CONTINUAL GROWTH:

FARMER PERSPECTIVES AND EXPERIENCES INTRODUCING THE NOVEL PERENNIAL GRAIN, KERNZA

by

Marisa K. Lanker

Thesis submitted in partial fulfillment of the requirements of
Master of Science
(Agroecology)

University of Wisconsin-Madison
2018

TABLE OF CONTENTS

ACKNOWLEGEMENTS

This research would not have been possible without the willing and active involvement of the participant farmers, to whom I offer the utmost gratitude for offering their time and thoughts in the midst of a busy growing season. I would also like to thank my advisors, Valentin Picasso and Michael Bell, for their continual guidance over the past two years. To Kelly Maynard, thanks for sharing efforts and findings. I appreciate my lab mates—Nicholas, Kate, Joe, Jeremie, Joel, and Xu— who were abundantly giving in their support of my research endeavors last summer. I am grateful to the strong women at Plovgh, who sat down to share ideas and information with me amidst their busy schedules. To the Land Institute, I of course must also extend thanks for the vision which is the origin of this research. Thanks to those deep-listening friends who have become better than me at spreading the Kernza word wide-and-far. Thank you to my mother for checking in on my mental wellbeing, to my Aunt Lois for providing a happy resting place during some of my farm travels, and to my father for joining me in navigating rural Illinois with nothing but an atlas, an endless smile, and a fishing pole in the trunk.

ABSTRACT

Kernza is a novel perennial grain crop with ecosystem service potential, which commercial growers have recently begun to introduce onto their farms. Yet, no prior research has been conducted with Kernza growers as subjects. Through qualitative methods of in-depth interviews with Kernza growers, this agro-eco-sociological study aimed to understand 1) why farmers begin to grow Kernza and 2) how Kernza is fitting into growers' farm systems. Findings revealed that adoption/diffusion theory is not suitable to explain why farmers' begin to grow Kernza. A politicized actor-network theory framework better illuminates the case of Kernza, where both the crop and the growers are agents in Kernza's introduction to the farm. Kernza played a marginalized role in growers' farm systems and varied in the degree to which it matched existing farm structures, both of which shaped farmers' overall experience of growing Kernza. Growers utilized and valued Kernza as a multiple-use crop, with less emphasis on grain production. Kernza growers expressed desire for clearer guidance on planting, coping with decreased yields over time, and handling markets and economics.

INTRODUCTION

Breeders and researchers commonly promote novel crops on the basis of the potential of their distinct agronomic characteristics. However, in order for the novel crop to claim a significant portion of the agricultural landscape, its agronomic characteristics must fit into the larger picture of agricultural systems, farming systems, and their farmers. The perennial grain Kernza, an intermediate wheatgrass (*Thinopyrum intermedium),* is unique in that its promoted agronomic characteristics relate to its potential environmental-benfits. Kernza advocates even promote it as a possible paradigm-shifting agricultural crop (The Land Institute, n.d.). Still, work around Kernza could falter if it fails to deeply engage farmers and understand their livelihoods as a priority (Farrington & Martin, 1988; Leeuwis & Van Den Ban, 2004). Farmer engagement and understanding is especially critical for a novel crop at Kernza's stage, where it is simultaneously still in development while also beginning to be commercially grown.

At this stage, the first Kernza growers take more risk in growing the new crop, since much is still yet uncertain about best growing practices for optimized and enduring yields, including regional specificities and ideal equipment/infrastructure needs (Ryan et al, 2018). These farmers' experiences growing Kernza now could significantly shape the viability for expansion of Kernza growth into the future. Initial Kernza growers require support and guidance in their cultivation of this new crop in order to realize positive outcomes from adding Kernza to their farm systems. This research thus seeks to compile and synthesize practical information about the farm-based practice of growing Kernza, as expressed by the farmers themselves. It aims to inform how further Kernza development could suit on-farm settings and Kernza farmer livelihoods.

As follows, this paper will present the background on Kernza in the next section, move to an exploration of Kernza ‘adoption’ by growers in the first chapter, then continue on to an assessment of the fit of Kernza into growers’ current farm systems, and will lastly summarize conclusions in the final section.

BACKGROUND

The connection between industrial agriculture and global environmental degradation generates concern among farmers, consumers, and policymakers (FAO, 2011). Yet, the scale of the problem often overwhelms. Question has been raised as to whether small shifts to the dominant overarching agriculture-food system can piece together to form a cohesive solution which undoes our destructive track (Valenzulea, 2016). Rather, some contend that any true solution must mean a shift into entirely different systems of agriculture (Valenzuela, 2016). An implicit aspect of the current global agricultural system is the dominance of annual crops, such as rice, wheat, and corn (Awika, 2011; Monfreda et al, 2008). Grains are the world's most pervasive crop, accounting for the majority of the world's diet and occupying the majority of global croplands, and virtually all of them are annuals (Awika et al, 2011; Monfreda et al, 2008). Reliance upon annual grain is literally engrained in social and economic systems.

Yet, the practices accompanying annual grain agriculture bring environmental and societal damage (Pimentel et al, 2012). Consistent heavy irrigation drains underground aquifers and dries up rivers (Dalin et al, 2017). Plowing the soil to prepare the ground for each season's planting, fossil-fuel-powered tractors not only consume diminishing non-renewable resources, but also release greenhouse gas emissions, contributing to climate change (Shamsudheen et al, 2014). Tillage receives additional criticism for its instigation of soil erosion (Blanco & Lal, 2008). Other practices involved in annual agriculture compound soil erosion issues. Fields left bare, without an herbaceous cover or stabilizing roots, between one season's harvest and next season's growth easily lose topsoil to wind and precipitation (Durán Zuazo & Rodríguez Pleguezuelo, 2008). As fields lose topsoil, so too they lose nutrients. Fertilizers, often chemical, replace these lost nutrients. Frequently, they run off with the soil into waterways where they pollute drinking water, spur eutrophication in lakes, and poison aquatic species (Durán Zuazo & Rodríguez Pleguezuelo, 2008). What's more, when annual agriculture happens on marginal lands, such as steep, easily-eroded slopes, its environmental repercussions become amplified (Blanco & Lal, 2008).

The ecological problems resulting from conventional annual agriculture become social problems as continual loss of farmland quality and productivity undermines farmer livelihoods and as the global community absorbs the repercussions of pollution, resource loss, disrupted ecosystems and ecosystem services, and climate change (Panagos et al, 2018). The inputs which annual agriculture requires also produce social problems. Collectively, all the inputs—fuel for multiple runs of the tractor, running irrigation systems, fertilizers, pesticides—are expensive (Sands & Westcott, 2011). So too is the seed, which needs to be repurchased each year. Patented hybrid seed—which produce the dominant annual grains, corn and soybeans—are illegal to save for future plantings and, even if saved, would not produce the same desirable traits as the first generation (Clayton et al, 2009). Thus, annual grain agriculture can become costly for small and medium farmers.

The accumulating dangers of annual agriculture have not gone unseen. Responses have at-large consisted of piecemeal changes to the annual agriculture system. Cover crops, conservation tillage, proper fertilization rates and timing, and other like-motivated practices are all intended to mitigate the negative environmental effects of annual agriculture. However, some contend that such mediating practices actually contribute to the issue by enabling the dominant system to continue. In other words, annual agriculture with no-till and a winter rye cover crop is still annual agriculture. Indeed, practices intended to stymie one harm often unintentionally exaggerate another. For example, in order to maintain a no-till field, a farmer might resort to spraying otherwise-not-used herbicide to kill off a cover crop before the spring planting. A systemic issue requires a systemic solution. The root of the problem is not the practices but the paradigm. It is in this line of thinking that an alternate system has been forwarded, that of perennial grain polycultures.

Wes Jackson proposed the concept of perennial grain polycultures in *New Roots for Agriculture* shortly after initiating The Land Institute in 1976 (1980). The Land Institute and its collaborators' research for the past 40 years has involved an increasingly-heavy focus on breeding to produce agriculturally-viable domesticated perennial grains. Inspired by natural prairies, the perennial grain polyculture forms the core of The Land Institute's vision of 'natural systems agriculture' (Coz et al, 2010; Jackson, 1980).

Perennial grain polycultures could potentially bring the cyclical and regenerative aspects of natural ecosystems to agroecosystems. Perennials, lasting beyond a singular season, need only one pass of the tractor to plant seed for production throughout multiple years (Glover et al, 2010; Kane at al, 2016). They produce a constant plant cover, providing an above-ground herbaceous layer as well as a below-ground root network (Glover et al, 2010; Gonzalez-Paleo, 2016). Both decompose to provide more nutrient-rich organic matter for the soil. The former protects the soil from the elements while the latter holds the soil in place, creates good soil tilth, and absorbs excess water, all of which combat erosion. The aforementioned roots also grow deeper and more extensive, as perennials allocate more energy toward the physiological structures that enable them to persist longer-term. As a result, perennials can more readily take up water and nutrients already available in the soil, meaning lower irrigation and fertilizers needs (Glover et al, 2010). The more abundant and earlier-season herbaceous production by perennials requires more photosynthetic action, which could translate to higher carbon dioxide sequestration from the atmosphere (Glover et al, 2010; Gonzalez-Paleo, 2016). All these factors taken in conjunction, perennial grains have the capacity to decrease soil erosion, increase soil health, prevent nutrient run-off, diminish chemical pollution, lower fossil fuel consumption, and lessen the agricultural contribution to climate change (Glover et al, 2010). The organic matter provision, soil stabilization, and more extensive nutrient uptake characteristics of perennial grains make them excellent candidates to grow with less harm on, or even restore, marginal lands (with steep slopes and/or poor soils) already ravaged by annual grain fields (Glover et al, 2010).

