. They attributed the “strength of the ‘culture of corn’” to the resiliency smallholder corn producers have had in the face of neo-liberalization (Orozco-Ramírez & Astier, 2017). This assessment is in line with the Bellon et al. (2018) findings, suggesting that campesinos continue grow corn and steward its evolution despite the implementation of NAFTA.

1.4.2 International Research Outside of Mexico

There is far less research on on-farm genetic diversity of corn outside Mexico. This could be due in part that while corn landraces exist outside of Mexico, they are largely concentrated there. It could also be due to the reliance on corn germplasm in Mexico for global cultivation, making research there a priority. Despite the importance of traditional varieties in Mexico for ongoing evolution, the review of research conducted in the country shows a lack of research investment into the relationship between on-farm conservation and ongoing evolution. It is reasonable that there would be even less research focused outside the center of genetic diversity.

The most salient research justifications for outside Mexico focus on similar needs as in Mexico-focused research. These include the need to recognize the importance of corn landraces, assess the amount of diversity on the landscape, conserve existing landraces, identify landraces for future breeding, and understand informal seed systems and their role in conserving diversity. While traditional varieties are predominant on the Mexican landscape, they are found on many continents today, including Africa, Asia, Europe, and North and South America (Prasanna, 2012). One of the salient justifications given by researchers analyzing diversity outside of Mexico is the need to utilize these traditional varieties as genetic pools for future breeding. This is in line with similar research focused in Mexico. However, before corn landraces can be tapped for future breeding, their genetic characteristics and levels of diversity must be characterized (Vigouroux et al., 2008; Prasanna 2012).

Prasanna (2012) argues that because corn was spread throughout the world centuries ago, smallholder farmers throughout the world have been doing what campesinos in Mexico have been doing for thousands of years. He varies somewhat on the call from Bellon et al. (2018) to identify the role these farmers play in ongoing diversification, calling instead for research to focus on developing systemic methods to utilize genetic diversity of landraces throughout the world (Prasanna, 2012).

The cultivation of corn throughout the world has led to the breeding of many different lineages throughout time and space (Vigouroux et al., 2008). These new varieties have distinct genetic, physiological, and agronomic characteristics, and have been stewarded by smallholder farmers year after year (Vigouroux et al., 2008). This suggests vast genetic diversity outside of Mexico is yet to be understood both from an evolutionary standpoint and a present day assessment of diversity quality. Badstue et al. (2007) and Fenzi, Jarvix, Arias Reyes, & Latournerie Moreno (2017) cite the potential of new enhanced varieties to outcompete landraces and erode genetic diversity, both biologically and socially. Research focused outside of Mexico has identified the need to identify the quality of diversity due to these same concerns (Vigouroux et al., 2008).

Researchers have also identified a gap in research in measuring and monitoring on-farm corn genetic diversity in Peru. This is somewhat surprising considering Peru is a secondary center of diversity for corn (Stromberg, Pascual, & Bellon, 2010). Corn has been cultivated throughout the country for millennia and is significant to Peruvian culture (Stromberg, Pascual, & Bellon, 2010). It is an important staple crop throughout the Peruvian Amazon (Stromberg, Pascual, & Bellon, 2010).

As in Mexico, research focuses on better understanding the social, cultural, and economic conditions that support the informal seed systems in Peru (Stromberg, Pascual, & Bellon, 2010). Researchers argue that these seed systems are essential to conserving and expanding corn genetic diversity throughout the country (Stromberg, Pascual, & Bellon, 2010). Stromberg, Pascual, & Bellon (2010) note that discussions about the importance of these informal seed systems for farmers' access to seed is largely absent in the literature and argue this is because the research and extension community in Peru ignore on-farm genetic diversity and conservation (2010). This gap in the literature still exists and others are calling for similar efforts.

Researchers in Serbia, where corn has been cultivated for centuries, have also identified the importance of informal seed systems to genetic diversity on-farm. Serbian researchers argue that landraces throughout the country are declining at an alarming rate (Knežević-Jarić, Prodanović, & Mattias, 2014) and attribute this to farmers adopting new high-yielding and hybrid varieties, replacing the landraces previously grown. This trend has triggered a call to focus research on regions throughout the country, particularly where farmers have yet to adopt new commerical varieties, with the purpose of preserving landraces. Like in Mexico and Peru, Serbia-focused research has identified the need to understand the social, cultural, and economic factors impacting corn genetic diversity. And in particular, the agronomic and cultural diversity that has led to the preservation of landraces in some rural regions (Knežević-Jarić, Prodanović, & Mattias, 2014).

1.5 Measuring Genetic Diversity on U.S. Corn Acres: Snapshots in Time

There is a clear and distinct lack of research measuring on-farm genetic diversity in U.S. corn. A bulk of the early research was conducted and published by Donald Duvick in the 1970s and 1980s. Duvick was a private sector corn breeder who spent most of his career with Pioneer Hi-Bred Company where he retired as the Senior Vice President of Research. His research offers a snapshot into genetic pools and diversity in the company during his time there over thirty years ago.

In 1975 Duvick published on the importance of genetic diversity and uniformity to corn breeders and presented examples from Pioneer Hi-Bred Company germplasm pools to illustrate the broad genetic base used to develop their hybrids. Duvick noted that many of the company's high-performance inbreds had four major inbreds in their background: Wf9, B37, B14, and Oh43 (Duvick, 1975). He argued that the additional parental contributions to these inbreds may be extremely diverse (Duvick, 1975). Going back further in the breeding history, he cited that the company used 160 inbreds to create the hybrids for sale at that time, and that these 160 inbreds could be traced back to 33 open-pollinated varieties and nine synthetics (Duvick, 1975).

Duvick made an important comment about the hybrid offerings in 1975 – the difference between offerings and sales. He noted that some inbreds are relied on more than others and that 90% of their sales in 1975 depended on only 40 of their inbred lines. While these 40 inbred lines still had broad genetic base according to Duvick, sales were driving a relatively small number of inbreds to a large number of acres (1975).

The National Academy of Sciences reported that in 1970, 26% of all U.S. corn acreage had B37 in its background (1972). Duvick cites the 1970 figure and argues that while this is a large percentage of acreage with overlapping background, the odds of disastrous susceptibility to a disease or pest in B37 were low at the time and that these hybrids would not be equally susceptible because of varied background percentages (Duvick, 1975).

The National Academy of Sciences' findings showed that 70.6% of all U.S. corn acres were planted to six public lines. These included C102 (4.2%), Oh43 (11.7%), B14 (8.6%), B37 (25.7%), W64A (13%), and A632 (7.4%). What is worth noting is the increase in the use of B37 and W64A in a relatively short period of time. The Academy's data shows a 23.3% increase in use of B37 between 1964 and 1970 and a 12.1% increase in use of W64A in that same six-year period (National Academy of Sciences, 1972). This appears to be indicative of Duvick's comment about the difference between a seed company's offerings versus seed company sales.

Much of Duvick's writing around this time circles back to the National Academy of Sciences' *Genetic Vulnerability of Major Crops* published in 1972 as a response to the southern corn leaf blight epidemic that ravaged corn growers across the U.S. In 1981, he conducted a survey of U.S. crop breeding program directors that focused on their assessment of genetic diversity in their programs. This was done as a follow-up to the 1972 report from the Academy to understand what plant breeders were doing to "alleviate the problem of genetic vulnerability" (Duvick, 1984). From this data, Duvick concluded that genetic vulnerability, while important and dangerous, did not pose a threat to U.S. field crop production at that time (1984). The survey also indicated that the genetic base in field crop production was broader in 1981 than it had been in 1970 at the time of the epidemic (Duvick, 1984).

Duvick made an important distinction of *diversity in time*, referring to cultivar offerings being changed. These new catalogue offerings may be very closely related to what they replaced, however. Without knowing the genetic background of the inbreds, it is not possible to assess the differences. Duvick's 1981 survey data showed drastic changes in use of B37 between 1970 and 1979 – from 26% of the U.S. corn acres to 2%. During that nine-year period B73 was released and widely adopted along with Mo17. Mo17 was released in 1964 and planted to 12% of the U.S. corn acres in 1979. B73 was released in 1972 and planted to 16% of the corn acres in 1979 (Duvick, 1984). His survey data also showed a trend in breeders cultivating phenotypically similar cultivars, narrowing genetic diversity, and predicted this will continue (Duvick, 1984).

These surveys along with others conducted in the 10 to 20 year period after the southern corn leaf blight epidemic focused solely on popular or most used public lines, however. Stephen Smith (1988) argued that these assessments are not representative of the germplasm diversity in the U.S. because they do not include privately available lines. Smith, who at the time worked in the Department of Research Specialists at Pioneer Hi-Bred International, showed that in 1979, 74% of U.S. hybrid maize included one or more private lines and that this number had risen to 92% by 1984 (1988). This lack of private hybrid lines in diversity analysis coupled with Duvick's prediction that breeding will continue trending towards phenotypic uniformity in similar cultivars spurred Smith's 1988 survey. He cited the need to compile data for farmers so they can make informed choices about hybrid selection that will allow profitability and spread risk (1988).

Smith's 1988 survey included 138 hybrids, of which 98 were proprietary brands widely offered in the U.S. Corn Belt. His data shows that 40% of the private hybrids tested were unique and only 25% of the foundation seed company hybrids were unique (Smith, 1988). The survey also found that 60% of the proprietary hybrids had one of three inbred lines as their major genetic background: B73, Mo17, or A632 (Smith, 1988). Circling back to Duvick, it is important to note that Smith's analysis is of *available* hybrids, not what was actually planted. This could likely mean that diversity on the farm was even more narrowed than what companies were offering.

There is a noticeable gap in attempts to survey on-farm genetic vulnerability in corn between the late 1980s and early 2000s, which may be related to intellectual property restrictions on seed. In 1970, the federal government passed the Plant Variety Protection Act (PVPA) that allowed breeders to protect their germplasm, though largely corn breeders did not utilize this until the early 1980s (Mikel & Dudley, 2006). Then in 1985, the U.S. Patent and Trademark Office allowed corn inbreds and hybrids to be patented (Mikel & Dudley, 2006). These protections restrict research on privately held lines, including genetic analysis on diversity and pedigree background.

Today, the majority of proprietary corn hybrid lines are protected under U.S. patent and/or the PVPA (Mikel & Dudley, 2006). Proprietary lines protected by PVP expire (ex-PVP) and become available to the public for breeding and research after 20 years (Mikel & Dudley, 2006). Mark Mikel and John Dudley at University of Illinois surveyed the genetic lineage of the 908 inbreds with expired PVPs that had been protected during the period of their study. The germplasm surveyed was from four companies, Dekalb Genetics, Holden's Foundation Seeds, Pioneer Hi-Bred International, Inc., and Syngenta. This represented 80% of protected germplasm and 90% of hybrid corn being sold at the time (Mikel & Dudley, 2006).

Their survey found that of the 43 inbred lines with the most patent "hits," three are public founder lines: B73, A632, and Mo17 (Mikel & Dudley, 2006). Of these three founder lines, B73 received the most patent hits of any commercial or public line and it is the pivotal contributor to all Stiff Stalk lines surveyed (Mikel & Dudley, 2006). Mikel and Dudley concluded that breeders were largely recombining the most elite lines to develop new products and that this would likely decrease genetic diversity over time (2006). Mikel and Dudley's research is a snapshot of germplasm diversity from 20 years before their publication and 34 years prior to this paper being written.

In 2012, Joost van Herwaarden, Matthew Hufford, and Joffrey Ross-Ibarra (2012) analyzed the diversity, ancestry, and selection effects on the North American corn genome. They used germplasm from the USDA's National Plant Germplasm System and divided the accessions into four eras: early landraces, inbreds from before 1950, public inbreds from the 1960s and 1970s, and commercial inbreds from the 1980s and 1990s that had come off PVP (van Herwaarden, Hufford, & Ross-Ibarra, 2012). They found that the modern heterotic groups are derived from one common landrace population. In line with Mikel and Dudley's findings, their data shows that while breeding efforts created differentiation among breeding pools, breeding consisted of intermating elite and closely related inbreds and selecting among the progeny resulting in decreased diversity in the ancestry of individual lines (van Herwaarden, Hufford, & Ross-Ibarra, 2012). Though more recent, the 2012 findings again only show us a snapshot of diversity 20 years ago.

Coffman et al. (2019) conducted a high-density haplotype analysis on 212 maize inbreds to understand the haplotype sharing between ex-PVPs and major founding lines (2019). Their findings show that 81.6% of the ex-PVP genome is shared with one of the 12 founder lines [Figure 5]. Further, their data shows that 59.6% of the ex-PVP genome is shared with just three lines: B73, Mo17, and Ph207 (Coffman, et al., 2019).

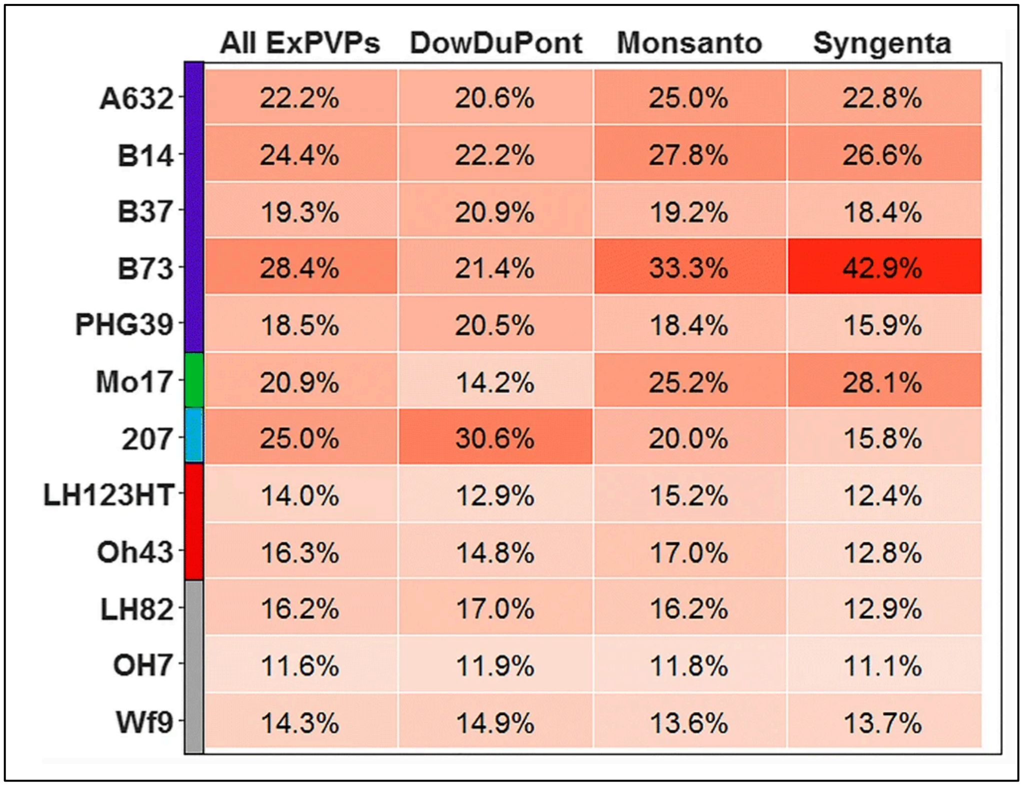

Figure 5. Haplotype sharing between ex-PVP and 12 founder lines as owned by company. Founders on the y-axis are sorted and colored by heterotic group: Stiff Stalk is purple; Non-Stiff Stalk is green; Iodent is blue; and Oh43 is red; and gray are unassigned groups. From: Coffman el al., 2019.

