Grants and Education to Advance Innovations in Sustainable Agriculture

Kernza® in Wyoming: Evaluating Perennial Grains to Revitalize Wyoming Dryland Agriculture

2021 Western Professional + Producer Grant

ID: 698306

Link to share: https://projects.sare.org/proposals/show/698306/11942

Grant Type: On Farm Research/Partnership

Region: Western

Application Year: 2021

Status: Submitted on 11/04/2020 11:30am EST

Amount Requested: $74,804.00

Principal Investigator:

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Proposal submitted by: Hannah Rodgers

Description for search results if funded: We will plant Kernza intermediate wheatgrass, a perennial grain, at 5 farms in eastern Wyoming to evaluate its viability as a potentially sustainable and resilient alternative to wheat-fallow.

I have read the Call for Proposal (CFP)

I have read the Call for Proposal

- Yes

Project Basic Information

Subject Matter

Field/Vegetable Crop Production

Practices

- **Crop Production**
  - cropping systems
  - drought tolerance

- **Soil Management**
  - soil quality/health

Commodities

- **Agronomic**
  - grass (misc. perennial)
  - other
  - wheat

Project Objectives

Kernza Viability: Determine agroecological viability of Kernza intermediate wheatgrass in eastern Wyoming under different farming strategies.

1. **Economic Analysis:** Evaluate Kernza profitability under different farming strategies.
2. **Soil Health:** Evaluate effects of Kernza on soil health and carbon sequestration compared to wheat-fallow and CRP land.
3. **Drought Response:** Predict and compare Kernza and wheat-fallow yields across the Central High Plains ecoregion using a model for water use.

Outreach

1. Maintain stakeholder engagement and cooperation.
2. Host events to engage with the local community about perennial grain agriculture.
3. Publish our findings on Kernza profitability, soil health, and drought response.

Primary State

Wyoming

Proposed Start Date

April 1, 2021

Proposed End Date

March 31, 2024

Brief Description of the Agricultural Business/Operation of the Project Members

Producers involved in this project are leaders in the eastern Wyoming farming community, and have been working with the PIs since 2008 on projects concerning dryland wheat agriculture. Participating farmers grow primarily hard red winter wheat, though some have irrigated land and grow hay, corn, alfalfa, or cover crops. Farms include a mix of conventional and certified organic acreage, as well as reduced-till, no-till, and conventionally tilled wheat-fallow. These farmers have extensive experience with dryland wheat agriculture, as well as planting intermediate wheatgrass and other perennial grasses for forage or as part of CRP land, meaning they have the knowledge and equipment to trial Kernza intermediate wheatgrass on their farms. Many project

members' families have been farming in the region for generations, and consistently try new methods to improve soil health such as reduced- or no-till, compost, or cover cropping. More information about specific farms is included under "Project Team Members' Roles."

Farmers on this project have repeatedly expressed how wheat-fallow agriculture is becoming infeasible in eastern Wyoming. Organic wheat markets have dropped to the point where some farmers have been unable to even sell their organic wheat. Some current wheat farmers are changing their operations to grow perennial grasses for hay, and more and more farmers are leaving the area. Due to these issues, many of the participating farmers have been interested in growing Kernza for some time, and several plan to plant additional acreage beyond the 10 acres funded by this project.

Is this current submission a re-submission of a previous proposal to Western SARE?
No

How did you learn about this call for proposal?

- Extension Agent
- Google/Internet search
- Professor
- Word of mouth

Summary

Summary

Production of Kernza intermediate wheatgrass for grain promises to provide a sustainable alternative to wheat-fallow while producing food for a growing population. Winter wheat constitutes 135,000 acres in Wyoming, yet degraded soils, climate change, and weak markets threaten farming in this region. Kernza has not yet been planted in Wyoming, where the drier climate presents unique challenges, yet the High Plains Region stands to particularly benefit from the adoption of a perennial crop. We plan to plant Kernza at five farms across southeast Wyoming and at SAREC extension center under a variety of different management strategies, and to collect economic, soil health, and water use data. Our research will address the questions: "Can Kernza be profitably grown in eastern Wyoming?" and "What can soil health and water use data tell us about Kernza's long term viability in this climate?"