Still, to reduce the argument for the promise of perennial grain polycultures to a list of potential benefits may imply a similar reductionism that afflicts the paradigm of annual grain agriculture. Outcomes of large-scale perennial grain agriculture would be systemic with complex, branching effects and feedbacks. Overall, perennial grain polycultures could prove more self-regulating and resilient. The social implications of such a system could be important. Perennial crops' higher durability through variable conditions of weather mean farmers may stand less risk in bad years (Glover et al, 2010). With lower inputs for several years of crop harvest from one year's seed, agriculture's financial burden diminishes greatly, so both sticking with farming—for small and medium farmers—and entry into agriculture—for new farmers—may become more accessible (Glover et al, 2010). Further, after their initial planting year, perennial grains demand minimal labor, creating a manageable workload for small and medium farms with little budget for hired hands. Perennial grains are thus not just more ecologically suitable for marginal lands but are more socially and economically suitable for marginalized farmers. Since marginalized farmers typically occupy marginal lands, perennial grains may hold significance for them.

With all the theoretical promise of perennial grain polycultures, the compelling question is whether the on-the-ground application and operation of perennial grain polycultures will fulfill expectations. While the majority of the Land Institute's perennial grain plants require more years of breeding progress to become possible crops, a certain perennial grain has made significant breeding gains toward prime perennial grain crop candidacy. It is not only being grown in experiments at agronomic research stations but has also made its way into farmers' fields. Kernza, intermediate wheatgrass (*Thinopyrum intermedium)*, is grown, harvested and sold by select growers throughout the upper regions of the United States, particularly the Midwest. Market interest has greeted the supply, as artisan bakeries and farm-to-table restaurants turn Kernza grain into breads, crackers, and pastas. With the release of Patagonia Provisions' Long Root Ale beer (brewed from Kernza grain) and the announcement of General Mills' Kernza research investment, the demand for and publicity around Kernza is on the rise. Plovgh, the distributor of Kernza seed to growers and the buyer of Kernza growers' grain harvests as well as the managing party of the Kernza trademark, has been receiving increasing requests from farmers looking to start planting Kernza in their own fields.

However, amid this building momentum, much remains to be understood about the viability of Kernza as a crop that fits into the needs of a farmer livelihood and the structures of a farm system. A few research publications have assessed perennial grain potential utilizing farmer subjects *interested* in growing perennial grain, but not farmer subjects actually growing perennial grain (Adebiya et al, 2015; Marquardt et al, 2016). A research-based evaluation of the successes or challenges faced by the farmers growing Kernza has yet to be published. If farmers continue to be left out of the loop, Kernza will stay in the minds of perennial grain visionaries, breeders, and researchers, never fruitfully spreading across farmers' fields as more than an experimental or niche crop, much less to the extent of transforming the agricultural landscape. Thus, in an aim to garner a more comprehensive, nuanced, and systemic picture, this research engages farmers on the question of the on-the-farm implications of Kernza agriculture.

METHODS

The methodology for this project comprises semi-structured, in-person individual interviews of Kernza farmers in the U.S. Midwest. The interview questioning focused on 1) why the farmer decided to grow Kernza; 2) the methods the farmer has utilized to grow and harvest Kernza; 3) the farmer's assessment of positive and negative aspects of growing Kernza, including agronomic, economic, and social aspects; 4) questions/uncertainties on Kernza production about which the farmer seeks information; and 5) improvements/changes to Kernza systems desired by the farmer (Appendix).

I completed 10 interviews with current Kernza farmers. I identified these participants through Plovgh's list of official Kernza growers. At the time of conducting the research, this list included 36 farmers, four of whom my outreach to farmers identified were not actually growing Kernza. The research sample size thus represented approximately 31% of the identified Kernza farmer population. Interviews took place in-person at each farm during June and early July of 2017. The on-site visits also enabled the collection of observational data about each farm's physical characteristics and socio-familial dynamic, and its Kernza field condition (Photo 1). All interviews were transcribed and then coded to identify themes.

I also followed the internal and external dialogues of the larger Kernza network, including involved breeders, researchers, growers, organizations, and businesses, by attending the Land Institute's fall 2016 Prairie Festival in Salina, Kansas, the summer 2017 Annual Kernza Meeting in Minneapolis, Minnesota, the fall 2017 Green Lands Blue Waters Conference in Madison, Wisconsin, and Kernza talks at the MOSES (Midwest Organic and Sustainable Education Service) farming conferences in spring 2017 and 2018 in La Crosse, Wisconsin. This enabled me to situate farmers' perspectives into the broader context of the pre- and post- farm complexities of Kernza's ongoing development.

Photo 1. Taking samples in a Kernza stand

Farmer Participants Description

The ten farmers who participated in the research were geographically located throughout the U.S. Midwest, with farms in Illinois, Wisconsin, Minnesota, and Iowa (Graph 1). All participants were male (Table 1). They ranged from 30 to 80 years old, with most on the older side of that age range—two farmers were in their 30s and the rest were above 50 years old. Participants had 7 to 61 years of farming experience. All participants grew up farming, so differences in years of farming experience were a result of age and time spent away from the personal farm to travel for other agricultural work. Eight of the ten growers cited their farm as their primary source of income.

Sizes ranged from 160 to 10,000 acres, with three small farms (less than 400 acres), three medium farms (400 to 1,000 acres), and four large farms (greater than 1,000 acres). Most participants grew soy (10 farmers), small grains (9 farmers), and corn (8 farmers). All but one grew alfalfa/clover and/or perennial grasses. Four had livestock on their farm, four grew forage crops for seed, and one had woody perennial crops. Except for one corn-and-soy farmer, farms were diverse, relying on at least four different crop types and incorporating frequent rotations, including of new crops/crop varieties. Most of the farms were at least semi-organic (4 entirely organic, 3 organic-conventional mix), with only three farms being entirely conventional, excluding their Kernza field, which was organic. Six of the farms utilized their family as a source of labor, meaning the labor force depends upon the size and contribution of the family, occasionally with the addition of part-time hired hands. Only three farms had a full-time hire.

Two farms had small amounts of land used for Kernza cultivation (1 and 2 acres), six had medium amounts (8, 8, 11, 14, 15, and 16 acres), and 2 had large amounts (27 and 38 acres). Four participants were new Kernza growers, having planted their first Kernza stand in fall 2016 and not having reached their first harvest period by the time of my farm visit and interview. Six participants were experienced Kernza growers, with stands of two to six years old. All farmers were growing their Kernza either officially or unofficially organically (on organically-certified land versus not on organically-certified land, but without non-organic inputs).

Graph 1. Geographic Distribution of Farmer Participants (number per state)