Three companies own the 157 ex-PVPs that Coffman et al. analyzed: Corteva (DowDuPont), Bayer (Monsanto) and Syngenta (Chem-China) (2019). Within these three companies, B73, Mo17, and 207 share haplotypes with ex-PVPs in 53.0% of DowDuPont germplasm, 62.9% of Monsanto's, and 69.7% of Syngenta's (Coffman et al., 2019).

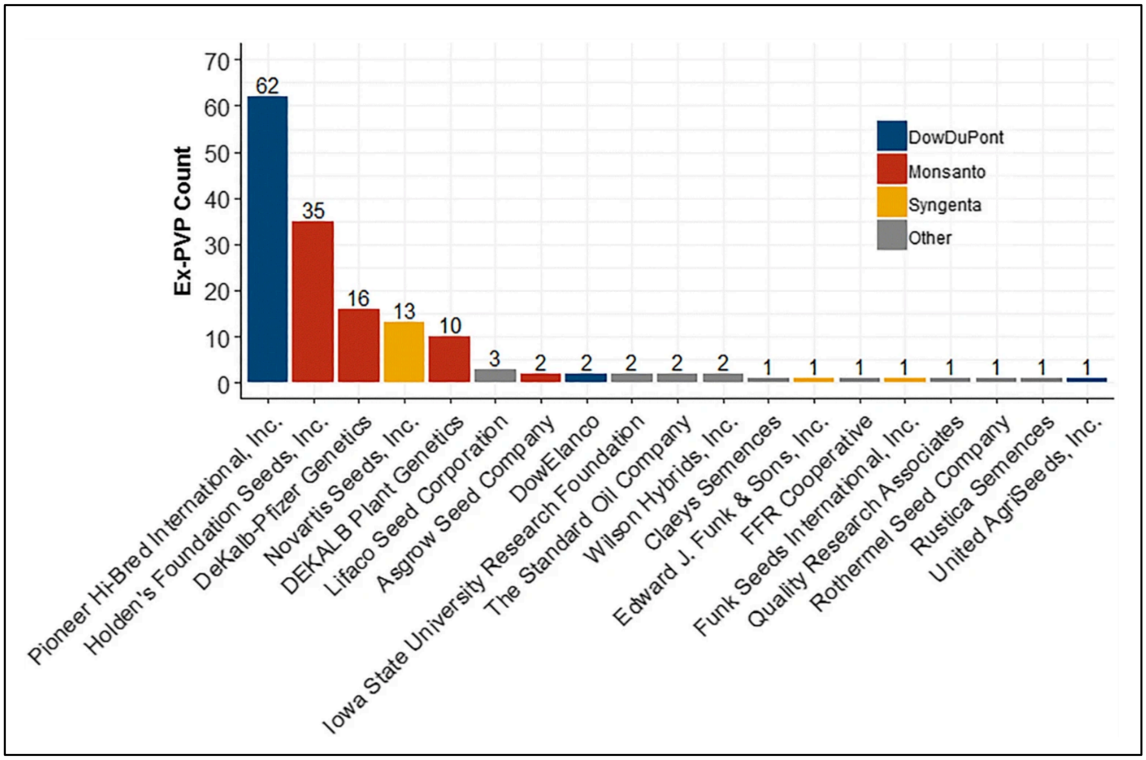

Figure 6. Company ownership of 157 ex-PVP lines analyzed for haplotype sharing. The x-axis shows original patent holding companies and the color-coded bars show the 2019 ownership by largely three major companies. From: Coffman et al., 2019.

The recent mergers and acquisitions in the seed industry have resulted in just three companies owning the majority of germplasm from the most important legacy breeding programs that was once owned by 19 individual companies [Figure 6] (Coffman et al., 2019).

1.6 Concentration in the Corn Seed Industry: Who Owns What?

In the U.S. federal intellectual property policies, most importantly the 1985 allowance for utility patents on plants, have helped create the most concentrated seed industry in recent history (Howard, 2018; Kloppenburg, 2004). This shocking corporatization and concentration of the seed industry into four agrochemical seed companies helps produce a system that favors farming based on fewer crops and fewer varieties on the landscape. Consolidation in the seed industry and privatization of genetic resources shape the first input to a farming system – seed – and enable the production of monoculture on the landscape. These factors allow for specialization and develop a market that is both produced by and produces monocultures.

Today's concentration levels in the seed industry are particularly alarming. Privatization and restrictive intellectual property protections are driving staggering levels of concentration in the global seed industry and reducing competition in the marketplace (Howard, 2015; Kloppenburg, 2004; Matson, Tang, & Wynn, 2014). Philip Howard's Seed Industry Structure [Figure 7] maps the dizzying levels of market concentration that lie within four major companies represented as the large red circles.

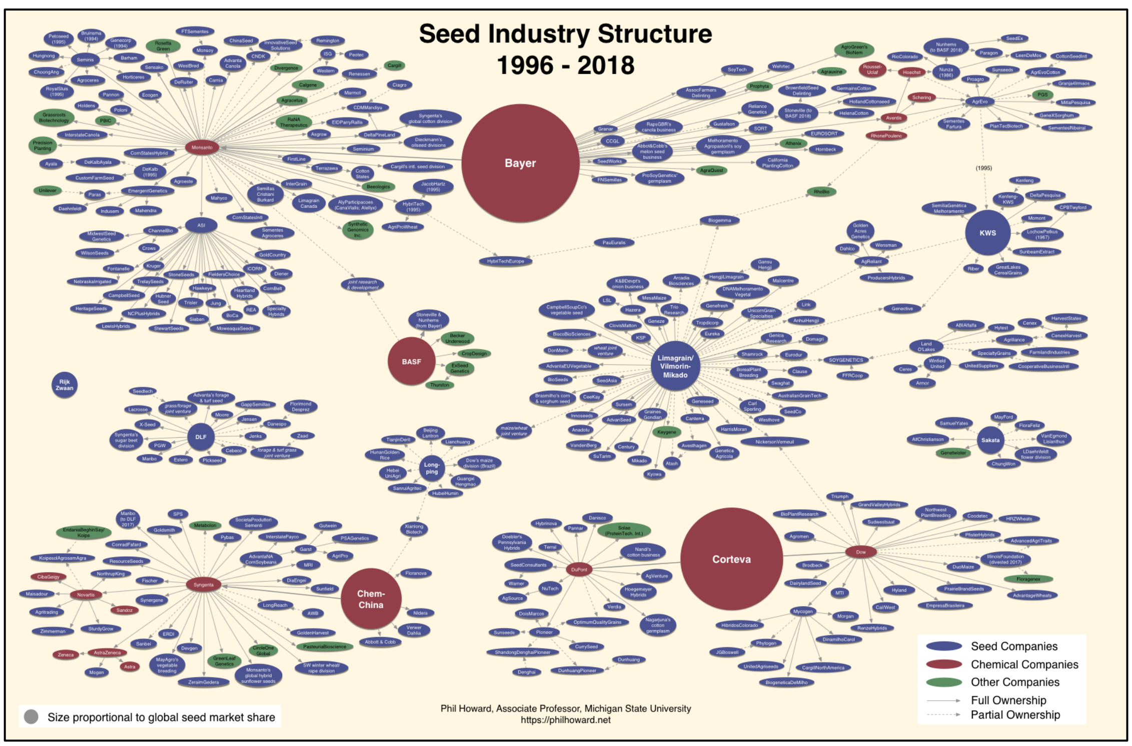

Figure 7. Map of global seed industry concentration from 1996 through 2018. From: Phillip Howard, 2018.

Concentration levels in the seed industry are particularly significant in corn. Four major companies controlled 85% of corn seed in 2015, a nearly 35% increase in market share since 1988 (MacDonald, 2017). These increased levels beg the question of how, if at all, it is impacting genetic diversity in their catalogue offerings and sales, i.e. on-farm. Analyses of genetic diversity of ex-PVP germplasm, offering a snapshot from 20 years ago, elicit concern and a call for additional research. It begs the questions: Where are we now? What is the diversity in farmers' fields today?

1.7 Research Objectives: What's a Farmer to Do?

Seed is the foundation of agriculture – one of the most vital resources of our food system. Stewardship of seed has enabled humans to coevolve with plants for the past 10,000 years. The seed system in the Upper Midwest, across the U.S., and globally, has changed drastically over the past sixty years. Recent waves of seed and chemical company mergers have resulted in concerning levels of consolidation within the seed industry.

The drastic shift of seed management as a public natural resource to a privatized commodity is a new development in human existence (Matson, Tang, & Wynn, 2014). This shift has occurred rapidly in relation to the timeline of humans practicing agriculture. We need to understand the details of how seed systems are being managed in the U.S. and globally, and the implications to on-farm genetic diversity.

Debates about the genetic diversity of cultivated crops have riled the scientific community. While there is growing scholarship on measuring genetic diversity among crop types, less research focuses on measuring on-farm genetic diversity. More specifically, there is a distinct lack of research measuring on-farm genetic diversity in

U.S. corn today. With approximately 90 million acres of field corn planted in the U.S. annually, it's imperative to understand the genetic diversity of the varieties most planted in farmers' fields. My research focuses on identifying the genetic diversity of the U.S. standing field corn crop.

My initial research question was: What is the status of field corn diversity on farms in the Upper Midwest today? Due to intellectual property restrictions, that data is not available for measuring the diversity of genetic pedigrees in fields today. This information is trade secret and heavily guarded (Kloppenburg, 2004; Mikel, 2008).

Along with the drastic commodification of seed in the U.S. over the last 100 years has come the privatization of germplasm management and monitoring of genetic vulnerability.

This makes my research questions even more imperative. If I, a land grant university research student cannot legally access the genetic pedigree information, farmers cannot either. This led me to start my research at the farm level to see how farmers are managing their corn acres without access to this information.

My research question now is: Given the majority of corn producers in the Upper Midwest do not have access to genetic background information of the seed they purchase, what are their perspectives and strategies for managing on-farm genetic diversity in their corn crop?

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Chapter 2. Methods

2.1 A Qualitative Approach for Understanding the Unexplored

In the previous chapter I illustrated the gap in literature on farmers' roles in measuring and managing on-farm diversity of U.S. corn. For my methodology, I draw on Orne and Bell's description of a "multilogical world," one that recognizes that the social world has some unified logistics among people, space, and time, but that there is "not only one such relatively unified logic for any person, space, or time – or for all persons, spaces, and times" (2015, p.10). The concept of a multilogical world tells us that individuals in different locations have different logics and different experiences (Orne & Bell, 2015).

Farmers and farming communities in the Upper Midwest are no exception to this concept of the world. They have different geographies, different markets that they serve, different seed choices, and therefore, different perspectives of the world. This broad canvas coupled with the lack of research focused on my questions informed my choice to use qualitative methods for answering my research questions. My goal is to better understand this understudied realm of the relationship between Upper Midwest corn producers and managing on-farm genetic diversity.

In total, I conducted twenty exploratory interviews with corn growers in Illinois, Iowa, Michigan, Minnesota, and Wisconsin. The interviews set out to answer the following questions:

1. What are Upper Midwest farmers' perceptions and strategies for managing on-farm diversity on their corn acres?

2. Do farmers have the genetic information they need to make decisions about which corn varieties they plant?
3. What role are farmers playing to managing on-farm diversity in their corn acres?

I originally planned to conduct exploratory interviews with ten corn producers in the Upper Midwest and use the data to inform a broader survey with the same theme of corn growers in the region. My thought was that the blended methodological approach would allow me to generate a generalizable data set. What I was learning during my first seven interviews led me to slightly change course. I realized that I needed to expand my sample to include farmers with a wider range of cultivation practices, markets, and sizes. This early shift in my methods and interview sample was the result of listening to the interviewees and an early assessment of the data. As Orne and Bell tell us, “a good qualitative interviewing project is going to listen to the participants and follow their lead to new kinds of people to interview” (2015, p. 70).

Informed by the early interviews I conducted, I expanded my interviewee *n* to twenty and tabled the survey. I quickly realized that the gap in research in this direction would best be addressed with understanding the broader context and conditions, rather than an attempt at a quantitative data set. My refined goal became to gain a broad understanding of perceptions of and management strategies for on-farm genetic diversity from corn growers in the region. This includes both salient points among the interviewees as well as outlying perspectives.

2.2 Theoretical Sampling: Identifying Interviewees

As stated above, my original sampling size was ten corn producers, which I increased to twenty interviewees. I drew on Orne and Bell's theoretical sampling process to inform all of my recruiting (2015). I chose my initial sampling frame to focus on conventional growers. The majority of corn grown in the Upper Midwest is done conventionally, in contrast to certified organic practices which the USDA defines as "the application of a set of cultural, biological, and mechanical practices that support the cycling of on-farm resources, promote ecological balance, and conserve biodiversity (USDA, 2015).