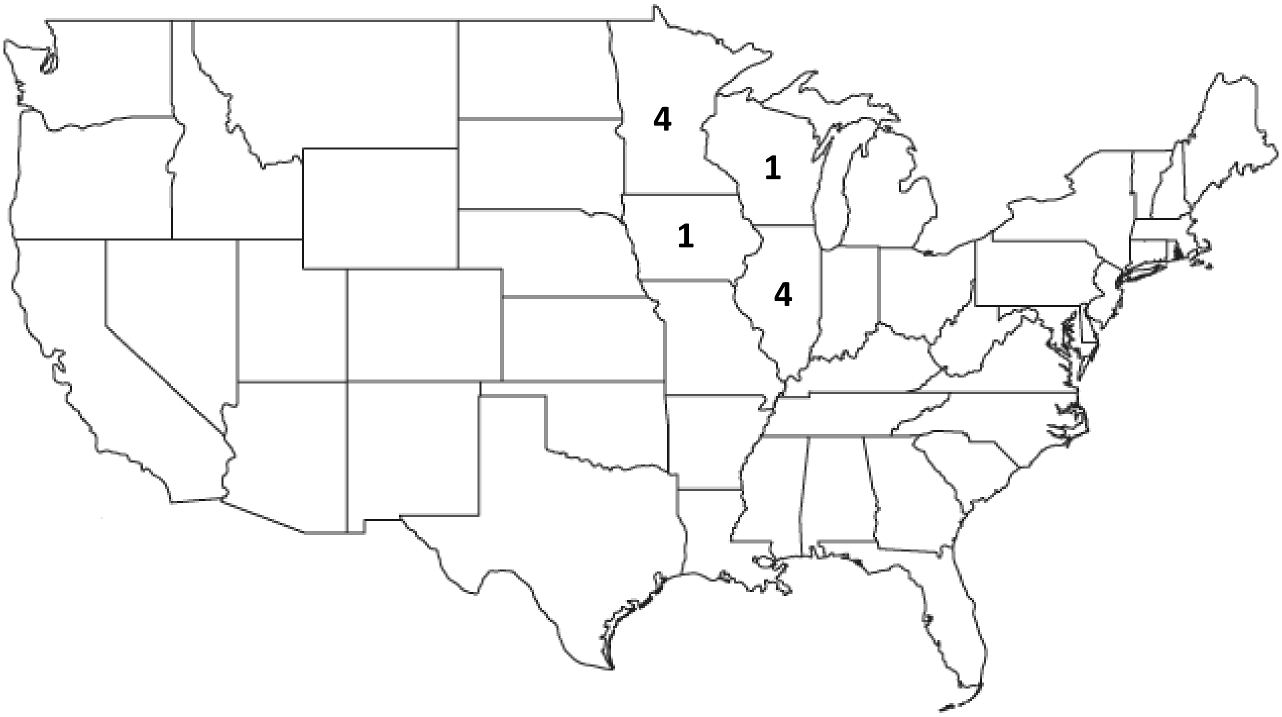

Table 1. Farmer Participants' Farm Characteristics

Farmer	Gender	Age (yrs)	Years Farming	Grew Up Farming?	Farm Management	Total Farm Area (ac)	Organic/ Transitional Area (ac)	Number of Main Crops	Livestock?	Size of Work force	Farming as Main Income?	Kernza Start Date	Years Growing Kernza	Kernza Area (ac)
1	M	80	61	Yes	Mixed	2100	1000	4	Yes	Medium	Yes	Fall 2016	1	10-12
2	M	64	7	Yes	Conventional	550	0	2	No	Small	Yes	Fall 2016	1	8
3	M	76	54	Yes	Organic	>2000	>2000	7	Yes	Medium	Yes	Fall 2011	6	27
4	M	56	35	Yes	Conventional	10000	38	5	No	Medium	Yes	Fall 2014	3	38
5	M	30	8	Yes	Conventional	500	14	4	No	Medium	Yes	Fall 2014	3	14
6	M	56	30	Yes	Mixed	160	50	5	No	Solo	No	Fall 2016	1	16
7	M	60	52	Yes	Mixed	1200	200	4	Yes	Small	Yes	Fall 2016	1	14-16
8	M	36	12	Yes	Organic	350	350	7	Yes	Small	No	Fall 2015	2	8
9	M	76	45	Yes	Organic	400	400	4	No	Solo	Yes	Fall 2011	6	2
10	M	60	>30	Yes	Organic	320	320	5	Yes	Large	Yes	Fall 2014	3	1

Farmer ‘Adoption’ of Kernza

Adoption/Diffusion of Innovation Literature

The reasons and rates of adoption and diffusion of innovations have long been a focus of research, especially in agriculture. The main origins of the dominant theory of adoption/diffusion can be traced to Ryan and Gross’s 1943 study of hybrid seed corn, which spurred the development of the bell-shaped curve of innovation adoption (Simin & Jankovic, 2014; Valente & Rogers, 1995). In 1962, Everett Rogers’s publication of *The Diffusion of Innovations* brought the tenants of adoption/diffusion theory to rural sociology. After that point, it became the standard theory utilized by agricultural extension agents and agricultural marketers and endures today as the fifth edition of Rogers’s book was published in 2003 (Padel, 2001).

Standard adoption/diffusion theory defines adoption as, “the continued usage of a practice. In terms of time, adoption takes place at the point in time when the farmer has decided he is satisfied with its use and will continue to use the practice in the next decision-making period” (Beal & Rogers, 1962, pp. 4). The process of adoption focuses on the individual-scale adoption of an innovation, examining the causal patterns and actions leading to an individual’s adoption. An individual moves through five stages on the trajectory toward eventual innovation adoption: awareness, information, application, trial, and finally adoption (Beal & Rogers, 1962). Diffusion, on the other hand, deals with the dissemination of an innovation through the population of potential users over time. The diffusion process focuses on the social flows of ideas and communication (Beall & Rogers, 1962).

Adoption/diffusion theory asserts that diffusion of innovation adoption follows an S-shaped/bell-shaped curve, where the rate of adoption starts off low, increases until reaching a peak, decreases, and returns to a low rate (Beal & Rogers, 1962; Rogers 2003). Adopters are categorized by where they fall along this curve. 'Innovators' and then 'early adopters' are the minority at the beginning of the curve. The 'early majority' follow. After the adoption rate peak come the 'late majority. Finally, the 'laggards' make up the minority at the tail of the curve (Diederen et al, 2003). Innovation/diffusion research explains the spread of an innovation across a population through the spread of information across networks (Beal & Rogers, 1962). Thus, innovators and early adopters have been represented both to have higher levels of social capital as well as to be better-informed than the later adopters (Simin & Jankovic, 2014).

However, for an innovation to be diffused, adoption/diffusion theory expects it meets certain requisites. Three key requisites are that the innovation be divisible (testable on a small scale), low risk, and of obvious economic advantage (Beal & Rogers, 1995; Padel, 2001; Simin & Jankovic, 2014). Beyond these requisites, farmers' adoption of an innovation on the individual-scale, according to adoption/diffusion theory and resultant research, is largely determined by farmer characteristics (Beal & Rogers, 1962; Padel, 2001; Simin & Jankovic, 2014). Practical characteristics (such as farm size, existing capital, region/land type, crop type) are related to the financial logic of innovation adoption. What cannot be explained through practical characteristics is explained through characteristics of farmer attitude. Research especially examine attitudes toward risk and uncertainty and toward ingenuity (Baerenklau, 2005; Jensen, 1981; Just, 1974; Marra et al, 2002). Generally, innovators and early adopters are expected to be less averse to risk and uncertainty and to have more innovative characters (Padel, 2001).

This dominant theory of innovation/diffusion emerged within a distinct historical context. Rogers's *Diffusion of Innovations* was published alongside the occurrence of the Green Revolution (Simin & Jankovic, 2014). The theory grew in-line with the agricultural paradigm of the time which prioritized high production. It thus developed more for, as Rogers described, ‘hardware’ innovations—machinery and physical technology—rather than ‘software’ innovations—information-based (2003).

In recent decades especially, innovation/diffusion theory has been subject to multiple critiques. Given the productivity paradigm from which it grew, many researchers have found the theory limited in its applicability to innovations emergent from the counter sustainability paradigm (Padel, 2001). As a result of this critique, much adoption/diffusion literature has begun to distinguish the *kind* of innovation under study. Standard adoption/diffusion theory studied ‘commercial’ or ‘technological’ innovations. Thus, it does not necessarily apply to what have variously been termed ‘transformative,’ ‘radical,’ ‘environmental,’ and ‘social’ innovations (Adebiyi, 2015; Padel, 2001; Simin & Jankovic, 2014). The latter category encompasses innovations that were developed not mainly from intent for productivity and profit, but also from intent for transforming agricultural relations with the land toward improved environmental and social outcomes.

Studies of soil conservation practices and organic farming particularly pushed forth the concept of environmental innovations (Adebiyi, 2015; Bultena & Holberg, 1983; Choi, 2016; Chouinard et al, 2008; Clearfield & Osgood, 1986; Daloglu, 2013; Daskaloupoulou & Petrou, 2002; Ervin & Ervin, 1982; Fuglie & Kascak, 2001; Padel, 2001; Pampel & van Es, 1977; Simin & Jankovic, 2014). They found the farmer characteristics examined by standard adoption/diffusion theory lacking in their explanatory capacity for why farmers ‘adopt’ environmental innovations. Thus, they expanded the examined motivations for farmer adoption. With regard to practical motivations for adoption, organic and soil conservation farming research emphasized both the examination of short-term versus long-term financial benefit and the inclusion of soil erosion/soil health benefits (Adebiyi, 2015). Additionally, these studies shifted the focus from farmer attitude to farmer ideology/philosophy (Adebiyi, 2015; Padel, 2001; Pampel & van Es, 1977; Simin & Jankovic, 2014). Farmer ideology ascribes influence to farmers' environmentalism or care for the landscape. Organic farming research describes farmer ideological motivations expanding beyond more environmentally-sound farming practices to concern for sustainable rural society/communities (Simin & Jankovic, 2014).

At the same time, another critique of the dominant adoption/diffusion theory is its heavy focus on farmer characteristics at the cost of losing sight of the economics, structures, and institutions of agriculture in which farms are embedded (Padel, 2001). An example of this oversight comes from the negatively-connoted designation of last adopters as 'laggards.' Under adoption/diffusion theory, the idea prevails that 'laggards' failure to adopt an innovation results from their own lack of information or personal barriers (Padel, 2001). This idea negates the possibility that the issue could be the technology itself and/or the structures surrounding the technology to the extent that lack of adoption not be deemed a failure.

A simultaneous critique of adoption/diffusion theory is the notion that it is a magical process generated by an invisible source wherein trickle-down knowledge ensures that diffusion of an innovation eventually covers an entire farmer population (Padel, 2001). Thus, there exists at the same time both the criticism that individual farmer agency is over-accounted for in the innovation adoption process and that criticism that the concept of inevitable and predictable occurrence of diffusion of innovations leaves actors out of the process entirely.

Understanding Adoption/Diffusion through the Case of Kernza

How do farmers ‘adopt’ Kernza?

As a perennial grain, Kernza presents a distinct agricultural innovation which means it also presents a distinct case for standard adoption/diffusion theory. It is a new and still-developing innovation being grown and sold on a highly limited scale. As such, it does not clearly meet adoption/diffusion theory’s requisite characteristics of an innovation. According to the bell-curve of innovation adoption, all current Kernza growers fall into the ‘innovators’ or possibly ‘early adopters’ phase of diffusion.

Understanding diffusion as a process of information spreading across networks is critical in the case of Kernza adoption, but also limiting. All Kernza growers in our study had a key social connection to the small but tight Kernza network. The longer-established Kernza growers all received Kernza knowledge and seed through personal connections to the Land Institute itself or to a university researcher collaborating with the Land Institute. Those farmers with a family member in the Kernza network expressed familial social influence as a key reason for growing Kernza. The newer Kernza growers had this personal connection to the Land Institute and/or had sufficient farm scale, equipment, and production capacities to be selected by Plovgh to obtain seed. In the latter case, Plovgh vets applications from farmers seeking to grow Kernza, but who do not have the social connection to obtain seed directly from the Land Institute, to select which farmers obtain seed. They prioritize farm’s physical capital because they want farmers who already have a conducive set-up to grow Kernza in order to receive higher and more assured Kernza grain/seed output.

In other words, social connections are not only important for finding out about Kernza but also for access to the physical innovation as manifested through Kernza seed. Kernza seed is not yet open-access. The limited scale of Kernza fields on the landscape alongside Kernza plants' limited productive capacity results in limited seed yields. Further, as the Land Institute continues to breed better Kernza, new generations of Kernza seed displace old generations. All of this translates to limited and inconsistent Kernza seed supply. Additionally, Kernza is a trademarked seed. All growers sign agreements, maintained through Plovgh, to uphold the Kernza trademark, which entails a crop inspection and payment of the small trademark fee. Thus, the physical technology of Kernza, as manifested through its seed, is both limited and semi-controlled.

Plovgh has received hundreds of requests from farmers for Kernza seed. Giving various talks at farm conferences and meetings, farmers consistently approach me afterward wondering where they can buy Kernza seed. Yet, less than fifty farms grow Kernza. This discrepancy challenges standard innovation/diffusion theory's findings that innovators and early adopters are better-informed than later adopters. It does not align with the concept that spread of information about an innovation leads to farmer interest which leads to the farmer beginning the adoption process. With Kernza there is a break-down between farmer interest and farmer 'adoption' due to the physical limit of Kernza seed. Social capital and physical capital thus become critical in enabling farmers who actually know of Kernza to even have the opportunity to 'adopt' Kernza. Farmers with social capital within the 'Kernza sphere' and/or with the sought-after physical capital are the exclusive set of farmers selected to receive Kernza seed. In the case of Kernza, it is the innovation, and the network supporting it, which chooses its adopters.

Why do farmers 'adopt' Kernza?

While Kernza necessitates first asking whether farmers can 'adopt' Kernza, this does not negate the question of why those farmers who can do start growing Kernza. Part of the farmer explanation, as just discussed, is enmeshed in social networks which induce peer pressure and social influence. What further explanatory capacities does adoption/diffusion theory's framework of focusing on farmer characteristics offer in the case of Kernza 'adoption'?

First, it is notable that Kernza does not clearly meet adoption/diffusion theory's requisite characteristics for an innovation to be readily adoptable by farmers. Kernza is divisible. All growers in our study started off putting only a small portion of their farm's acres into Kernza with the aim to see how Kernza performed before increasing acreage. However, Kernza is not definitively low-risk and it does not have obvious economic advantage. Farmers currently apply little-to-no inputs on Kernza which reduces the crop's risk, alongside the small field allotments. At the same time, best Kernza management techniques are not yet established and yields are also both lower and less predictable than for other grain crops, adding distinct risk to any Kernza venture. Markets and grain prices are uncertain, rendering economic advantage possible but far from obvious.

Thus, a profit and productivity lens does not suffice to understand farmer motives to grow Kernza. Indeed, the original vision behind Kernza's inception aims to work against the productivity paradigm of industrial agriculture. Kernza is more appropriately examined as a transformative/radical/environmental/social innovation in the vein of soil conservation practices and organic agriculture. The contribution of transformative innovation research to diffusion/innovation theory expands farmer characteristics to include ideology as well as attitude and practical attributes.

Kernza growers' attitude toward risk and uncertainty in our interviews was nuanced. Farmers described the multiple uncertainties involved with Kernza as a disadvantage of growing the crop. Despite the negative depiction of uncertainty, though, farmers did not necessarily frame it as a deterrent to their initial ‘adoption’. All Kernza farmers did express an ‘innovative’ attitude toward the introduction of Kernza on their farms. As the farmers declared:

> “It was just another opportunity to try something a little different and see what’s out there.”
>
> “We’re always interested in looking at something different that might be beneficial.”
>
> “I guess I was just interested in something new, looking to try something different.”
>
> “The unknown is the pioneer part of me. We came here in the great migration of the 1600s so we’re all about trying something new.”

An important practical characteristic of farmers in adoption/diffusion theory are their financial motivations. This can appear discordant with Kernza’s lack of obvious economic advantage. Transformative innovation literature’s distinguishing between short-term and long-term economic benefit is important in clarifying Kernza growers’ financial mindsets. Farmers in our study demonstrated both short-term and long-term perspectives when worried about the financial aspect of Kernza. For example, short-term worries included the current uncertainty of Kernza grain markets and prices while a long-term fear was that Kernza grain markets could eventually stagnate or become oversaturated. However, when hopeful about the financial aspect of Kernza, growers exclusively demonstrated this hope through long-term thinking. All but one farmer in our study had diversified farm operations and viewed farm diversity as part of their long-term financial resiliency. Kernza was another crop with niche market potential to add into their crop portfolio. One farmer stated, “I don’t believe there’s been a year since 1959 or 1960 that I haven't grown some specialty crop or contract type crop. We've always been on that edge. Consequently, this was just another little step in the game."

Long-term perspectives clearly shift the way a farmer foresees the practical benefit of a perennial crop, such as Kernza. Kernza's yield drop-off after the first-year dilutes the economic gain from reaping multiple season's harvest off a single years' planting. However, farmers in our study did vision maintaining a Kernza stand for multiple years, because of the motivation for ecological improvement to their farm. All interviewed farmers brought up the eventual ecosystem service benefit of Kernza's perenniality and its associated long roots would bring to their soil, enhancing health and decreasing erosion.

Ideologically, some growers extended ecological concern beyond their own land outward to the larger landscape. While this environmental ethic was presented, implicitly or explicitly, by six growers, all growers' language blurred the line between ecosystem services and environmental ethic and even niche cropping for sustainability markets. It thus becomes difficult and also misguided to delineate farmer motives as practical versus idealist. Kernza grower motivations do not fall squarely into either category, rather sliding along a spectrum of coexistence where the practical and the ideological operate together. This is perhaps exemplified by the consistent critical reflection of Kernza growers on the historical trajectory of rural societies. The paradigm-shifting potential of Kernza represents the possibility of more sustainable rural communities, which serves the interests both of the environment and society at-large and of farmers trying to hold onto their land and livelihoods.

Discussion: Do Farmers 'Adopt' Kernza?

Utilizing dominant adoption/diffusion theory as a frame to assess how and why farmers 'adopt' an innovation presumes the farmers are indeed adopting the innovation. However, this presumption presents a problem of definition. Beall and Rogers (1962) defined adoption as "the point in time when the farmer has decided that he is satisfied with its use and will continue to use the practice in the next decision-making period" and the adoption process "centers around the individual adopters though patterns and actions." Beside the problematic sexism of assuming the farmer as male, this definition also asserts a linear trajectory toward adoption in which there is a singular point in time when innovation is adopted as determined by the singular moment when a farmer decides s/he is satisfied. Further, it views farmers as individual actors with full agency to decide adoption through their own patterns and actions.

However, the Kernza farmers in the study were continually shifting their opinions and ideas about their Kernza over time since their initial planting. At periods, they did not actively think about it at all. None of the growers, regardless of their years of experience growing Kernza, had reached a point of deciding they were succinctly satisfied with Kernza. Due to Kernza's perennial nature, growers do not have to decide to continue utilizing Kernza into the growing season. The Kernza plants make that decision on their own as they continue living, growing, and reproducing for years. Growers must rather decide to discontinue adoption.

Further, Kernza bolsters the simultaneous critiques of adoption/diffusion theory that the theory over-accounts for individual farmer agency in the adoption process and that the idea of diffusion as inevitable and predictable leaves actors out of the process. Kernza, as an innovation being put onto the market at the same time that it is still in-development, comes bound to inhibiting organizational, social, and market structures alongside technological issues with the innovation itself. These are all outside the scope of the individual farmer and makes an examination of farmer characteristics motivations limiting in explanatory capacities of 'adoption.' The inevitable and predictable portrayal of diffusion assumes the limitless availability of an innovation, but Kernza is in limited supply. Its 'diffusion' is thus neither preordained nor certain to occur along a smooth bell-curve.

Kernza, as an innovation in its early stage, defies standard adoption/diffusion theory language and assumptions. Alternately, a turn toward actor-network theory, for its broadened understanding of woven networks of simultaneous actors, better illuminates the case of Kernza when also embedding the non-human and human actors into a political reality (Arora & Glover, 2017; Watts & Scales, 2015;). In this framework, both the farmer and the innovation—including the physical technology itself and the networks involved in its development and dissemination—are actors. Embedded in a political reality, these actors, both farmer and innovation, are dynamic. The process resulting from their interaction is non-linear and ongoing without a singular endpoint of 'adoption.' The innovation of Kernza, with its limited and controlled availability, is not readily able to be adopted by farmers. Farmers, though, readily adapt Kernza, as they both variously reject and accept the innovation at different points. As they simultaneously reject and accept certain parts of it, farmers also transform the innovation. Thus, farmers do not 'adopt' Kernza. Kernza adopts farmers and farmers adapt Kernza.

Kernza's Fit into Growers' Existing Farm Systems

Growing in the Margins

Kernza is presently a marginal crop within the larger agricultural landscape. To say it is 'marginal' is not to say it is 'marginalized.' As a new crop, Kernza has not been pushed to the margins but rather has grown up and out in the margins, figuratively and literally. Kernza represents the possibility of an alternative agricultural paradigm. Thus, while Kernza is still incipient and has yet to heavily shift the agricultural system, it must grow and develop in the space outside of the dominant paradigm, expanding from the edges.