To identify initial potential interviewees, I contacted university corn researchers in Iowa, Minnesota, and Wisconsin, and regional farmer organizations including Practical Farmers of Iowa and Wisconsin Farmers Union. Two university researchers suggested I reach out to the Minnesota Corn Growers Association, which I did. I shared details about my research questions and asked for suggestions of potential interview candidates. Researchers in Iowa and Minnesota responded and I identified three interviewees via follow-up emails to candidates from their suggestions. Practical Farmers of Iowa and the Minnesota Corn Growers Association forwarded details about my research to their listservs and I identified four interviewees via follow-up emails to candidates from this group. A seventh interviewee was identified from the Wisconsin Farmers Union. I began conducting interviews with my list of seven farmers and expected to identify additional candidates as recommended by my initial interviewees.

The initial set of interviews were very beneficial in identifying ways in which some Midwestern corn growers perceive and manage on-farm diversity in their production fields. I noticed sharp distinctions between interviewees based on agronomic practices, in particular between growers who were certified organic or practicing progressive practices contrasted with some of the large-scale conventional producers. These distinctions were so sharp that I decided it would be important to include additional certified organic growers to the sample. I expanded the number of interviews to twenty and used the same questions for all interviewees.

I followed the same recruitment process for identifying the second set of interviewees. I contacted corn researchers focused on organic and/or sustainable practices at universities in Iowa, Minnesota, and Wisconsin, and a large organic food-grade corn purchaser in the region. This resulted in my research being shared on the Organic Grain Resource and Information Network (OGRAIN) listserve. I identified six interviewees via the OGRAIN listserve, two from a university contact suggestion, one suggested by a regional organic corn seed company contact, and two identified through suggestions from Organic Valley. I also reached out to three regional farming organizations, including Women, Food and Agriculture Network, American Agri-women, and the Midwest Organic and Sustainable Education Service (MOSES). MOSES shared my project details with their farmer listserve and in their quarterly newspaper. I identified the remaining interview candidates from this effort.

There is a considerable amount of demographic similarity among the farmer interviewees [Table 1]. Most notably is that all farmer interviewees were white and all but one interviewee were male. These demographics are in line with the USDA's 2017 Census of Agriculture that shows 97.6% of Midwest producers are white and 66.7% are male (United States Department of Agriculture, 2017). Among farmer interviewees, 65% were between the age of 35 and 64, 20% were under the age of 35, and 15% were over the age of 65. Three of the interviewees under the age of 35 were operating land with their parents and one of the interviewees was operating land with an older farmer as part of a transition plan that they developed in partnership.

					Age		
Name	Location	Acres	Gender	<35	35 – 64	65<	Race
D.H.	Iowa	80	Male		X		White
M.B.	Illinois	85	Female		X		White
A.H.	Wisconsin	290	Male		X		White
D.K.	Wisconsin	300	Male		X		White
F.A.	Iowa	400	Male		X		White
M.S.	Wisconsin	500	Male		X		White
P.G.	Minnesota	650	Male		X		White
R.R.	Iowa	700	Male			X	White
J.W.	Wisconsin	750	Male	X			White
J.B.	Iowa	800	Male			X	White
D.M.	Minnesota	900	Male		X		White
L.G. & K.G.	Iowa	1,200	Male	X (K.G.)	X (L.G.)		White
R.H.	Wisconsin	1,400	Male		X		White
A.K.	Minnesota	1,500	Male	X			White
M.D.	Wisconsin	1,800	Male		X		White
R.P.	Iowa	1,800	Male		X		White
J.L.	Michigan	2,100	Male		X		White
K.W.	Wisconsin	3,100	Male			X	White
W.H.	Wisconsin	5,000	Male	X			White

Table 1. Farmer interviewee demographics

2.3 Conducting the Interviews

I conducted all twenty interviews in person between the summer of 2018 and the winter of 2019. Of these, I traveled to 12 of the interviewees' farms to conduct their interview on-farm. I met with two of the farmers in restaurants near their farms as per their request. I conducted one at the University of Wisconsin-Madison campus because the grower was traveling through Madison and asked if we could meet there. I conducted five interviews at the annual Midwest Organic and Sustainable Education Service (MOSES) winter conference held in La Crosse, Wisconsin, because these growers were all planning to attend the conference.

All interviews were conducted using the same bank of 16 questions [Table 2], which were developed by McCluskey and Tracy with input from University of Wisconsin–Madison professors in Community and Environmental Sociology, and Sociology departments. The questions were created for their exploratory purpose and included opportunities for the farmers to share about their practices, history of their farms, percent of acreage grown to corn, how they identify corn varieties to plant, how they monitor genetic diversity on their farms, their perceptions of on-farm diversity, if they had suggestions for other interview candidates, and so on.

How long have you been farming?
How did you get started farming?
Describe your farm. What types of crops do you grow?
Approximately how many acres do you farm each year?
Of that acreage, approximately how many acres of corn do you grow annually?
On those corn acres, how many different varieties do you grow?
What strategies do you use to monitor the genetic diversity of your corn crop year to year? Have these strategies changed at all over time and if so, how?
What is the average length of time that you grow a particular corn hybrid?

Who do you most often consult with when deciding which and how many varieties of corn to grow each season?

Are there any economic factors that play into your decision to grow multiple corn varieties each year?

Are there any biological factors that play into your decision to grow multiple corn varieties each year?

Are there any social factors that play into your decision to grow multiple corn varieties each year?

Do you have any concerns about on-farm diversity of corn in the U.S.? If so, what are they?

Are you a member of any farming organizations? If so, which ones and what are the benefits?

Are you willing to be contacted in the future for more discussion on the topic of on-farm diversity?

Anything else you'd like to share about on-farm diversity of corn in the U.S.?

Table 2. Interview guide. Approved by the University of Wisconsin-Madison Institutional Review Board on June 29, 2018.

Interview questions did not follow the same order for each interview because of the exploratory nature of the research. Each farmer told their story and brought up themes and concepts in their own ways. The question bank was used a guide to ensure all interviews included each question. Interviews lasted between one and two hours, were audio recorded, and professionally transcribed.

2.4 Thematic Analysis: Coding the Data

Due to the amount of data and the exploratory nature of both the interviews and my research questions, I conducted thematic analysis on the transcribed interviews (Charmaz, 2006; Glaser & Strauss, 1967; Orne & Bell, 2015). Drawing on grounded theory, I approached the coding and analysis with an inductive lens to determine themes as presented by the farmers rather than fitting farmer interview data into existing theories (Charmaz, 2006; Glaser & Strauss, 1967; Orne & Bell, 2015).

I conducted a line-by-line coding of each interview, applying codes of meaning to the data. Throughout my interviews I noticed a sharp distinction in reactions and strategies related to on-farm genetic diversity in corn between certified organic and conventional farmers. I categorized the interview data based on this distinction and coded the two data sets separately to begin. I did a second round of coding handling all of the interviews as one data set. I wrote memos throughout the coding process to organize the codes into theoretical categories. I identified themes that were identified by both organic and conventional farmers, and themes that were unique to organic and conventional farmers. Finally, I returned to the interview data to test themes and concepts that emerged from the coding and memo writing (Charmaz, 2006; Charmaz, 2008).

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Chapter 3. Results

I reveled in every hour of driving throughout the Upper Midwest, visiting farms, and listening to farmers' stories about how they started farming, their successes, their struggles, the uncertainty of the future, and how they see and manage diversity in their corn acres. I drove over 2,500 miles winding my way through Iowa, Minnesota, and Wisconsin. The visits resulted in over twenty hours of recorded interview data, one home cooked breakfast by a nervous interviewee staying busy while answering questions, and chocolate chip cookies made from freshly ground corn flour grown on the farm and tucked away in a bag for my drive home to Madison.

Drawing on the line-by-line coding and memo writing from the twenty exploratory farmer interviews, I identified eight salient themes related to my research questions. The goal of these interviews was not to identify data that is generalizable to all corn producers in the Upper Midwest. Rather, my goal was to identify salient themes and unique perspectives among the interviews related to their perceptions of and management strategies for on-farm genetic diversity in their corn acres. In this chapter I will present the interview data that relates to these research questions:

4. What are Upper Midwest corn farmers' perceptions and strategies for managing on-farm diversity in their corn acres?
5. Do these farmers have the genetic information they need to make decisions about which corn varieties they plant?
6. What role are these farmers playing to managing on-farm diversity in their corn acres?

I assigned each farmer interviewee a pseudonym to protect their anonymity. I will also present comments from one seed dealer who a farmer called over to join us during the interview. He has also been assigned a pseudonym.

Name	Location	Total acres	Corn acres*	Corn varieties*	Farming practice
D.H.	Iowa	80	20	10 to 11	Organic
M.B.	Illinois	85	40	1	Organic
A.H.	Wisconsin	290	80 to 110	3	Organic
D.K.	Wisconsin	300	50	2 to 4	Organic
F.A.	Iowa	400	140	3	Conventional
M.S.	Wisconsin	500	110	3 to 5	Conventional
P.G.	Minnesota	650	200 to 250	2 to 4	Both
R.R.	Iowa	700	180 to 200	6 or more	Organic
J.W.	Wisconsin	750	100 to 150	3 to 4	Organic
J.B.	Iowa	800	400	3 to 4	Conventional
D.M.	Minnesota	900	600 to 700	4 to 5	Conventional
L.G. and K.G.	Iowa	1,200	650	6 to 8	Conventional
R.H.	Wisconsin	1,400	650	2 to 10	Conventional
A.K.	Minnesota	1,500	750	7	Conventional
M.D.	Wisconsin	1,800	300 to 600	5 to 6	Organic
R.P.	Iowa	1,800	1,620	4 to 5	Conventional
J.L.	Michigan	2,100	350	4 to 6	Both
K.W.	Wisconsin	3,100	700	16	Organic
W.H.	Wisconsin	5,000	2,100	5 to 7	Both

Table 1. Farmer interviewee details, including reported number of total acres planted, number of acres planted to corn on average per year, average number of corn varieties planted per year, and if the farming operation is conventional or certified organic. Acres rounded to the nearest acre.
*Average per year

I heard sharp and nuanced distinctions in responses between certified organic and conventional farmers throughout the interviews. These are related to the size of their farm, the markets they serve, and the differences in corn varieties they can access. Generally, the conventional farmers operate more land than the organic growers, supply ethanol or animal feed markets as opposed to food for human consumption, and have more corn varieties available, that are bred for their system compared to organic growers. I will discuss distinctions between the grower types within the themes that are relevant to my research questions. Largely themes identified by conventional and organic farmers' responses overlap, however. Both distinctions and similarities are important to my research and analysis and I will be noting these throughout the themes [Table 2].

Themes identified in interviews	Farming Practice		
	Conventional	Organic	Overlap
Management			
1. Plants multiple varieties for risk aversion			X
2. Lacks access to genetic background information			X
3. Relationships with seed dealers are central to selecting varieties			X
4. Lacks access to quality genetics		X	
5. Has worked for seed companies in the past and that experience informs management decisions			X
Perception			
6. Most farmers are not managing on-farm genetic diversity in their corn acres			X
7. Younger/next generation of farmers manage on-farm genetic diversity differently	X		
8. Genetic diversity as a marketing tool	X		

Table 2. Themes identified in interview data uniquely identified by conventional or certified organic, and an overlap of both farming practices.

The farmer interviewees represented a wide spectrum of farming practices and farm size, with the largest grower operating 5,000 acres, another growing 1,800 acres of continuous corn, and the smallest grower operating 80 highly diversified acres. Interviewees identified several practices for managing on-farm diversity in their corn, which largely focused on rotating varieties. Nobody wants to put “all their eggs in one basket” on the farm by planting a limited number of varieties. And some, but not all considered the second level of diversity in their hybrids: the parental background. All farmers discussed some sort of management practice for their corn acres, be it diligent record taking and long conversations with seed dealers, to putting full faith in their dealers to make variety decisions. Taken together, these farmers have many nuanced perceptions about on-farm genetic diversity in their corn acres, their concerns vary based on their size and markets, and they have some sort of strategy for managing on-farm diversity be it delegating another person to make those decisions or struggling to access information to manage it on their own.

3.1 Planting Multiple Varieties for Risk Aversion

All interviewees plant multiple corn varieties on their acres each year. When asked why they plant their stated number of corn varieties on their farm, the majority of interviewees identified this as a management practice to spread their risk. This was the case for farmers growing three or four varieties to farmers growing six or seven varieties on a similar number of acres. Farmers identified the need to plant multiple varieties of corn to protect themselves from risk such as drought, lodging, and pests.

Several organic farmers operating smaller acres of corn planted a comparable number of varieties to conventional growers growing larger acres of corn. This could be related to a number of phenomena. First, many organic farmers identified a lack of quality corn varieties. This refers to corn varieties that have been bred specifically for organic systems and have qualities that thrive in their system and with their farming practices. I will return to this theme in more detail below. Conversely, not one conventional farmer talked about limited variety options. It could be that organic farmers are planting more varieties on smaller acres as a way to identify what thrives on their farms or spread risk against varieties that do not perform well in their organic system. Second, many of the organic farmers had more crop diversity on their farms than the conventional growers who largely operated a corn and soybean rotation. The organic farmers may inherently plant more in-species diversity within their crops as well.

Regardless of the variance in number of varieties each grower plants per year, this was clearly identified as a management strategy for diversifying their corn acreage. Farmer R.P. worked as a Pioneer sales representative for 32 years before retiring recently. He shared a story about a local customer who did just the opposite.

> *I had a customer and he was a large farmer. We had a very high-yielding hybrid and he wanted 100% of that. And it was 100% of his acres and I strongly discouraged him and told him every year is different even though it may have been the best for the last couple years. He decided he wanted all of that – he loved it. So he plants 100% of it and we – this was before fungicides and stuff – and we got some diseases came in. And this hybrid happened to be very susceptible to one of them that came in. So I get a call on Labor Day – '[R.P.], my corn just died.' So, I went over there and it was dead. Obviously, if he wouldn't have 100% of*

that corn, he would only have 50% of the entire whatever – I mean another one may have been more resistant.

Planting multiple varieties of corn represents the surface level of genetic diversity – the number of different varieties grown on the landscape each season. None of the farmer interviewees discussed only planting one corn variety across all of their acres each season.