On the farm-scale, Kernza is also marginal within growers' farm systems. As notable in the "Farmer Participants Description" section, no farmer grew more than 38 acres of Kernza, with the majority growing less than 20 acres. Farmers cultivated hundreds to thousands of acres each of total crops, and farm acreage positively correlated to Kernza acreage (large farms had higher Kernza acreage, small farms had lower Kernza acreage). This means that Kernza represents a marginal portion of the growers' overall farm system in terms of scale. When farmers commented on this choice, they explained it through language of uncertainty or risk-aversion. In line with this, the two farmers who planted the most acres (27 acres and 38 acres) of Kernza planted them for prearranged contracts which paid out by acre planted rather than by yield, lowering uncertainty and risk. Further, farmers continually referenced the advice they received from their personal contact at The Land Institute or a university Kernza research lab as the external information source for their early decision-making. The Land Institute and researchers have intentionally advised farmers to initially plant smaller areas of Kernza, learning how to manage Kernza and how it does on their farms before expanding.

Marginality on the farm is a theme that runs beyond Kernza's physical scale. Farmers also explicitly recognized selecting marginal field sites to plant their Kernza. Field margins, areas difficult to access with field equipment, and fields with irregular shape, uneven topography, or poor soils were popular locations for Kernza fields—in other words, locations that, as one farmer put it, did "not lend (themselves) to row crop production." Additionally, given Kernza fields' frequent spatial situation on field margins, farmers admitted that Kernza resultantly often grew alongside existent weed banks. For example, one farmer planted his Kernza into a field which he knew contained "persistent" brome and reed canary grass. One farmer's statement that "honestly, it's going in areas that are not of prime production for us, so it's a small part of the operation, a part of the operation that we are willing to sacrifice to experimentation" reflects the general sentiment of interviewed farmers about their decision-making process in siting their Kernza.

Post-planting, farmers exhibited the marginality of Kernza in their farm systems through their management. Kernza was repeatedly a low priority in terms of growers' allocation of labor and time. Kernza farmers already gave time and effort and took risk in planting Kernza. Farmers aimed to compensate for a risky crop, such as Kernza, by focusing their resources on the more secure crops in their farm systems. Farmers did not buy new equipment to best suit the specificities of Kernza seed but rather used existing equipment. Depending on the crops they were already equipped to handle, this hindered some farmers and suited others. One farmer summarized,

> "We've already got the equipment that can handle the stuff. It's a specialty crop. It's a lighter seed than most. Other people aren't used to that. But our equipment can already handle that, so

we don't have to invest in new things... And it fits with our operation. We've got cleaning facilities that can handle it. It just seems like it could be a great fit if it really takes off more."

The lack of investment extends beyond equipment to inputs as well. Only four of the farmers interviewed ever applied any kind of input. The four who did apply inputs all applied organic fertilizers. Two of these farmers applied the inputs (for one, compost and the other, manure), because they had left-overs after applying them to another non-Kernza crop field and the Kernza field was a convenient site to deposit the rest. The other two farmers, who purchased turkey manure specifically for their Kernza fields, were notably the two farmers with set paid contracts. Additionally, Kernza is also a marginal part of growers' operations at the point of harvest. From year-to-year, farmers are inconsistent in their utilization of Kernza's potential outputs.

Kernza's on-farm marginality relates to many of the challenges experienced by farmers which this paper will explore in-depth in the following sections. First, though, marginality also presents distinct opportunities for growers. When farmers do utilize Kernza's outputs, they do so with little to no inputs of pesticides and fertilizers, reducing both cost and labor. Further, Kernza's marginal role combined with its unique agro-eco-physiological traits give it the ability to fit into gaps in the farm system. Farmers viewed Kernza as a tool for areas where more standard crops would not be suited or would produce lower yields, such as rolling land, riparian buffers, edges of fields, or otherwise 'marginal' land.

One of the advantages farmers most frequently experienced growing Kernza was the decrease in work of planting year after year and regularly passing the tractor through the field for tilling. This is a critical factor at decisive dates in the growing season, particularly planting, when farmers attempt to balance high time and labor demands from multiple main crops simultaneously. As observed by one farmer, “the advantage is like for other perennial crops…It’s seeded in the year prior so it’s one less thing you have to do in the spring.” Another grower elaborated,

> “One of the things we do fight around here is the pressure of spring and fall because we do have a very narrow window and so springtime comes and you’re wet so to get out in the field, to do tillage… To be able to move away from tillage, you don’t need tractors, you don’t have as much equipment. Life is very simple and nice because you don’t need all that stuff and you don’t need to burn fuel and all this. So there’s a lot of advantages that way that you could see in that type of a system.”

Multiple Uses

While breeding has focused on making Kernza a viable grain crop, the grass’s perennial nature enables it to have a number of potential uses and value streams.

Grain production is the main intended use of Kernza in commercial agriculture. However, a farmer who plants Kernza is not necessarily a farmer who harvests Kernza. Of the six farmers who had had opportunity to harvest (four farmers were in their first year of Kernza and had not reached harvest stage at the time of my visit), half had never harvested a Kernza grain crop. Of the three farmers who had harvested grain, the only two to have done so every season after planting were the two farmers pre-contracted to harvest grain. Growers most actively chose not to harvest their grain when they viewed their stand as either sparse or heavily weedy to the extent that the resultant yield would be too low or contaminated with weeds to justify the effort of harvest. Other more passive reasons farmers did not harvest were small plot size, inconvenient location of the plot, not having the right equipment, and inexperience with harvesting especially small grain. One farmer faced several of these challenges and justified his decision not to harvest:

> "On the harvesting side, that's an issue because the seed is so fine that my combine settings—I'd have to buy some other parts to probably put inside my harvester to be able to get that fine seed and not lose it all. It could be done, but for 8 acres, you know, it doesn't hardly make sense… The problem is—if I had my own combine, my own equipment—but I have to pay someone to come do it and if I only get a few hundred pounds, I'm losing a lot of money. It'd be nice to have some seed off it but if I have to do it at a loss, I might as well wait for next year.

Additionally, the best harvest timing and method (direct combining versus swathing) for Kernza are still an uncertainty for farmers. Notably, though, the three farmers who had harvested their grain were confident in their methods due to their prior experience harvesting grass seed crops. A farmer who direct-combined said, "(Harvesting's) not a problem. We know how to set a combine… I've harvested orchardgrass and sweet clover, red clover, so that's not a problem," while a farmer who swathed demonstrated similar confidence, "General practice is to swathe and let 'em lay in windrows. Dry 'em, bale 'em, and then harvest the crop. As far as timing of swathing, it's kind of based on, you know, ryegrass, bluegrass, other species as far as what they look like."

Consistently, among all farmer participants, the theme emerged that grain yield matters. Yield matters particularly to farmers in regions where corn/soy cropping systems are dominant and productive. A farmer explained that around his area, farmers consistently grow 200 bushels of corn and 40 to 60 bushels of soybeans—equating to thousands of pounds of production of each—in comparison to Kernza's "light" production, implying the numbers meant Kernza could not compete with corn and soy. Of concern is not only quantity of grain but also the size of the grain and the consistency of yield across years. The farmers see Kernza grain as small and light. Especially to those whose main crops are large grains, it is difficult to adapt their mindsets and management practices to Kernza grain's smaller size.

Beyond grain, Kernza can also serve the uses more typical of other agricultural perennial grasses: grazing, forage, and bedding material. Two farmer participants have grazed their own cattle on their Kernza, one plans to graze, and one knows a friend farmer who grazes his Kernza. Two farmers used Kernza as forage to feed to their cattle. Three farmers used Kernza for bedding—one gave the Kernza straw to the neighbor who had baled it for him, another sold the straw bales, and another used it as bedding for his own cattle. Only one farmer did not use Kernza for any of these three purposes. Grazing, forage harvest, and straw bedding harvest all occurred regardless of whether grain was harvested. This demonstrates Kernza's potential dual-use in a single growing season and Kernza's possibly higher accessibility to farmers as a traditional forage crop over as a grain crop.

Growers' interest in Kernza for pasture or forage varied in accordance with whether their farm had livestock, the local supply of forage in their region, and their perception of Kernza's forage quality. Farmers without livestock had to expend effort finding an outlet for their forage or straw and derived less direct benefit from it. A corn-soy farmer lamented that without cattle to whom to feed his Kernza, he could only hope to reap benefit from the more uncertain grain harvest. A farmer who consistently harvests and sells his grain noted that his friend's Kernza, which was grazed as well as harvested, "has a lot more utility for him because of the cattle." The same farmer did not consider harvesting his Kernza for forage to sell, because his area has an abundance of high quality forage. The forage market in his region was saturated and he did not believe that Kernza forage was high enough quality to compete.

Farmers satisfied with their Kernza stand's establishment found Kernza's biomass offered an abundant quantity of potential forage. Forage quality was the salient question for the farmers. Farmers judged the quality of forage on their timing of grazing or forage harvest—they assumed that Kernza's forage quality varied with growth stage similarly to other forage grasses—and how well their livestock appeared to consume the Kernza. In each case where farmers used Kernza for bedding, the harvest of Kernza biomass in the form of straw took place post-grain-harvest or late in the season, when the forage quality was presumably low. Late-harvested Kernza straw thus was a lower-value use of Kernza but also a convenient use for farmers who already harvested grain or who did not have time to deal with their Kernza in the height of the growing season. Farmers who fed their livestock on Kernza varied in their assessment of their cattle's preference for it, but were in agreement that forage quality tests were needed to determine their continued and future use of Kernza as forage. As one farmer stated,

> "We'll send (the forage) to the lab and see what we got. If you're not doing that, then you're flying blind. Just because your calf gobbles it up doesn't mean it's good for them."