3.2 Lacking Access to Genetic Background Information

Overall, farmer interviewees said that they do not have access to genetic background information about the corn seed varieties they are planting. This comes as no surprise since the genetic background information is trade secret and well protected by seed companies. I knew this to be the case and it is one of my motivations in conducting these interviews to understand how, if at all, this was impacting farmers. What I want to draw attention to in this theme, however, is the varied responses given by the conventional growers.

I expected to hear from some interviewees that they did not really care about the genetic background information of their corn varieties. Some of the organic growers said that knowing this information would be one of many tools for managing their farms and serving food grade markets. Two of the conventional farmers said they definitely did not have access to this information. Another two farmers said they were unsure if they had access to this information. Of these one said they were pretty sure that they could find that information out if they asked their dealer. The other had not considered this level of detail and jotted down a note to himself that he should ask his dealer about it.

Farmer L.G. was particularly adamant that the pedigree information was not important to him and that his seed dealer had access to this information if he wanted to know it.

> *I've been to meetings all the time, they say, we need to have the genetic family on the tag so we can read it. So we know that if I'm buying Pioneer and whatever, company X, so I can compare the tags and see that it's different genetics. Well, I'm not smart enough to do that. So I don't. I'm sure we could find it out. I just never have. It's not a big deal to me. Our dealer could tell us.*

He returns to this multiple times throughout our interview – that he was not smart enough to know what to do with that information if he had it but that he could find it out if necessary. His reliance on his seed dealer was so prevalent throughout the interview that he called him and asked him to come over to the farm so that I could interview him. Luckily, I had already received Institutional Review Board (IRB) approval to expand my research to include interviews with seed dealers based on the overwhelming response from interviewees about their reliance on them for selecting corn varieties. I will return to this in the next section.

Farmer M.S. who operates approximately 500 acres of cropland including 110 acres of corn each year shared a much different opinion than L.G. about access to genetic background information. In preparation for our interview, M.S. pulled out several seed catalogues to share with me and illustrate the lack of information that is available to him.

> *I used to do very detailed analysis that compared everything…But for the past probably three years, the seed companies do not show you the base genetics anymore…I don't have access…If you look at the Cropland manual across the top*

> *you'll see the internal traits they're selling to farmers. This is really marketing materials. This is not science and its subjective opinion…So this is all I have to deal with.*

M.S. spoke many times throughout our interview about his frustration over only having access to what he considers marketing materials to make seed selection decisions on his farm.

Farmer A.K., however, said that while genetic background information was somewhat challenging to find out, he was having good success in sorting it out on varieties that are important to him. He described having good conversations about it with his "dealer network" and while he cannot know exactly the details of what is in the background, he can get enough information for his needs. When asked why he was interested in this information, he said that it is, "…the next step in managing the risk of trying something new." I asked him why he thought some companies were willing to share these details and he figured it was related to marketing. A.K. is considering upgrading to a multi-hybrid planter. Knowing how the varieties differ and by how much is an important component in selling these tools. I will go into more detail about this in the theme of genetic diversity as a marketing tool.

3.3 Limited Access to Quality Genetics for Organic Growers

For many organic growers I interviewed, concerns around access to genetic information were overshadowed by the lack of organic corn genetics on a whole. Many of the interviewees said that they did not have high-quality corn varieties bred to thrive in organic systems. They perceived the conventional seed companies as holding genetics back from organic growers and breeders. Farmer M.D. from Wisconsin used the term "hijacked" to describe what he sees as the current state of seed in the U.S. as, "…I think we have gone backwards a lot. We really took the breeding programs out of the land grant universities and let big chemical companies hijack all the germplasm." I heard similar perspectives from several of the organic farmers.

Farmer P.G. shared a related sentiment in saying, "…the way I understand how hybrids become available there are probably only a few actual people that actually put out the genetics that these seed companies get to fight over and there probably isn't all too much difference." P.G. manages both conventional and organic acreage and went on to describe his frustration in the quality of organic corn seed.

> *The organic I try to pick one that's proven I guess. I'm not a real – I don't know if I should say this – but I'm not really sold on buying organic seed just because it's organic. I've seen and done that and paid way more for organic seed and put it in trial next to untreated conventional seed and it's behind by 20-30 bushels. You know and I'm just like I can't afford I mean I'm losing money not just buying the seed but planting. I'm taking a yield hit.*

P.G. manages about 650 acres and the corn acreage is split half conventional and half organic. He plants one variety on his organic acreage and two to three on the conventional land. I asked him why this is the case. He attributed this to the "headache of the paperwork," in reference to the paperwork associated with organic certification, and reiterated the lack of quality in the organic corn seed. We do not know how diverse the genetic background is of the conventional seed P.G. plants. But we do know that he is planting more varieties on his conventional land than on his organic acres, which means that his conventional acres are more diverse on the surface level than his organic acres.

Farmer W.H. operates 5,000 acres in Wisconsin with his family. The farm is about three-quarters non-GMO conventional and one-quarter organic, and they grow 2,100 acres of corn each year. Like P.G., W.H. talked about the differences in seed quality between the conventional and organic varieties available to him, and identified investments in research funding as the reason.

> *There's just a bigger market, there's more money in research and development. What it comes down to is the conventional side has more customers so they have more money to do research and development, and plant breeding. And the organic side is just getting there. I think in maybe 20 years the difference between the two might not be so much, but in my experience it seems like the conventional markets just have stronger genetics that are more vigorous.*

W.H. talked about the issues he's had with finding organic seed for their farm and said, "…we are able to get everything we need on the conventional side."

None of the conventional farmers I interviewed talked about issues around quality of seed. Two of them discussed losing access to older varieties that were replaced with newer ones and that this could be frustrating at times. Availability of certain varieties in certain regions was also brought up by two of the farmers and one noted the related practice of regional pricing. These were lightly discussed and interviewees did not express more than low-levels of frustration about it or access to high-quality seed that performs well on their farms. Since many of the organic farmers talked about their concern about poor quality organic corn seed available to them, we should consider if the genetic diversity of organic corn acres is different from conventional acres due to access of genetics in organic seed.

3.4 Relationships with Seed Dealers are Central to Selecting Varieties

A majority of the farmers, both conventional and organic, spoke in detail about the importance of relationships with their seed dealers in making decisions about what corn varieties to plant. I did not ask interviewees directly what role their seed dealers played in on-farm management. Rather they identified this relationship in response to my questions about who they most often consult with when they make decisions about what varieties to plant, or what information about genetic backgrounds they have access to in informing their choices. Farmers used words such as "trust" and "faith," one said, "I think the relationships are more than anything," when describing their reliance on seed dealers for selecting their varieties. The relationship with seed dealers was a strong theme among interviewees and appears to be an important, if not central, strategy for managing on-farm diversity.

Several of the farmers trust that their seed dealers have access to genetic background information and that they are using it to inform appropriate levels of genetic diversity on their farms. R.P. who spent 32 years as a Pioneer sales representative and is since retired told me this in response to my question about looking into the background of hybrids in his selection process:

> *I think on the label it does actually tell a little or you can have them traced back. I mean, they're not going to tell you exactly what it is but they're going to say, you know, you could ask your rep, 'Does any of these – you know, I've got four hybrids here, how many of them have the same – one of the same parent?'…They could find that out.*

He clarified that this information was not unique to him as retired Pioneer dealer but that an average farmer without those ties to the company could find out the genetic background information. R.P. reiterated the reliance on the relationship between farmers and dealers later on when he shared, “I also know from working with a lot of farmers that they rely on me to keep that straight for them.” Here he is referring to his former farmer customers relying on him to select corn varieties back when he was a Pioneer representative.

Farmer J.B. operates about 800 acres including 400 acres of corn in Iowa and spoke of relationships with seed dealers as being important in how he selects the three or four corn varieties he plants each year.

> *A lot of it is based on relationships I have with the local seed dealers. Part of it is based on my history with a particular variety. Part of it is on the history of the piece of property it’s going to go on…But it’s largely a relationship I think.*

J.B. and his wife own the century farm that he runs and mentioned the importance of relationships with seed dealers and neighbors throughout our interview.

Let’s return to farmer L.G. and his insistence on having his seed dealer M.G. join us for the interview. M.G. lives right down the street from L.G. and works for Beck’s Hybrids, which markets itself as having a genetically diverse catalogue of offerings.

> Me: “M.G., do you know the genetic background, does Beck’s tell you that?”
>
> M.G.: “No, not really. No, but if you’ve been in it long enough, I can normally tell what germ pool they’re coming out of.”
>
> Me: “The parents?”

M.G.: “Following the traits…They normally don’t disclose that. Now, there’s a lot of people that know what that is, and if I asked our corn breeder, I could probably find out what that background…”

L.G.: “They don’t put genetic information on a seed tag?”

M.G.: No.

L.G.: “Because I thought they did.”

M.G.: “I can follow it by traits, normally…But they don’t disclose that to us. In fact they don’t even want the farmers [to know], but most farmers understand the traits, and so they know where it’s coming from anyway. And some don’t care. L.G. doesn’t care, probably, as long as it yields on his farms.”

This was an interesting interaction to witness. It was literally the moment when L.G., who had vehemently told me that his seed dealer had this information readily available to him and was using it to make decisions, heard differently directly from M.G..

By “traits,” M.G. is referring to biotechnology traits that have been added into the seed. This seed is often referred to as “traited” and includes some type of insect or herbicide protection such as glysophate resistance or corn borer resistance. Varieties can have several types of traits added to them, or what some interviewees referred to as being “stacked.” M.G. described following the traits as a way to decipher which company the hybrid is from because traits are proprietary.

Conventional and organic farmers alike identified relationships with their seed dealers as important to making variety selections. And this makes sense particularly if we consider that the farmer’s success is in the best interest of their seed dealer who wants to keep the farmer as a customer. What is concerning, however, is that many of the interviewees perceive their dealers as having access to and utilizing genetic background information to inform their variety selections. M.G., of course, does not represent all seed dealers and each company may have different protocol regarding information access. Because of the reliance on these relationships, further inquiry with seed dealers may be important in understanding their role in managing on-farm diversity in corn.

3.5 Former Work for Seed Companies Informs Management Decisions

Five of the twenty farmers I interviewed shared that they had worked for seed companies in the past. This was not a question I asked directly, but rather a point that they drew on when discussing aspects of their strategies for managing on-farm diversity. These farmers made comments about their past work with seed companies and drew on their experiences to inform certain aspects of their management. One farmer talked at length about a practice of particular importance: relabeling.

Farmer F.A. has lived and farmed in an area of Iowa where companies produce much of the hybrid corn seed. He shared the following with me about working at a seed corn company in the area.

> *Two winters I worked for them. Bagging corn and I mean, you tell people that it's the same corn but it went in four or five different companies' bags and they* [other farmers] *say, 'no, that's not possible.' They can't believe it, you know. They figure each company has got their own germplasm and they don't want to believe it. And that's why I buy my corn from Vince, because when I went to school at Hawkeye, that's what the one instructor told us. Buy all your corn from one company and buy all your soybeans, because you're not going to be getting mixed.*

Vince is the person who owns what F.A. calls the "mom and pop" company where he purchases his corn seed. He clearly identifies seed relabeling which some companies practice. As F.A. describes, it is possible for a farmer to unknowingly purchase the same corn variety from different companies that is labeled under different names (or numbers, in the case of conventional seed). This is clearly an issue for farmers who are not aware of this practice and are managing surface level on-farm genetic diversity by planting multiple varieties.

3.6 Perception that Farmers are Not Managing On-Farm Diversity

When asked if interviewees had any concerns about on-farm genetic diversity of corn in the U.S., the majority of the organic farmers and two of the conventional growers responded yes. Levels and nuanced aspects of concern varied among respondents. Importantly, a number of interviewees perceive that other farmers are not managing on-farm genetic diversity in their corn acres.

Three of the organic farmers said they feel farmers do not pay attention to genetic diversity due to a bottlenecking of intellect or that farmers have "gotten lazy" and "dumbed down." Early in my interviews, R.P. described a spectrum of farmers' interest in managing on-farm diversity. He shares, "…there are some people that are really into it, really down on it. And you got other people that they don't want anything to do with it. You pick it [the variety] and that way I could blame you if you didn't get the right one in the right place or whatever." The farmers that R.P. talks about as being "really into" managing diversity on the farm is what L.G. refers to as "nerdy farmers."

> *Now you have, for lack of a better term, you have nerdy farmers that do want to know. They want to know everything on that tag. And I know some of those and*

that's fine. I'm just not smart enough to figure any of that out. I don't want too much information. I want the basic information. You know, you got all kinds of people – all the way from 'you can't give me enough information' to down here where 'I don't need much information. Just give me the stuff and I'll throw it in the planter and get it in the ground.'

Despite L.G.'s description of "nerdy farmers" that he says he knows, he drove the point home in his interview that he does not think farmers care about genetic diversity at all.

Certainly, some of the farmer interviewees have management strategies for diversity on their corn acres. The point here is that several of them talk about their perception that other farmers or farmers on a whole are not managing it. This was not coupled with a sense that the interviewee is doing a great job managing their genetic diversity and other farmers are not doing it as well. There was not a sense of heroism, but rather a feeling that on the whole, corn acres in the U.S. are not being managed with a lens for genetic diversity.

3.7 Next Generation of Farmers Manage Genetic Diversity Differently

Interviewees discussed perceptions about younger farmers being more interested in tracking and managing on-farm genetic diversity than the current generation of growers. A.K. returned to his family farm after years away and took over the seed purchasing. He says his parents were using an agronomist that they had hired and they did not think they were getting an unbiased opinion about what seed to purchase. They all farm together, but A.K. has taken on the work of managing their variety selections and on-farm diversity. He is tech-savvy and described meticulous management techniques. His interest in knowing more about the genetic background information of his hybrids is related to risk aversion and getting a jump on new varieties informed by the genetic details. He says that "…the younger folks as a whole I would say are the ones ore interested in being deeper in that information," when I asked if there were other farmers in the area doing the same.

K.G. is L.G.'s son and participated in the interview because he has taken over the seed purchasing from the farm. L.G. said that K.G. is doing things much differently than he used to when it comes to selecting varieties, which he supports. K.G.'s strategy for ensuring there is a good amount of genetic diversity in their corn acres is to purchase all of their seed from one company: Beck's Hybrids. This is the management strategy that F.A. talked about at length – going to one company for all of your corn seed to avoid relabeled varieties. K.G. said that dealing with one company has made things simpler and ensures that they know what their getting in the bag. He also identified that their new company is different, that, "Beck's is unique because they have their own corn…they are one of the few companies that can source. They source from Pioneer, Syngenta, and Monsanto." He said that the breadth in their catalogue has added more genetic diversity to their farm.