While grain was the main commercial output intended for Kernza and the secondary use for forage is emerging as important especially when grain yields are still relatively low, the Land Institute envisioned its ecosystem services would be the source of Kernza's transformative capacities. Ecosystem services do not only impact the larger landscape, but can also have value at the farm scale. While farmers did not explicitly cite ecosystem services as a use of their

Kernza, nine of the farmers found that the associated ecosystem servicing effects to their land were a main benefit experienced growing Kernza.

In contrast to the Land Institute's vision, though, the farm-level ecosystem impact most frequently discussed by growers was weed community shifts. Three of the farmers cited weed prevention as a main use of their Kernza, while four farmers expressed weed suppression as one of the greatest benefits experienced by growing Kernza. These farmers repeated phrases that Kernza is so "persistent and tough" that is does "not pay attention to any weeds" and "pretty much squeezes everything else out." One farmer is promoting Kernza to manage giant ragweed.

However, the storylines which emerged around Kernza and weeds were more complex and contrasting, not only between farmers but also over the course of a single interview with a farmer. Another frequent message about Kernza was that it could quickly become a "weedy mess." Two of the farmers continue to struggle with high weed pressure, while other farmers who were initially concerned with high weed pressure reported decreased weed-to-Kernza ratios after a spring or summer mowing/cutting of the field. According to one farmer who could barely identify the Kernza plants amidst the weeds after planting,

> "I thought, 'there's too much of this odd-looking stuff for it to be just weeds—that must be what (the Kernza) is. (We) mowed it off and probably within two weeks or so, the Kernza appeared."

While farmers vocalized fairly firm positive or negative opinions about the relationship of weeds and Kernza, the weed storyline became more nuanced over the course of an interview and across interviews. Different weed storylines emerged from farmers' differing farm system contexts, differing focuses of attention to distinct problem weed varieties in their area, and differing number of years of Kernza growth experience. Weed pressure in Kernza was often linked by farmers to factors of the type/condition of the land of the Kernza field and the perceived level of success of initial stand establishment. Farmers who experienced more weed pressure were those who established their Kernza on a field with or near an established weed bank and/or whose Kernza stand established poorly and remained sparse. Additionally, rather than simply being low or high, or increasing or decreasing, farmers throughout interviews amended their weed pressure characterization to emphasize varietal shifts. All farmers with stands older than one year noted that weed varieties in their Kernza field shifted over time from annuals to perennials.

In all cases, farmers' perceptions of their experience with weeds in their Kernza plot was a central point. Farmers who downplayed weed pressure or who saw it as low or decreasing had more positive perspectives on growing Kernza in general. Conversely, farmers who emphasized high or increasing weed pressure had more negative perspectives on growing Kernza. Conventional farmers were especially sensitive to weed presence. Since conventional farmers' norm and ideal is to have weed-free field, they suffered poor reception from family and neighbor growers who noticed weeds in their Kernza fields.

Kernza's value for weed suppression was a contentious topic, but farmers were in agreement over the positive potential of the ecosystem services more intentionally promoted by the Land Institute, such as soil regeneration, erosion control, and nutrient/pesticide runoff prevention. Particularly, farmers couched these benefits within the image of Kernza's deep root system:

> "It's a great conservation crop and the land it's going on needs that. It's a benefit that by being a solid root mass crop it controls both wind and water motion."

> "In terms of that issue of nitrogen, I think a deep-rooted crop could do a lot for catching, or at least preventing, a loss of a lot of this nitrogen."
>
> "I think its capacity to develop root mass is going to be very beneficial for soil-building."
>
> "For me, the benefits are definitely in the roots…There's no loss of nutrients from a Kernza field."

Establishment

Kernza's position as a new crop means that there are still many agronomic uncertainties involved in the growing process. The uncertainties faced by breeders and researchers amplify on the fields of farmers growing Kernza without any set guidelines. While many farmers had connection to the breeders and researchers as well as to some other Kernza farmers, the farmers relayed mixed messages about the advice they understood they should follow for Kernza cultivation. This uncertainty about what guidelines to follow was itself a concern for Kernza farmers. One farmer pointed out,

> "With Kernza, this is all new, you have no idea. You don't have basic guidance on 'Should I terminate this? Is this an adequate stand? Where am I at?" Another farmer bluntly stated, "I don't know what constitutes a good stand. Apparently, nobody does."

For farmers, some of the most critical agronomic uncertainties revolved around planting/seeding the Kernza crop. Issues with planting timing was experienced by all farmer participants and was a clear high point of frustration in interviews. Issues around planting timing were not simply about knowing the best date to plant—farmers had the rough idea that they should plant before the end of September—but more so about the inability to plant when the farmer estimated ideal. Five farmers blamed delayed planting for initial difficulties with stand establishment. The most largely cited reason for seeding delay was delay in receiving seed supply. The Kernza seed harvest (typically in July or August) from one year, which must first be sent to Plovgh for processing and redistribution, serves as the seed supply the same year for farmers planting. Turnover is tight. Seed often does not reach farmers by the time they expect it. The result for farmers has been later-than-anticipated-or-desired planting of fields:

> "We were hampered this year because of supply delay…We should've had (the Kernza seed) in late September. We didn't get it in until late October."
>
> "So I waited around. I was back-and-forth with (Plovgh in) Wisconsin, 'Where's my seed? I need to plant this stuff.' Never came, never came, never came. They finally got it here and it was raining and the whole thing—the time was bad. If I had the timing right, I'd have a beautiful field right now, but that's farming. I have an okay field, but I'm going to have to wait 'til next year probably to get a crop out of it."
>
> "Part of it was the contract—Patagonia not making the decision they wanted it until late. (Then) the seed not coming 'til late. Just everything happened too late…I was a little gun-shy about (seeding late September or early October)."

Beyond timing, farmers' methods of planting varied, especially since Kernza seed is smaller and lighter than standard row crops, such as corn, soy, and even wheat. Thus, in seeding, farmers implied a choice to view Kernza as either a grain row crop or a grass in their agronomic treatment of it. The majority of farmers drilled their Kernza into rows, while three farmers broadcast their seed. Farmers who had more experience with growing grasses were those who drilled their Kernza at a lower seeding rate (due to the light weight of the seed) or who broadcast.

Largely, farmers expressed that, although their seeding methods were sufficiently effective, they were uncertain if their method was actually the best-suited to Kernza, especially with regards to spacing.

Other Agronomic Issues

Uncertainties for farmers abound not only when first planting the stand but also in the later years of an established stand. Farmers with longer-established Kernza stands consistently contemplated how to cope with an aging stand. These farmers noticed significant grain yield drop-offs successively after year 2 of Kernza harvest. They attributed the lowered productivity to plants becoming 'root-bound' with increased stand density, itself the result of continual tillering. While neither the idea that Kernza becomes 'root-bound'—a concept more common to potted plants in which roots become too dense and tangled to further grow—nor that this 'root-bound' state is the cause of decreased yields are yet confirmed by research, one of the two participants with the oldest stands of six years highlighted dealing with a root-bound stand as a top priority for research. He attempted to "open up" the stand and "disturb some of the root system" by "discing up" the field with a no-till drill and over-seeding with red clover in spring 2017 and was waiting to gauge the results at the time of the interview. Other farmers with multi-year stands contemplated taking similar measures, whether mechanically cultivating, grazing, or burning. An additional question for farmers, rather than extending yield longevity, was the possibility incorporating the Kernza into a crop rotation in which Kernza grew for just two to three years. This prompts another question for farmers—how to terminate a Kernza stand. In fact, two growers feared that Kernza had the potential to become an invasive species.

Farmers raised the topic of other agronomic uncertainties with less frequency. Farmers wanted to know whether Kernza could be intercropped, but only one first-year grower was actively attempted to intercrop between his woody perennial crops. One conventional farmer in particular was interested either in potential non-organic methods for managing Kernza or more specific organic management guidelines. Besides one exception, farmers were not concerned about managing Kernza fertility, either because they planted their Kernza into fields they expected had a sufficient stock of nitrogen from previous use or they had added manure or compost to the field in a later year of Kernza growth. In terms of pests, only observations were geese disturbance (2 farmers) and deer disturbance (1 farmer). Ergot was the only disease mentioned and was only mentioned by one farmer. Only one grower brought up lodging as a problem.

Economic Issues

Beyond the scope of agronomic management, all farmers introduced the theme of markets and economics at various phases in their interviews. Three farmers expressed that research on Kernza profitability and market infrastructure should be a priority. Three separate farmers cited one of the biggest disadvantages experienced growing Kernza was the market and income uncertainty. Farmers were aware that there were bakers and brewers and now General Mills interested in buying Kernza grain at a higher price than other grains due to its growing reputation as a 'sustainable' crop. However, apart from the two contracted growers, farmers were unaware how much Kernza markets were actually demanding and what price farmers would receive for grain. In other words, farmers had no form of financial analysis to surmise whether growing Kernza would be a profitable endeavor for their farm. Farmers who envisioned Kernza as a niche crop articulated a confident or neutral stance on the economic potential of Kernza for their farm. Three such farmers even discussed the hope of direct-marketing their own Kernza grain. Another stated, "There's a disadvantage for a person who is looking for dollars of income, but we weren't looking for that—we were looking for balance." Farmers who directly compared Kernza to standard row crops, like corn and soy, articulated pessimism about Kernza's economic potential on their farm. As one grower summarized, "Really, it comes down to economics. Not only does Kernza need to be profitable, but it probably needs to be as profitable as the best other crop too."