The majority of the farmers I interviewed were older and more than one of them talked about being too old to make big changes to their farming practices. Neither their resistance to fundamental changes or their perception that the next generation might be more engaged with monitoring their on-farm diversity come as a surprise. More than one of the growers did not have a succession plan in place for their farm and had no idea what the future would hold for the land.

3.8 Genetic Diversity as a Marketing Tool

As mentioned above, A.K. talked about his meticulous record keeping and developing strategies for managing on-farm diversity in his corn acres. He also shared that he was having several good conversations with his seed dealers about the genetic background information of his hybrids. When asked why he thought his dealers were open to these conversations, he said it comes down to marketing.

Beck's Hybrids has recently moved into his region in Minnesota and A.K. is trying out some of their corn varieties. While he is not using Beck's seed as a diversification strategy per se, he says their marketing begs the question about parental background.

> *…they have a portfolio that's diverse across many different platforms and that's* [genetic background] *what you need to know to make some of those decisions. Because you start looking at some performance or where things fall in relative maturity and that number looks very similar to this one over there. Why?…That's kind of part of what they're pushing and selling to you is we have this diversity and there is why it's good or bad…So I think, yeah, they're not going to tell you the details of what they're doing exactly but it's pretty open conversation about where it's coming from and what they're trying to do with it.*

A.K. felt that Beck's model makes it easier for him to have conversations with them about background details and he is taking advantage of that opportunity.

A.K. is having these conversations with multiple seed company sales representatives because he is interested in upgrading the technology on the farm. They currently use a precision planter and have for a few years. One of the more open conversations A.K. has had about genetic background in hybrids is with his precision planting dealer.

> *I have a good relationship with the dealer and I can have pretty good conversations. But there's also our precision planting dealer and they're trying to push – they're going to push yield. They're trying to work multi-hybrids. So you're kind of have to be more involved in that conversation to understand what is and isn't going to work because they're going to try and sell you a $40,000 upgrade to your planter.*

The investment in a multi-hybrid planter is quite high and A.K. said he needs the parental background information on the hybrids to understand if it pencils out to be worth it. Those conversations were going well enough that he figures they will make that upgrade.

3.9 Conclusion

I have presented eight salient themes from the twenty exploratory interviews I conducted with corn producers in the Upper Midwest. The interview data is not generalizable and that is not my goal. Rather, I have identified several important points that farmer interviewees discussed which allow us a better understanding of the dimensions of farmers' roles in managing on-farm genetic diversity in the corn acres as well as their perceptions of on-farm diversity.

Management techniques largely include planting multiple varieties for risk aversion. This relates to the surface level of diversity, the number of varieties planted, but not how closely related their backgrounds may be. It is clear from the data that the farmer interviewees do not have easy access to parental background information of their corn varieties. While this was not important to all of the interviewees, it is important to note that the farmers had different perceptions of what information they could access and what information their seed dealers knew. Nearly all of the farmers talked about relying on their seed dealers to have that information and use it to help them select varieties.

Chapter 4. Discussion

Each year, U.S. farmers plant approximately 90 million acres of hybrid corn, much of which is concentrated in the Upper Midwest. The environmental and economic risks that corn's predominance on the landscape makes understanding the genetic diversity of the crop imperative. Intellectual property restrictions are rampant in the corn industry and do not allow farmers or researchers access to genetic information or testing. The twenty exploratory interviews I conducted with corn growers in the region resulted in a better understanding of strategies some farmers use to manage their on-farm diversity in the absence of genetic background information, as well as their perceptions about it. The data indicates that farmers lack access to genetic background information about their corn seed and plant multiple varieties for surface level genetic diversification as risk reduction; companies sell the same corn seed under different variety names and farmers need strategies to navigate this practice of seed relabeling; and that relationships and trust in seed dealers appear to be central in selecting varieties and managing diversity. Along with the extreme commodification of seed in the U.S. over the last 100 years has come the privatization of germplasm management and monitoring of genetic vulnerability. The drastic shift of seed management as a public natural resource to a privatized commodity is a new development in human existence (Matson, Tang, & Wynn, 2014). We need to understand how seed systems are being managed in the U.S. and globally, and implications to on-farm genetic diversity.

4.1 Ethanol and Corn Monoculture in the Upper Midwest

Most farmer interviewees described managing surface level genetic diversity by planting multiple varieties each year for risk reduction. This surface level management does not account for the genetic background of varieties. In my introduction chapter I presented the literature about corn monoculture and posed the question: Just how monoculture is the corn monoculture in the U.S.? There are numerous factors producing corn monoculture on the landscape in the Upper Midwest, including the troubling concentration trends in the seed industry. One of the major drivers contributing to the production of corn monoculture in the region is ethanol production.

Nearly all of the farmer interviewees identified the practice of planting multiple corn varieties each year to manage risk on their farms. Yet, many of those same interviewees largely plant a corn monoculture or perhaps diculture in a corn and soybean rotation. This practice opens the farmer up to risk as well, so why are they still practicing monoculture despite identifying the risk associated with narrow genetic diversity that they are addressing by planting multiple corn varieties each year?

Several of the farmer interviewees identified ethanol plants as one of the markets for their corn. Farmer R.P., the former Pioneer sales representative who returned to farming full time since retiring from the company lives in Iowa and noted the impacts of new ethanol plants built in the area on corn production.

> *We were very fortunate that they decided to build a lot of ethanol plants around our area and that was probably the biggest change in our farming…I mean as far as income-wise and changing how we look at things…We typically grow 90% corn and about 10% beans…I want to say it was '06 or '07* [when they built the ethanol plants]*…Just their presence and then enough of them competing against*

> *each other in our, you know, local coop bids that it really helped the market a lot. It used to be eastern Iowa, east always along the river always used to have the highest bids. Now we compete with them in our – we have similar bids…That makes a difference…I mean, we changed our operations some to growing more corn.*

As farm size increases cropping practices become more specialized and production volume increases. Specialization and increased investment in inputs and improved equipment have resulted in a steady increase in corn yields over the last eighty years. The development of the ethanol market in the U.S. over the last thirty years has been pivotal in providing a market for some of this increased corn production.

Drawing on Neil Smith's theory of uneven development, we can see how the integration of monocropping and social processes produces the landscape. An anthropologist and geographer, Smith pivots from conceptual frameworks of linear thinking that space is a reflection of society. Uneven development theory asks us to push back against the conventional linear thought that corn monoculture is the result of farmers simply planting what they want to plant. Smith's (2010) theory allows us to turn towards an exploration the "integration of space and society" (p. 7) so we can understand the ways in which capital produces nature and space in its own image. I use uneven development theory to explore how federal policies and corporate investments are reflected on the landscape in the Upper Midwest, and why we cannot remove the linkages of subsidies, corporate investments, and land tenure from agricultural production of corn monoculture in the region. From here we can better understand how corn monoculture is produced and reproduced. Smith (2010) tells us, "[i]t is not just a question of what capitalism does to geography but rather of what geography can do for capitalism" (p. 4). And so, we must also consider how the production of monoculture in the Upper Midwest is both driven by and for capital.

In chapter 1, I established the extent of corn monoculture in the Upper Midwest and the benefits of diversified cropping systems. This illustrates that while diversified cropping systems offer farmers multifunctional benefits and risk reduction, the practice is largely rejected for monoculture. In this section I will present the linkages between federal corn subsidies, corporate investment, and ethanol used for fuel, and how they produce monoculture on Upper Midwest cropland by providing financial incentives and markets for farmers to plant corn. Since subsidies alone cannot overwrite the agronomic reality of risk associated with monoculture cropping, I will then explore the relationships between land tenure and adoption of sustainable practices such as crop diversification.

4.1.1 Ethanol Policies and the Changing Face of Agriculture

Federal and state policies underwrite the economic cost of doing business in the corn production world. Growers receive subsidies that encourage and reward them to overproduce corn, and policies have helped to develop markets that will absorb their crops (Roesch-McNally et al., 2017). These have shifted from human consumption (domestic and international) to animal feed and most recently to ethanol.

These subsidies include commodity and conservation payments, crop insurance, and disaster programs paid to growers and non-operator landowners, and are mandated through the federal Farm Bill (Environmental Working Group, 2019). Corn subsidy payments come in several forms and are not necessarily consistent from Farm Bill to

Farm Bill, which is renewed every five to six years. These include deficiency, crop insurance, counter-cyclical, agricultural risk coverage, price loss coverage, price support, market loss assistance, and average crop revenue election (Environmental Working Group, 2019).

Between 1995 and 2019 the federal government paid $113.9 billion in corn subsidies. Roughly half of that has gone to farmers in the Upper Midwest (Environmental Working Group, 2019). Six of the ten states in the region are in the top ten recipients of federal subsidy payments [Table 1] (Environmental Working Group, 2019). Corn received more than twice the amount of subsidy payments for wheat, which was the next highest subsidized crop. Federal governmental policies are effectively producing monoculture in this region through corn subsidy payments, deepening the hold on the land through ethanol subsidies and the RFS. That may just be why it's "king."

Rank	State	Total subsidies*	Corn subsidies*	Crop #1	Crop #2
1	Texas	$37,505,759,005	$2,629,314,219	Cotton	Wheat
2	Iowa	$33,265,789,548	$19,444,666,200	Corn	Soybean
3	Illinois	$27,730,296,760	$16,444,869,636	Corn	Soybean
4	Minnesota	$23,110,782,487	$10,861,056,102	Corn	Soybean
5	Kansas	$22,975,862,019	$4,428,117,056	Wheat	Corn
6	Nebraska	$22,828,363,883	$13,079,059,214	Corn	Soybean
7	North Dakota	$21,654,740,454	$2,895,402,991	Wheat	Corn
8	South Dakota	$16,828,180,687	$6,347,406,775	Corn	Soybean
9	Missouri	$14,373,592,622	$3,975,063,084	Corn	Soybean
10	Indiana	$14,035,767,765	$8,163,666,907	Corn	Soybean

Table 1. Subsidies by state ranking from 1995 to 2019. Source: Environmental Working Group (2019) Farm Subsidy Database.
*Total dollar amount paid by USDA.

“Ethanol is going to change the face of agriculture in Wisconsin” (p. 9), executive director of the Wisconsin Corn Growers Association Bob Oleson told the Wisconsin Agriculturist in 2003. His prediction was accurate for both the state and the Upper Midwest region.

Specialization and federal policies have contributed to increasing corn yields over the last thirty years [Figure 1]. The undulations of yields throughout the period indicate effects of markets, policies, and environmental conditions that interlock to produce corn monoculture on the landscape. The “alcohol for fuel use” portion shaded yellow in Figure 2 illustrates how the development of the ethanol market in the U.S. over this time has been integral to absorbing a portion of this increased corn production.

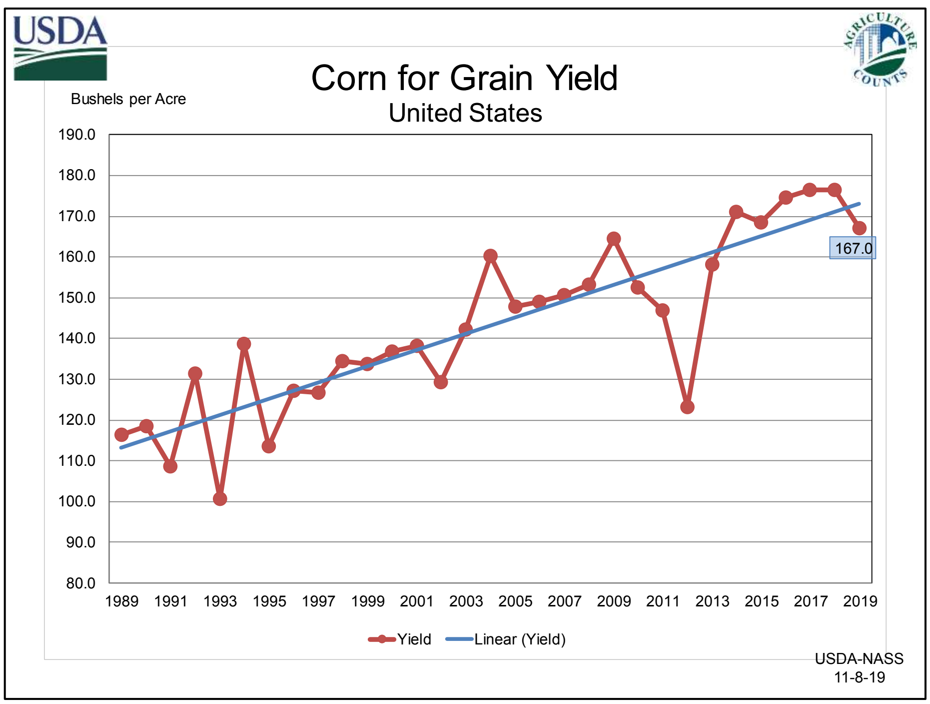

Figure 1. Corn for grain yields in the U.S. from 1989 through 2019. From: USDA National Agricultural Statistics Service, 2019.

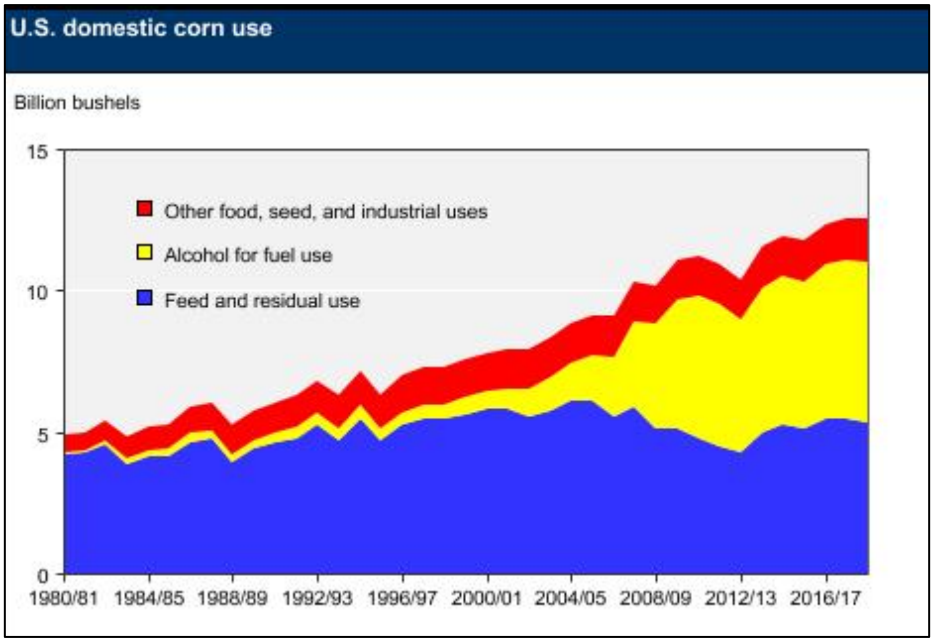

Figure 2. U.S domestic corn use from 1980 through 2016. The "alcohol for fuel use" portion shaded in yellow illustrates how the development of the ethanol market in the U.S. has been integral to absorbing a portion of increasing corn yields of this same period. From: USDA Economic Research Service.

The first subsidies on ethanol were mandated in the Energy Act of 1978 by establishing a tax exemption for ethanol as fuel [Table 2]. Numerous related federal policies followed and in 2005 the Energy Policy Act established the Renewable Fuel Standard (RFS). The RFS required all transportation fuel sold in the U.S. include a certain amount of renewable fuels, including ethanol (Tyner, 2007). The RFS was renewed with the Energy Independence and Security Act of 2007 that incrementally increased the mandated use of ethanol for transportation fuel to a projected level of 36 billion gallons by 2022 (Magdoff, 2008).

Year	Legislation	Description
1978	Energy Tax Act of 1978	$0.40 per gallon of ethanol tax exemption on the $0.04 gasoline excise tax.
1980	Crude Oil Windfall Profit Tax Act and the Energy Security Act	Promoted energy conservation and domestic fuel development.
1982	Surface Transportation Assistance Act	Increased tax exemption to $0.50 per gallon of ethanol and increased the gasoline excise tax to $0.09 per gallon.
1984	Tax Reform Act	Increased tax exemption to $0.06 per gallon.
1988	Alternative Motor Fuels Act	Created research and development programs and provided fuel economy credits to automakers.
1990	Omnibus Budget Reconciliation Act	Ethanol tax incentive extended to 2000 but decreased to $0.54 per gallon of ethanol.
1990	Clean Air Act amendments	Acknowledged contribution of motor fuels to air pollution-oxygen requirements for motor fuels.
1992	Energy Policy Act	Tax deductions allowed on vehicles that could run on E85.
1998	Transportation Efficiency Act of the 21st Century	Ethanol subsidies extended through 2007 but reduced to $0.51 per gallon of ethanol by 2005.
2004	Jobs Creation Act	Changed the mechanism of the ethanol subsidy to a blender tax credit instead of the previous excise tax exemption. Also extended the ethanol tax exemption to 2010.
2005	Energy Policy Act	Established the renewable fuel standard starting at 4 billion gallons in 2006 and rising to 7.5 billion in 2012. Eliminated the oxygen requirement for gasoline, but failed to provide MTBE legal immunity.
2007	Energy Independence and Security Act of 2007	Established a renewable fuel standard totaling 36 billion gallons (1 billion biodiesel) by 2022.

Table 2. History of ethanol subsidy legislation. The first subsidies on ethanol were mandated with the Energy Tax Act of 1978 and continued to promote the domestic use of ethanol fuel. The Energy Policy Act of 2005 significantly increased the amount of ethanol used for fuel with the establishment of the Renewable Fuel Standard. From: North Dakota Chamber of Commerce, 2006, Tyner, 2007.

Ethanol production throughout this time of federal subsidization has steadily increased [Figure 3] with a huge increase in production since the Energy Policy Act of 2005 was established and another large jump after the 2007 renewal. Ethanol processing plants are concentrated in the Upper Midwest and most heavily in regions of highest corn production areas [Figure 4].

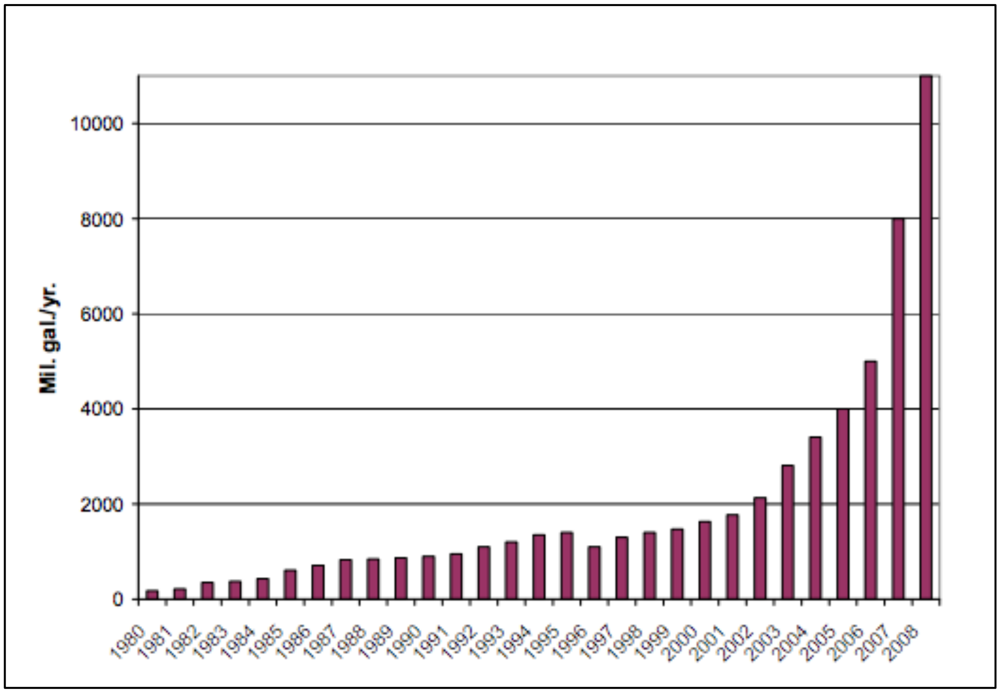

Figure 3. U.S. ethanol production steadily increased between 1980 and 2008 with significant jumps after changes in subsidies in 2005 and 2007. From: Tyner, 2007.

In 2015, agrichemical and seed company DuPont (now Corteva) built the largest cellulosic ethanol processing plant, the POET facility, in the Upper Midwest with a construction price tag of $225 million (Pentland, 2015). No doubt the company selling seeds and chemicals to corn producers in the region had a vested interest in building the facility, resulting in the continued production of corn monoculture on the landscape. DuPont sold POET to a German biofuels company just two years later after the Dow DuPont merger in 2017. The POET project received $14 million in state grants and over

$3.5 million in tax credits (Eller, 2017). This exemplifies government policies interlocking with corporate investments to develop markets and incentives for the production of corn monoculture in the Upper Midwest.

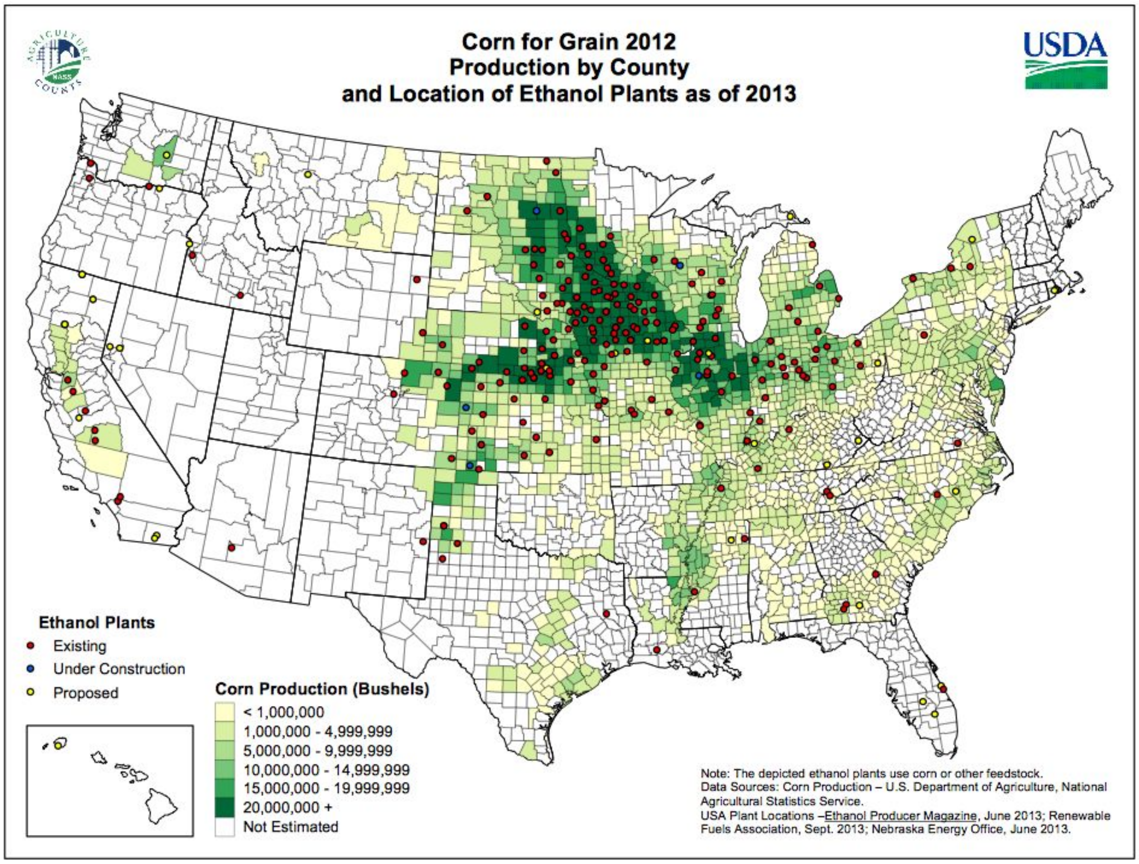

Figure 4. Corn for grain 2012 production by county and location of ethanol plants as of 2013. This map illustrates a concentration of corn produced for grain and ethanol plants in the Upper Midwest, particularly in Iowa and Southwest Minnesota. From: USDA National Agricultural Statistics Service.

The increasing use of corn grain for ethanol production was a factor in the rising cost of corn leading up to the 2008 economic crash. It is logical for farmers to sell their corn harvests for a higher price. In this way capital continues to produce corn monoculture by creating a new market for a crop that was already firmly established on the landscape. The result is increased intensification, making it more difficult for Upper

Midwest farmers to transition from monoculture cropping to diversified systems (Magdoff, 2007).

Glenna and Cahoy (2009) argue the economic benefits that corn producers are currently experiencing from the biofuel industry are not long-term. Drawing on William Heffernan's (2011) work that farmers growing commodities do not benefit from concentration in the agricultural industry, they argue that increasing patents and concentration in biofuel industry will have the same result in rural economies (Glenna & Cahoy, 2009). Another bubble set to build and burst in the agricultural sector. Will there be any soil or clean water left, before companies and governmental policies redirect capital to different investments? More likely it will produce (another) new market for the production of corn monoculture.

It's too narrow to consider that subsidies and ethanol production alone produce corn monoculture. Uneven development theory tells us that capital interrelates nature and society as it produces the landscape. Why would farmers put their land, their soils, and their water supply at risk by continuing to plant monocultures? We cannot accept that subsidies alone overwrite the agronomic reality of risk associated with continuous corn or limited crop rotation. The relationships between land tenure and adoption of sustainable practices offer insight to other motivators.

4.1.2 Which Landowners Choose Conservation?

My interviews did not include questions about farmland ownership. Some of the growers shared details about how much of the land they operated was owned or rented, but this was not the case with all interviewees. While the interview data does not include details about land tenure, the correlation between land ownership and on-farm genetic diversity is important to explore.

Conservation farming practices create changes to the biological landscape opposite the effects on monocultures. Conservation practices can reduce soil erosion, nutrient and mineral loss, build topsoil, and increase levels of beneficial soil microbial activity (Altieri, 1995). Michael Carolan (2006) identifies these ecological benefits as “nonvisible” to farmers and their communities. While it is arguable that many farmers monitor the quality of soil structure on their farms, Carolan’s (2006) point is that some environmental benefits are not as visible on the landscape in the immediate time. The benefits build with the adoption of long-term management practices like diversified crop rotations. These types of farming practices must be carried out over multiple years for the effects to be recognizable (Carolan, 2006). But not all conservation practices are long-term and not all farmers operate on land that they own, so we must consider relationships between adoption of practices that take multiple seasons for affects to be realized and land tenure.

Approximately 39 percent of all U.S. farmland is owned by “non-operators” and rented by farmers for cultivation (Bigelow, 2016). Of that, more than half of the cropland is rented and concentrated in grain production areas (Bigelow, 2016). These percentages are much higher in the Midwest where landowners who rent out land instead of farming it themselves own 84.9 percent of the agricultural land in the region (Zhang, 2015). The literature on relationships between adoption of conservation practices, farmers renting land, and non-operator owners is somewhat sparse. Nassauer, et al. (2011) argue that early literature describes these relationships in very different ways but overall conclude that there is little effect of landownership on adoption of conservation practices. A 2008 review of literature focused on the U.S. found no single factor consistently impacting the adoption of conservation practices on the farm (Prokopy et al., 2008). The increase of non-operators in the Upper Midwest makes it important to return to these questions (Nassauer et al., 2011) and tease out the critical factors, including interplay between how the type of rental agreement and landowner demographics might affect adoption of long-term conservation practices such as crop diversification.

Rental agreements in the U.S. vary and their details have important implications for the adoption of conservation practices (Petrzelka & Marquart-Pryatt, 2011; Soule, Tegene, & Wiebe, 2000). The two most common arrangements are cash lease and share crop lease. Soule et al., (2000) present two major factors of tenure's impact on conservation practices and how they vary based on lease arrangements. First is the timing, cost, and return on investment of the conservation practice. Second is how different lease agreements affect adoption of conservation practices (Soule et al., 2000).