Discussion

Kernza is currently a marginal part of farmers' whole farm systems, in terms of space, time, and resource allocation. This marginality lowers risk in growing Kernza and also lends Kernza to fit into gaps in growers' farm systems. At the same time, this marginality is both is fueled by and fuels agronomic uncertainties about Kernza.

Of Kernza's multiple output uses, grain harvest is infrequently practiced by farmers, largely due to uncertainty that harvesting the grain will provide enough yield to merit the effort. Farmers more frequently utilized Kernza for grazing, forage, and bedding. Farmers who had their own livestock and who utilized Kernza for this dual-use experienced increased benefit from Kernza's potential outputs. Kernza also provides ecosystem service value to farmers. Kernza's effects on weed populations was contentious due to contrasting contexts among farm systems. While some farmers were excited about Kernza as a weed suppressant and others found Kernza a "weedy mess," more nuanced reflection revealed that weed populations did not simply decrease or increase in a Kernza field but rather shifted, often from annual to perennial weed varieties. All farmers agreed on the soil benefits associated with Kernza's deep root system.

Other agronomic Kernza issues most frequently focused upon by farmers were planting, especially ability to plant on time, and coping with an aging stand with reducing yields. Less frequently discussed were intercropping, organic versus non-organic management, fertility, pests/disease, and lodging. Beyond agronomics, markets and economics around Kernza were a consistent focus, suggesting that farmers need more guidance not only on the agronomic management of Kernza but also on the financial viability of growing Kernza in order to scale it up past a marginal role in their operation.

As it currently stands, Kernza was most suited to farmers who already had the specific equipment and experiential knowledge to deal with a small grain or grass seed crop, and who had the complexity of farm system to be able to take advantage of Kernza's multiple uses. In all cases, Kernza farmers sought more research-based guidance to shift Kernza cultivation away from well-informed guesswork and uncertainty toward systematic management with defined returns.

Marquardt et al (2016) and Adebiyi et al (2015) each utilized interviews of non-perennial grain farmers to garner farmer perspectives on how they foresaw perennial grain fitting into their farm systems. In contrast, this study utilized Kernza grower interviews to understand their perspectives on how Kernza actually fit into their farm systems. The foreseen fit of Kernza into farmers' systems shares significant overlap with the experiences of farmers who have begun growing Kernza.

Non-perennial grain farmers expected they would plant perennial grain on under-utilized or marginal fields (Adebiyi et al, 2015). They thought of a multitude of uses for perennial grain on their farm, especially emphasizing the dual grain-forage value (Adebiyi et al, 2015). Farmers were interested in the soil quality improvement capacities of perennial grain's deep roots (Adebiyi et al, 2015; Marquardt et al, 2016).

Expectations around weeds in perennial grain systems are simpler than Kernza grower's experiences. Non-perennial grain farmers predicted that planting perennial grains would increase their both their annual and perennial weed pressure (Marquardt et al, 2016). While some Kernza growers experienced an annual weed increase, others promoted Kernza as an annual weed suppressant, and perennial weeds emerged as the longer-term problem. Organic non-perennial grain farmers expressed more concern over weeds than their conventional counterparts, who expected to chemically manage weeds (Marquardt et al, 2016). In practice, though, conventional-farming Kernza growers struggled with weeds, since they were not applying herbicides to their Kernza as was their solution for weeds in their conventional crops. Both non-perennial grain farmers and Kernza growers wondered about the possibility of perennial grain plants themselves becoming invasive weeds (Marquardt et al, 2016).

Agronomic management questions, including planting, arose amongst non-perennial grain farmers, signifying the importance for farmers of having a mental map of the logistical fit of a new crop into their farm systems even before operationalizing the crop (Adebiyi et al, 2015). Contrasting our study of Kernza farmers, Adebiyi et al (2015) and Marquardt et al (2016) both found that perennial grain yield was of low importance to farmers and that most were little concerned with economic and market viability of perennial grain. It is thus likely that these are issues that take on greater focus for farmers once they actually take on the risk of planting perennial grain and naturally come to face its financial realities. On the other hand, non-perennial grain farmers articulated concerns, such as increased disease pressure, which have not proven to be salient issues for Kernza growers in practice (Marquardt et al, 2016).

As Adebiyi at al (2015) suggests, interface with farmers provides distinct and practical insight for Kernza researchers and breeders as the crop continues to develop. Inclusion of farmer perspectives should be continual throughout the development process, as different agronomic issues shift importance as more and different farmers gain experience growing Kernza on-farm.

CONCLUSIONS

Kernza is a novel perennial grain crop bred for its potential environmental benefits. At the time of research, it was officially grown on only 36 farms amidst the dominantly annual grain agricultural landscape of the U.S. Midwest. This study, by conducting in-depth, on-farm interviews with ten Kernza growers, aimed to begin to fill the gap in research of the social and agronomic reality of incorporating Kernza onto the farm. Such research is key to making Kernza accessible and useful to farmers, which in turn is critical to enable Kernza's potential to shift the agricultural paradigm.

Kernza does not fit into the mold of standard adoption/diffusion theory which understands 'adoption' as a linear, non-dynamic process. At this stage in its development process, Kernza is not an open-access innovation. Kernza can 'adopt' its farmers and those farmers can adapt their Kernza. Thus, the case of Kernza demonstrates the importance of incorporating other theory, such as actor-network theory, into the understanding of how and why farmers begin growing Kernza.

Due to the novel nature of Kernza, it is still surrounded by much agronomic uncertainty. Therefore, Kernza remains a marginal part of growers' farm systems. Kernza growers are utilizing Kernza for its multiple outputs, less frequently for grain and more frequently for as a forage or an ecosystem service-provider. Farmers are especially concerned with research questions which address planting timing, dealing with decreasing yields over time, and economic and market certainty.

Kernza is moving into an important phase as it transitions from breeding to commercialization. Farmers are a key part of this transition. The findings presented intend to serve as a baseline for future research. Further study should continue to incorporate Kernza grower's experiences and perspectives, especially on a larger-scope than this ten-participant study. Additional research should also incorporate more dialogue between Kernza growers and Kernza breeders, researchers, processors, distributors, and buyers.

REFERENCES

Adebiyi, J., Olabisi, L.S. & Snapp, S. 2015. Understanding perennial wheat adoption as a transformative technology: evidence from the literatura and farmers. *Renewable Agriculture and Food Systems* 31(2): 101-110.

Arora, S. and Glover, D. 2017. *Power in Practice: Insights from Technography and Actor-Network Theory for Agricultural Sustainability*, STEPS Working Paper 100, Brighton: STEPS Centre

Awika, J.M. 2011. Major cereal grains production and use around the world. In Advances in *Cereal Science: Implications to Food Processing and Health Promotion* 1089:1–13. ACS Symposium Series 1089. American Chemical Society.

Baerenklau, K.A. 2005. Toward an understanding of technology adoption: Risk, learning, and neighborhood effects. *Land Economics* 81(1): 1-19.

Beal, G. M. & Rogers, E. M. 1960. The adoption of two farm practices in a central Iowa community. *Iowa State University Digital Press Special Report*. 16.

Blanco H., Lal R. 2008. "Tillage Erosion." In *Principles of Soil Conservation and Management*. Heidelberg, Springer: 109-136.

Bultena, G.L. & Holberg, E.O. 1983. Factors affecting farmers' adoption of conservation tillage. *Journal of Soil and Water Conservation* 38(3): 281-284.

Choi, H. 2016. A typology of agro-innovation adoptions: the case of organic farming in Korea. *Regional Environmental Change* 16(6): 1847-1857.

Chouinard, H.H., Paterson, T., Wandschneider, & Ohler, A.M. 2008. Will farmers trade profits for stewardship? Heterogeneous motivations for farm practice selection. *Land Economics* 84(1): 66-82.

Clayton, G.W., Brandt, S., Johnson, E.N., O'Donovan, J.T., Harker, N., Blackshaw, R.E., Smith, E.G., Kutcher, H.R., Vera, C., & Hartman, M. 2009. Comparison of Certified and Farm-Saved Seed on Yield and Quality Characteristics of Canola. *Agronomy Journal* 101(6): 1581-1588.

Clearfield, F. & Osgood, B. 1986. Sociological Aspects of the Adoption of Conservation Practices. *Technical Report #T014*, Washington, D.C.: USDA National Resources Conservation Service.

Cox, T.S., Bender, M., Picone, C., Van Tassel, D.L., Holland, J.B., Brummer, E.C., Zoeler, B.E., Paterson, A.H., and Jackson, W. 2002. Breeding Perennial Grain Crops. *Critical Reviews in Plant Science* 21(2): 59-91.

Dalin, C., Wada, Y., Kastner, T., & Puma, M. J. 2017. Groundwater depletion embedded in international food trade. *Nature* 543:700–704

Daloglu, I., Nassauer, J.I., Riolo, R.L., & Scavia, D. 2013. Development of a farmer typology of agricultural conservation behavior in the American Corn Belt. *Agriclutural Systems* 129: 93-102.

Daskalopoulou, I. & Petrou, A. 2002. Utilising a farm typology to identify potential adopters of alternative farming activities in Greek agriculture. *Journal of Rural Studies* 18(1): 95-103.