Unlike the findings from Nassauer et al. (2011), Soule et al., (2000) state that land tenure is an important factor in adoption of both short and medium term conservation practices. In particular they show that cash renters and share renters are less likely to adopt medium-term conservation practices than owner operators. The authors attribute this to the magnitude of investment and the length of time it takes for a farmer to recover the costs. This suggests there may be strong relationships between land tenure and adoption of the long-term practice of crop diversification. Magdoff (2015) might identify this as rational behavior in their economic system. Cash renters and share crop renters who may not stay on the land for multiple season have less incentive than land owners to invest time and money into medium or long term conservation practices (Magdoff, 2015).

Daloğlu et al. (2014) created a typology of Corn Belt farmers to further tease out factors related to conservation adoption behavior. Their four types of farmers are traditional or small growers; farmers who supplement their farm with off-farm income; business-oriented growers that are medium to large in size and secure most of the income from the farm; and non-operators. Like Soule et al., (2000) their data suggest a strong correlation between land tenure and adoption of conservation practices, adding farm size, income source, and information networks as important factors. They found that not one single land tenure factor correlates to conservation adoption (Daloğlu et al., 2014).

We cannot simplify the non-operator owners by homogenizing the group and must consider this category to vary in demographics. There is a gap in the literature and strong need for further characterization of non-operator owners (Daloğlu et al., 2014; Nassauer et al., 2011; Petrzelka & Marquart-Pyatt 2011; Soule et al., 2000). Petrzelka and Marquart-Pryatt (2011) aim to understand this group more by looking at the influence of gender on non-operator conservation decisions in the Great Lakes Basin, correlating gender and power relations between landlords, tenants, and land stewardship. Their data suggests that tenants make the majority of farm management decisions, and female landlords are less involved than male landlords in decision-making (Petrzelka & Marquart-Pyatt, 2011). Specifically, their findings indicate “stark gender differences” related to both involvement in making operating decisions on a whole and specifically regarding conservation practices, with female landlords having far less power than males (Petrzelka & Marquart-Pyatt, 2011). Their study calls for further characterization of these landlord groups based on gender and how they relate to local on-farm decision making. Males operate over 66 percent of farmland in the Upper Midwest (USDA, 2017), further emphasizing this need in understanding how gender may influence adoption of crop diversification in the region.

Research is needed to characterize non-operator landowners, rental agreements, and their effects on adoption of long-term conservation practices or radical transitions on the landscape. This could offer insight into opportunities for breaking the linkages producing corn monoculture in the Upper Midwest. If I were to conduct a second round of interviews with the same twenty farmers, I would strongly consider adding questions about land ownership. It would be useful in exploring if there are correlations between managing on-farm diversity on land they operate that is owned versus rented. More broadly, addressing the gap in this research could provide important insight into farmer adoption of long-term conservation practices such as managing on-farm genetic diversity.

Corn ethanol and renewable fuel policies ensure corn monoculture continues to attract corporate capital to the land, together producing monoculture in the Upper Midwest. Both non-operator landlords and farmers renting land receive federal subsidies for continued production of corn. Is it in the landowners', renters', or societies' financial interest to adopt long-term conservation strategies such as crop diversification that protect the land's ability to produce crops? Do the long-term benefits of land's ability to produce high corn yields outweigh the immediate opportunities created by ethanol markets and subsidies? Does the financial incentive outweigh the risk of another southern corn leaf blight epidemic? In the U.S. economic system, why would these groups pivot away from corn and towards long-term conservation of diversified crop rotations? This prioritization of profit over the long-term management of land for fertility and resiliency locks willing and unwilling farmers into the system and enables the production of monoculture on the landscape.

4.2 Participatory Research: An Alternative Framework

Industrialized corn production underpinned by federal and state subsidies prioritizes profit at the cost of environmental health. While economic soundness is important for farmers and agriculture on a whole, there are other agricultural models that address this while also decentralizing corn breeding and production. My interview data indicates that farmers do not have access to genetic diversity information and perceive that genetic diversity in corn is not being managed on the U.S. landscape. Participatory plant breeding (PPB), participatory hybrid breeding (PHB), and participatory variety selection (PVS) provide alternatives that rely on farmers as active participants in variety development and seed production, rather than passive seed purchasers who must develop management strategies in the absence of information held back by companies.

4.2.1 Participatory Corn Breeding in Portugal: The Integrant Model

The Portuguese Sousa Valley Project (VASO) is the world's oldest participatory corn breeding project and was launched in 1984 by Dr. Silas Pêgo (Mendes-Moriera 2006). Underpinning the project is Pêgo's integrant philosophy, which he developed in contrast to the productivist philosophy that has driven monoculture on the landscape since the Green Revolution [Table 3] (Mendes-Moriera 2006; Pêgo & Antunes 1997). Pêgo and his colleagues designed the VASO project to test the integrant approach in on-farm polyculture systems in the Sousa Valley.

The pilot project aimed to answer a question that agriculturalists and researchers still grapple with: can we grow enough food in a sustainable way that feeds the growing population? For Pêgo and the Portuguese farmers collaborating on the project, this focuses specifically on corn and preserving the genetic diversity in open-pollinated varieties that were eroded with the introduction of high yielding hybrid corn introduced to Portugal by U.S. companies after World War II (Mendes-Moriera & Pêgo, 2012). Unlike in the U.S., Portuguese farmers operate in a context of land scarcity and high population density. The result is that farmers are not well served by the industrial agricultural model (Mendes-Moriera 2006).

Contrasting factors	Philosophical model	
	Productivist	Integrant
1. Profession of faith	Yield is the determinant factor	Farmer's decisions are rational
2. Decisive centre	The seed (breeder)	The farmer
3. Dynamic action	Centripetal	Centrifugal
4. Energy	Fossil	Renewable
5. Raw materials	Exotic, inbreds	Local adapted populations
6. Science		
6.1. Gene action	Non-additive (heterosis)	Mainly additive
6.2. Breeding methods	Genealogical selection (+) biotechnology	Recurrent selection (-) biotechnology
6.3. Pathology	Resistance	Tolerance
6.4. Technology	(+) Mechanization (+) agrochemical (-) manpower and monocropping	(-) Mechanization (-) agrochemical (+) manpower and polycropping
7. Type of seed	Hybrid, uniformity	Open-pollinated, diversity
8. Final output	High yielding, quantity	Moderate yielding, quality
9. Environmental effects		

9.1. Protection level	Soil, water and air pollution	Soil, water and air cleanness
9.2. Genetic resources	Erosion	Conservation
9.3. Farming continuity	Leading to exhaustion	Sustainability

Table 3. Contrasts between the productivist and integrant models. From: Pêgo & Antunes, 1997.

The VASO project implements Pêgo's integrant philosophy through three main components: 1) location choice, 2) germplasm selection, and 3) working alongside farmers (Mendes-Moriera 2006). The Sousa Valley region was selected in part because it is a traditional corn production area where corn still played a significant role in the polyculture system. The region also has high-quality soils and the local farmers association was supportive of participating in the project (Mendes-Moriera 2006; Pêgo & Antunes 1997).

The project includes two parallel breeding programs developed by the researchers and farmer-cooperators. The breeder's program combines three recurrent selection methodologies: phenotypic, S_1, and S_2 families (Mendes-Moriera 2006). The farmer's program uses an improved common mass selection methodology with two-parent control instead of the more traditional one parent control (Mendes-Moriera 2006).

The project has resulted in six improved populations that serve smallholder farmers growing for high-quality markets in sustainable systems (Mendes-Moriera 2006). Mendes-Moriera (2006) argues that the improved populations coming out of the VASO project can also serve as germplasm sources for the hybrid seed industry. In this way the integrant and productivist models could compliment one another and offer underserved farmers throughout the world economic opportunities in seed production. As an added bonus, this would also increase genetic resources instead of replacing them with varieties bred for high-input industrial systems.

Pêgo believed the transition to the integrant model was pivotal to the future of agriculture and noted that the VASO project was one of many possible models that could implore the integrant philosophy: "And, in between the two opposite philosophical approaches, a large spectrum of "hybrid" or complementary solutions should be required for this transition into the new century agriculture, supposed to sustainably feed an increasing world population" (Pêgo & Antunes, 1997). Conventional corn production in the United States operates within the industrial model, or what Pêgo and Antunes (1997) identify as the productivist model, and certainly several of the farmer interviewees operate within this model and seem satisfied doing so.

Conventional corn seed companies serve both conventional field and sweet corn producers in the Upper Midwest region. In contrast, small-scale organic corn growers have limited access to varieties bred for their unique environments, management needs, and certified organic markets. These producers, in particular in the Upper Midwest, are underserved by the formal seed sector. Several organic farmer interviewees discussed these constraints and their frustrations. The 'Who Gets Kissed?' project in the United States stands as another complimentary solution for the transition Pêgo envisioned, and one in which some of the organic farmer interviewees may be interested in participating.

4.2.2 Participatory Corn Breeding in the United States: Variety and Breeding Needs

Organic farmers, and public and independent plant breeders developed the 'Who Gets Kissed?' project to develop an open-pollinated sweet corn variety bred under organic systems (Shelton & Tracy 2016). The project was initiated by Martin Diffley, an organic vegetable grower in Farmington, Minnesota, and Dr. John Navazio, a scientist with Organic Seed Alliance of Port Townsend, Washington. Diffley was known in the region for his sweet corn, but was frustrated because his favorite varieties were often dropped by seed companies as they merged or closed. Diffley wanted a variety of his own. Diffley and Navazio contacted Bill Tracy a professor at the University of Wisconsin-Madison's Sweet Corn Breeding and Genetics Program (SCBGP). The three along with Wisconsin graduate students Jared Zystro and Adrienne Shelton designed a PPB project to develop a new open-pollinated sweet corn variety (Shelton & Tracy 2015).

Diffley explained the traits he wanted: excellent eating quality, good germination for direct seeding, resistance to common rust (*Puccinia sorghi*) and common smut (*Ustilago maydis*), and good stalk and root strength to ensure easy hand harvest. Tracy had two populations homozygous for the *sugary1* gene and with a high frequency of the *sugary enhancer1* allele. The populations were designated L and E. Tracy and Navazio designed a recurrent selection breeding program in which, during each summer season, 100 full-sib families from each population were grown in Farmington. Remnant seed from each family was saved in cold storage at Madison. The graduate students took data on disease resistance, germination and other plant traits. All participants were involved in quality evaluations, which made this activity much more of a social process than most plant breeding activities. Based on the data, 15 to 20 families were selected in each population. Remnant seed saved from the selected full sib families was sent to winter nurseries in Rancagua, Chile, where they were intermated within populations and full sib families were generated for the next round of selection so that a full cycle of selection could be accomplished in one year (Shelton & Tracy 2015).

They completed five cycles of selection and in 2014 chose to advance population L as new open-pollinated sweet corn variety under the name 'Who Gets Kissed?'. Given the interests of many in the organic vegetable farming community it was released with no intellectual property. Several regional breeding projects have grown out of 'Who Gets Kissed?'. Breeders and farmers in California, New Mexico, Oregon, and in Australia are adapting it their environmental conditions and local preferences. Under a PPB project led by Micaela Colley at Organic Seed Alliance in partnership with Nash's' Organic Farm in Sequim and the Organic Farm School on Whidbey Island have been adapting and selecting population E for the Olympic Peninsula in Washington.

4.2.3 Participatory Hybrid Breeding in Southwest China: A "Hybrid" Model

Pêgo identified the need for "hybrid" breeding models to serve corn growers operating in sustainable systems and with production goals that include high quality rather than simply high yield. Li and Lammerts van Bueren's work in southwest China is quite literally a "hybrid" breeding model. Their participatory hybrid breeding (PHB) model serves as a potential strategy in building seed systems that offer uniformity in the field while allowing farmers and researchers access to germplasm and genetic pedigree information (Li et al., 2012). None of the farmer interviewees discussed a desire to abandon hybrids for open-pollinated varieties. Yet the data indicates some farmers are frustrated by the lack of access to genetic background details of commercially available hybrids. These growers, as well as the organic farmer interviewees who identified the need for organic seed varieties that will thrive in their systems beyond just yields, may be strong candidates for the PHB model.

Li et al. (2012) surveyed and interviewed corn producers in southwest China about their perceptions and adoption of commercial hybrids. The data shows that farmers in the region steadily abandoned corn landraces for commercial hybrids between 1998 and 2008. Farmers cited the advantages of higher yields and lodging resistance that hybrids provided (Li et al., 2012). They also noted disadvantages including poor adaptability to their region, low seed quality, lack of availability of information about cultivars, and poor seed availability (Li et al., 2012).

The shift to commercial hybrid use is eroding landraces throughout the region, decreasing their quality and increasing vulnerability. This is leading to more abandonment by farmers (Li et al., 2012). The erosion of landraces is particularly concerning in light of the narrow genetic base of commercial hybrid varieties in China where 91.6% of the varieties are based on about 20 elite inbred lines (Li et al., 2002; Yao et al., 2007). Yet smallholder farmers in the region demand hybrid corn varieties for their increased yield and overall performance.

	Participatory breeding approach				Classical breeding approach	
	Population breeding[†]		Hybrid breeding		Population/hybrid breeding	
Breeding steps	Farmers	Breeders	Farmers	Breeders	Farmers	Breeders
Defining objectives						
Evaluating existing varieties on-farm	X	X	X	X	–	X
Prioritizing preferred traits and preferred diversity	X	X	X	X	–	X
Creating genetic variation						

Collecting, maintaining, and/or creating diverse (base) populations	X	X	X	X	–	X
Identifying crossing parents	X	X	X	X	–	X
Making crossings for OP breeding	X	X			–	X
Making crossings for hybrid breeding			–	X	–	X
– producing inbred lines			–	X	–	X
– making test crosses			–	X	–	X
– improving inbred lines			–	X	–	X
Selection (including test cross evaluation)						
In field (on-station and in multi-locational farmers' fields and kitchens)	X	X	X	X	–	X
In lab (e.g. disease resistance and quality tests)	–	X	–	X	–	X
Testing and evaluating expected varieties	X	X	X	X	–/X[§]	X
Registration	X	X	?	X	–	X
Seed production						
Parental seed provision	X	X	?	X	–	X
On-farm seed production	X	X	?	X	–	X

Table 4. Potential roles of farmers and breeders in participatory breeding approaches versus classical breeding approaches. From: Li et al., 2012.
X, yes; –, no; crosshatch, no applicable; ?, depending on institutional options.
[†]Including breeding for self-pollinating and cross-pollinating varieties.
[§]Depending on less (–) or more (X) active participation of farmers in evaluating expected varieties, such as in PVS.