Derwisch, S., Pierguiseppe, M., Troger, K, & Birgit, K. 2016. Investigating the drivers of innovation diffusion in a low income country context. The case of adoption of improved maize seed in Malawi. *Futures* 81: 161-175.

Diederen, P., van Meijl, H., Wolters, A., & Bijak, K. 2003. Innovation adoption in agriculture: Innovators, early adopters and laggards. *Cahiers d'Economie et de Sociologie Rurales* 67: 29-50.

Durán Zuazo, V.H. & Rodríguez Pleguezuelo, C.R. 2008. Soil-erosion and runoff prevention by plant covers: A review. *Agronomy for Sustainable Development* Springer 28 (1): 65-86.

Ervin, C.A. & Ervin, D.E. 1982. Factors affecting the use of soil conservation practices: hypotheses, evidence, and policy implications. *Land Economics* 58(3): 277-292.

FAO. 2011. The state of the world's land and water resources for food and agriculture (SOLAW) – Managing systems at risk. Food and Agriculture Organization of the United Nations. London: Rome and Earthscan.

Farrington, F. & Martin, A. 1988. *Farmer participation in agricultural research*. London, England: Overseas Development Institute.

Feder, G., Just, R.E., & Zilberman, D. 1985. Adoption of agricultural innovations in developing countries: A survey. *Economic Development and Cultural Change* 33(2): 255-298.

Fuglie, K.O. & Kascak, C.A. 2001. Adoption and diffusion of natural-resource-conserving agricultural technology. *Applied Economic Perspectives and Policy* 23(2): 386-403.

Garcia-Arias, A., Vasques-Gonzalez, I., Sineiro-Garcia, F. & Perez-Fra, M. 2015. Farm diversification strategies in northwestern Spain: Factors affecting transitional pathways. *Land Use Policy* 49: 413-425.

Glover, J.D., Reganold, J.P., Bell, L.W., Borevitz, J., Brummer, E.C., Buckler, E.S., Cox, C.M., Cox, T.S., Crews, T.E., Culman, S.W., DeHaan, L.R., Eriksonn, D., Gill, B.S., Holland, J., Hu, F., Hulke, B.S., Ibrahim, A.M.H., Jackson, W., Jones, S.S., Murray, S.C., Paterson, A.H., Ploschuk, E., Sacks, E.J., Snapp, S., Tao, D., Van Tassel, D.L., Wade, L.J., Wyse, D.L., & Xu Y. 2010. Increased food and ecosystem security via perennial grains. *Science* 328: 1638–1639.

Gonzales-Paleo, L., Vilela, A.E., & Ravetta, D.A. 2016. Back to perennials: Does selection enhance tradeoffs between yield and longevity?. *Industrial Crops and Products* 91: 272-278.

Griliches, Z. 1957. Hybrid corn: An exploration in the economics of technological change. *Econometrica* 25(4): 501-522.

Jackson, W. 1980. *New Roots for Agriculture*. San Francisco, CA: Friends of the Earth.

Jensen, R. 1981. Adoption and diffusion of innovation under uncertain profitability. *Journal of Economic Theory* 27(1): 182-193.

Just, R.E. 1974. An Investigation of the Importance of Risk in Farmers' Decisions. *American Journal of Agricultural Economics* 56(1):14-25.

Just, R.E. & Zilberman, D. 1983. Stochastic structure, farm size, and technology adoption in developing agriculture. *Oxford Economic Papers* 35(2): 3017-328.

Kane, D.A., Rog, P., & Snapp, S.S. 2016. A Systematic Review of Perennial Staple Crops Literature Using Topic Modeling and Bibliometric Analysis. *PLOS One* 11(5).

Knowler, D. & Bradshaw, B. 2007. Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food Policy* 32(1): 25-48.

Leeuwis, C. &A. Van Den Ban. 2004. *Communication for Rural Innovation: Rethinking Agricultural Extension*,3rd edition. Oxford: Blackwell Science.

Liu, M., Wu, L., Gao, Y., and Wang, Y. 2011. Farmers' adoption of sustainable agricultural technologies: A case study in Shandong Province, China. *Journal of Food, Agriculture and Environment* 9(2): 623-628.

Marquardt, K., Vico, G., Glynn, C., Weih, M., Eksvard, K., Dalin, P., & Bjorkman, C. 2016. Farmer perspectives on introducing perennial cereal in Swedish farming systems: a sustainability analysis of plant traits, farm management, and ecological implications. *Agroecology and Sustainable Food Systems* 40(5): 432-450.

Marra, M., Pannell, D.J., & Ghadim, A.A. 2002. The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: where are we on the learning curve?. *Agricultural Systems* 75(2-3): 215-234.

Micheels, E.T. & Nolan, J.F. 2016. Examining the effects of absorptive capacity and social capital on the adoption of agricultural innovations: A Canadian Prairie case study. *Agricultural Systems* 145:127-138.

Monfreda et al. 2008. 2008. Farming the Planet: 2. Geographic Distribution of Crop Areas, Yields, Physiological Types, and Net Primary Production in the Year 2000. *Global Biogeochemical Cycles* 22 (1).

Nowak, P.J. 1987. The adoption of agricultural conservation technologies: economic and diffusion explanations. *Rural Sociology* 52(2): 208-220.

Padel, S. 2001. Conversion to Organic Farming: A Typical Example of the Diffusion of an Innovation?. *Sociologia Ruralis* 41(1):40-61.

Pampel, F. & van Es, J.C. 1977 Environmental quality and issues of adoption research. *Rural Sociology* 42(1): 57-71.

Panagos, P., Standardi, G., Borrelli, P., Lugato, E., Montanarella, L., & Bosello, F. 2018. Costs of agricultural productivity loss due to soil erosion in the European Union: From direct cost evaluation approaches to the use of macroeconomic models. *Land Degradation & Development* 29: 471-484.

Pimentel D., Cerasale D., Stanley R.C., Perlman R., Newman E.M., Brent L.C., Mullan A., &Chang, D.T. 2012. Annual vs. perennial grain production. *Agriculture, Ecosystems and Environment* 161: 1-9.

Prokopy, L.S., Flores, K., Klotthor-Weinkauf, D., & Baumgart-Getz, A. 2008. Determinants of agricultural best management practice adoption: Evidence from the literature. *Journal of Soil and Water Conservation* 63(5): 300-311.

Rogers, E.M. 2003. *Diffusion of Innovations*, fifth edition. New York, NY: The Free Press.

Ryan, B. & Gross, N. 1943. Acceptance and diffusion of hybrid corn seed in two communities in Iowa. *Rural Sociology* 8:15-24.

Ryan, M.R., Crews, T.E., Culman, S.W., Dehaan, L., Hayes, R.C., Jungers, J.M., & Bakker, M.G. 2018. Managing for Multifunctionality in Perannial Grain Crops. *Bioscience* 4: 294-304.

Sands, Ronald & Westcott, P. 2011. Impacts of Higher Energy Prices on Agriculture and Rural Economies, ERR-123, U.S. Dept. of Agriculture, Econ. Res. Serv.

Shamsudheen, M., Sjogersten, S., Sparkes, D.L., Sturrock, C.J., Craigon, J., & Mooney, S.J. 2014. To what extent can zero tillage lead to a reduction in greenhouse gas emissions from temperate soils?. *Scientific Reports* 4 (4586).

Simin, M. & Jankovic, D. 2014. Applicability of diffusion of innovation theory in organic agriculture. *Economics of Agriculture* 61(2): 517-529.

Skinner, J. & Staiger, D. 2007. Technology adoption from hybrid corn to beta-blockers. In *Hard-to-Measure Goods and Services: Essays in Honor of Zvi Griliches* (pp. 545-570). Chicago, IL: University of Chicago Illinois Press.

The Land Institute. Vision & mission. n.d. Retrieved from https://landinstitute.org/about-us/vision-mission/

Valente, T.W. & Rogers, E.M. 1995. The Origins and development of the diffusion of innovations paradigm as an example of scientific growth. *Science Communications*. 16(3): 242-273.

Valenzuela, H. 2015. Agroecology: a global paradigm shift to challenge mainstream industrial agriculture. *Horticulturae*. 2(2).

Watts, N., & Scales, I. 2015. Seeds, agricultural systems and socio-natures: Towards an actor-network theory informed political ecology of agriculture. *Geography Compass* 9: 225-236.

APPENDIX

Semi-Structured Interview Outline

- Preliminary
    - Age
    - Years Farming
    - Acres farmed
    - Crops/livestock on the farm
    - Conventional or organic
    - Farming as preliminary income
    - Size of farm workforce
    - How many years have you been growing Kernza?

- How did you decide to start growing Kernza?
    - What role did you envision Kernza playing in your farming system?
        - How does Kernza actually fit as a part of your current farming system now?
            - Function, location/scope on farm, economic role
- What advantages did you foresee in growing Kernza?
    - What advantages have you actually experienced with growing Kernza?
- What disadvantages did you foresee in growing Kernza?
    - What disadvantages have you actually experienced with growing Kernza?
- How do you manage your Kernza agronomicallly?
    - Soil preparation, establishment density, weed control, fertilizers, pesticides, disease, harvest time, forage use, termination, intercropping, tillage
- What do you do with Kernza post-harvest?
    - How do you harvest your Kernza? How much does your Kernza yield? How many seasons has it produced?
    - To whom do you sell it? How much do they pay? For what do they use it?
    - Economic gain or loss? Inputs vs. outputs?
- What do other farmers say about you growing Kernza?
- What would you tell other farmers who are interested in growing Kernza?
- What issues would you like Kernza research to address? How would it help you?