PHB offers an opportunity for farmers and breeders to collaborate on developing hybrid varieties while preserving the farmer breeder relationship and centralizing farmers' needs. In PHB, farmers are involved in each step of the breeding process from identifying breeding goals and germplasm selection to be used for parents, to licensing agreements for commercialization (Li et al., 2013). Hybrid corn development on smallholder farms is challenging due to agronomic and biological issues. But breeders can manage tasks such as crossing at their research stations and include farmers in evaluating these before testing on-farm (Li et al., 2013). Breeders and farmers must negotiate agreements for ongoing seed production of finished hybrid varieties as part of the project. Like PPB, the model can take several manifestations based on resources, collaborators, motivations, and end goals.

4.2.4 Wisconsin and Participatory Variety Selection: An Historical Perspective

Both the PHB and the Wisconsin Experiment Station's participatory variety selection (PVS) models might be a good fit for farmer interviewees like A.K. who identified conducting extensive on-farm trials as a management strategy. Collaboration between farmers and researchers was a rich part of public breeding programs in the United States in the early to late 1900s. The Wisconsin Experiment Association was established in 1901 and included former and current agricultural students of University of Wisconsin charged with growing and disseminating new varieties and plants, and providing agricultural research information to farmers throughout the state (Norskog, 1995). In 1904 the Association arranged the first corn test plots in collaboration with 276 growers (Norskog, 1995). These on-farm tests expanded and in the 1930s were pivotal in developing corn hybrids adapted for the region (College of Agricultural & Life Sciences, 1986).

By the mid-1930s farmers throughout the state were adopting hybrid varieties and contracting with the university to produce hybrid seed crops. The number of farmers who became hybrid seed corn producers grew exponentially. In 1934 twenty farmers produced

1,800 bushels of seed on 109 acres (College of Agricultural & Life Sciences, 1986). That number grew to 433 farmers producing 340,000 bushels on 8,250 acres by 1940 (College of Agricultural & Life Sciences, 1986).

The Wisconsin Foundation Seed PVS model helped drive the hybrid seed production industry throughout the state. Famers were able to trial and license inbreds from Wisconsin Foundation Seed (Brickbauer, 2007; College of Agricultural & Life Sciences, 1986). They could use the lines to develop and sell their own unique hybrids, resulting in a bustling corn seed production industry throughout the state (Brickbauer, 2007; College of Agricultural & Life Sciences, 1986). This is in sharp contrast to today's unprecedented privatization and concentration of corn and breeding in the U.S. The result is a nearly extinct independent seed corn sector and has left small and medium sized corn producers with only one choice in their hybrid selection: from which company they choose to buy their seed.

4.3 Seed Relabeling: What's in the Bag?

Smith (1988) highlights the lack of genetic background information available to farmers, in particular relabeling, which is the practice of multiple seed companies selling the same corn variety under different names. My interview data indicates that relabeling is a practice that farmers must be aware of and develop strategies to avoid unknowingly planting the same corn variety. This is important to farmers who manage surface level on-farm diversity by planting multiple varieties each year, in particular for those planting a limited number of them on their farms.

A.K. discussed the ways in which some companies use genetic diversity as a marketing tool, including Beck's Hybrids and his precision planter dealer who was trying to sell him a $40,000 upgrade to a multi-hybrid planter. Genetic diversity is at the core of the Farmer's Business Network's (FBN) marketing strategy. According to it's website, "The FBN farmer-to-farmer network helps producers level the playing field by creating unprecedented transparency and competition…" (Farmer's Business Network, 2020). The company offers farmer members analytic tools, marketing products, seed and chemical inputs, financing, crop insurance, and health coverage.

FBN presents its analytic tools as "democratizing farm data." Among their many offerings is the FBN Seed Finder. The Seed Finder database is populated with information from seed tags submitted to the company by farmers in the network. Farmers send photos of their seed tags to FBN, which include the original variety name as per federal and state seed labeling regulations [Figure 5]. FBN analyzes the seed tags and uses this information to populate the Seed Finder database.

About two months after I interviewed him at his farm office in Iowa, I received a text message from R.P. about FBN's Seed Finder: "*Got the login to get trait info on corn hybrids. Email is [OMITTED]. Password is [OMITTED]. Go to seed finder. Click on also sold as*."

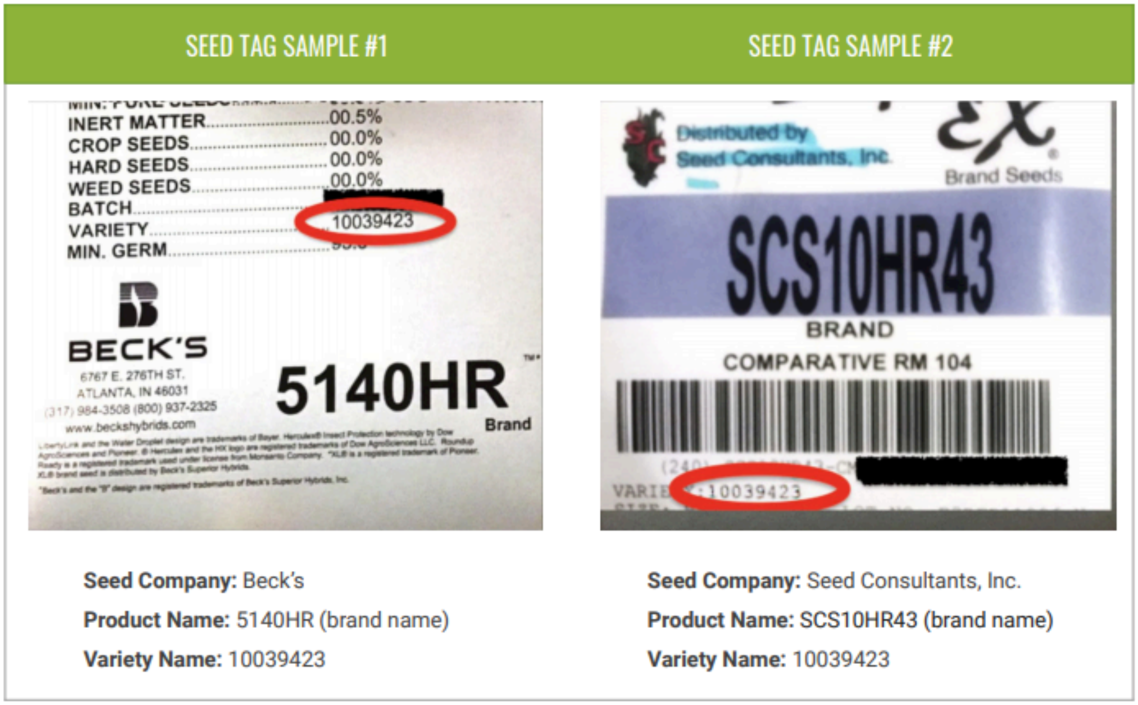

Figure 5. Two seed tags sent to FBN by farmers in their network. These tags are from different companies who have named the same corn variety 10039423 as two different varieties. From: Farmer's Business Network, 2020.

Farmer members can search varieties within the database and access a breadth of information to inform planting choices. Among these details is the ability to see if a variety is being sold under different names and if so, what they are. This helps ensure growers who purchase seed from multiple companies or multiple brands owned by the same company [Table 5] they are not getting the same varieties relabeled as something else.

Bayer	Syngenta	Corteva Agriscience	Agreliant
Dekalb	NK Seeds	Pioneer	AgriGold
Channel	Golden Harvest	Mycogen	LG Seeds
Fontanelle	Phoenix	Brodbeck*	Producers Hybrids*
Gold Country Seed	Innotech	Dairyland	Great Lakes*

Jung Seed Genetics	AgriPro	Pfister*	Wensman*
Kruger Seeds		Prairie Brand*	Golden Acres Genetics*
Lewis Hybrids		Agventure	Pride
REA Hybrids		Curry Seed Company*	
Specialty Hybrids		Hoegemeyer Hybrids	
Stone Seed		NuTech Seed	
Stewart Seeds		Terral Seed	
Hubner Seed		Doeblers Pennsylvania Hybrids*	
Westbred		XL Brand Distributed by Beck's Hybrids	
Asgrow		Power Plus Distributed by Beck's Hybrids	
		Seed Consultants	

Table 5. Seed companies and their brands. *Indicates the company/brand has been phased out. From: Farmer's Business Network, 2020.

Seed relabeling issues and farmers' rights to transparency appear to be core tenants of FBN's work. According to their data, about half of all corn and soybean seed on the market is relabeled (Farmer's Business Network, 2020). Among the farmer testimonials on their website is one who said, "Somebody's finally standing up for the farmers. Somebody is finally saying, 'You have some control'" (Farmer's Business Network, 2020). And it appears that plenty of farmers are ready to have more control. Since it's launch in 2014, the network includes over nine thousand farmers managing millions of acres (Farmer's Business Network, 2020).

My interview data indicates that farmers' relationships with seed dealers are central strategies to some in managing on-farm genetic diversity. What's troubling is the extent to which some of the farmers, like L.G., trusted that their seed dealer had access to parental background information on the varieties and use it to make variety suggestions. FBN's Seed Finder offers those "nerdy farmers" this information and control over their variety selections.

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Chapter 5. Conclusion

Few if any corn producers in the Upper Midwest have access to genetic background information of the seed they purchase. This thesis set out to understand farmers' perspectives and strategies for managing on-farm genetic diversity in their corn crop.

Farmer interviewees indicated that largely Upper Midwest corn producers do not have access to genetic background information of the seed they purchase. Interviewees described a range of strategies they use to manage on-farm diversity in their corn acres and the most salient was planting multiple varieties each year. This represents surface level on-farm genetic diversity. Next steps in research should include collecting data on top corn variety sales in the Upper Midwest to better understand the surface level on-farm diversity. This data could be triangulated with seed company offerings, which would indicate if there are differences between availability and planting.

Most of the farmer interviewees discussed the practice of planting multiple corn varieties in a season as a risk deterrent strategy. Interviewees identified this surface level diversity management as a tool to mitigate changes in climate and pest pressures. However, most of the farmer interviewees grow corn monoculture despite these same risks associated with this cultivation practice. Federal and state subsidies and policies that encourage farmers to grow corn for ethanol, coupled with corporate investments are producing monoculture in the Upper Midwest. To better understand why some farmers expose themselves to the risks associated with cultivating monoculture, we must consider land tenure and ownership in the region.

Over 84 percent of the agricultural land in the Upper Midwest is rented out to farmer operators. Both non-operator landlords and farmers renting land for cultivation receive subsidies to produce corn. The literature on the relationships between famers cultivating rented land and adoption of long-term conservation farming practices such as managing on-farm genetic diversity is somewhat sparse but indicates a correlation. More research is needed to better characterize non-operator landowners, rental agreements, and their effects on farmers adopting long-term conservation farming practices. Given the large percentage of land in the region that is rented out, addressing this gap could provide useful insights into corn growers in the Upper Midwest adopting important conservation practices such as managing on-farm genetic diversity.

Some of the farmer interviewees seem satisfied to operate within the productivist model of conventional corn production in the Upper Midwest. Others, in particular several of the certified organic interviewees, discussed being underserved by conventional corn seed companies. Models such as participatory plant breeding, participatory hybrid breeding, and participatory variety selection serve as alternatives to industrial breeding. These participatory research methods centralize farmers' needs and rely their partnership in developing new varieties. Farmer interviewees who expressed frustration with being underserved by the productivist model might be candidates for participatory research programs aimed to develop corn varieties that will thrive in their systems.

Interview data also shows the importance of farmers' relationships with seed dealers in attempting to manage on-farm genetic diversity in their corn. This appears to be a central tenant to many farmers in selecting their corn varieties each year. There was a range of perspectives about what genetic information seed dealers have access to and are able to draw on when making variety recommendations. I hypothesize that most, if not all, companies do not make this data available to their seed dealers. Given the importance of these relationships and the reliance on their expertise in managing on-farm diversity, semi-structured interviews with a set of corn seed dealers from several companies would provide useful information in understanding their roles and what information they have access to from their company.

A deeper understanding of seed relabeling in terms of legality and persistence in the marketplace is important, given farmer interviewees' core strategy for on-farm genetic diversity management is planting multiple varieties each year. Farmers planting limited varieties on their acres are particularly at risk to narrowed diversity if they unknowingly plant the same variety listed under different names. An extension report or articles in farmer publications that describe the seed relabeling and ways to avoid purchasing the same seed from different sources would be a useful contribution to the farming community.

Corn monoculture is embedded on the Upper Midwest landscape and understanding the in-species diversity can help us understand just how drastic and vulnerable it is. An assessment of parental genetic diversity in hybrid corn seed sold to U.S. growers annually is needed to analyze susceptibility to biological epidemics on the landscape. Given current intellectual property restrictions on seed, we must develop policies that allow federal and public entities to measure on-farm genetic diversity in major crops. Genetic diversity can be measured on multiple levels: genetic background, through time, and across landscapes and regions. Defining healthy and vulnerable levels of genetic diversity in each of these levels is also needed for future research.

Contemporary research focused on measuring on-farm genetic diversity of corn in the U.S. is extremely limited, due in part to intellectual property restrictions. This thesis identifies the gap in research, and offers reasons why assessing the genetic vulnerability in the corn monoculture in the Upper Midwest is imperative and presents a breadth of farmer perspectives of and strategies for managing on-farm diversity in their corn acres.

In the U.S., we have turned over the bulk of commercial corn germplasm to private companies. I have no doubt there are a number of scientists within these companies who are thinking critically about the importance of maintaining healthy genetic diversity on the farm and in the company. But at the end of the day, do we want to rely on their word or do we want to rely on data?

Markets change. Climates change. Farm practices change. What doesn't change is human reliance on seed. We need more than handshake to ensure our seed resources are being stewarded in our collective best interest.