All project members will collaborate to bring information about perennial agriculture and our project to the local community, and to support farmers interested in trialing Kernza. Findings will be shared through on-farm field days, extension meetings, and alternative venues such as social media, youth groups, and the state fair. Eventually, we hope to equip more producers with the knowledge to grow and sell this novel grain. We expect that despite lower yields, reduced input costs and higher market prices will make Kernza a viable option for Wyoming wheat farmers that can sustain the agricultural productivity of this area in the long-term.

Project Narrative

Relevance and Benefits to Sustainable Agriculture, Project Value and Benefits: (15% of review criteria)

Problems with Wheat-Fallow

The traditional wheat-fallow system inefficiently stores water, depletes soil organic matter (SOM) and nitrogen, and has a high potential for erosion (J. B. Norton, 2007). In the 70 years since the short-grass prairie was cultivated, tilled wheat-fallow systems in eastern Wyoming have lost 33-63% of their original SOM (J. Norton et al., 2012). However, planting perennial grasses during conversion to Conservation Reserve Program (CRP) land increased SOM by 22.2 Mg·C·ha−1, to 90% of levels under native grasslands, after 15 years (J. Norton et al., 2012). As SOM and nutrients decrease, water retention, microbial activity, and plant growth also suffer, creating a cycle of degradation and a reliance on external inputs that can lead to farmland abandonment. From 1973-2000, agricultural land declined by nearly 11% in the Northwestern and Western Great Plains, driven by drought, fluctuating markets, and marginal yields (Drummond, 2007). Furthermore, wheat agroecosystems are especially vulnerable to a changing climate (Asseng et al., 2015; Ghimire et al., 2013). Sustaining agriculture in this region will require alternative farming systems that can reduce erosion and maintain SOM while remaining profitable (Hansen et al., 2012; Smith et al., 2004).

Potential Benefits of Kernza

Kernza is a perennial grain crop harvested from a cultivar of intermediate wheatgrass developed at The Land Institute in Salina, Kansas. Kernza serves as a perennial replacement for annual wheat in food products such as cereals, bread, and beer. It is grown for three or more years between seedings, and can be harvested for both grain and forage. Kernza is the first perennial grain crop grown in the US, though efforts to introduce it have largely focused on the Midwest (Fig. 1). Kernza has not yet been planted in Wyoming, but it shows promise as a sustainable dryland crop for marginal lands (Bell et al., 2010).

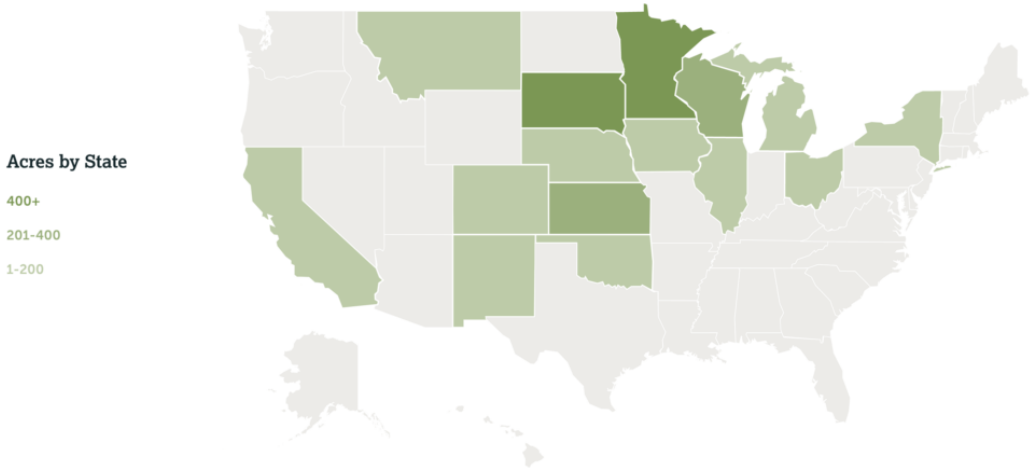

Figure 1: Map of Kernza in states across the US by acreage (accessed 10/21/20). ("The State of Kernza®," Kernza.org)

Kernza has the potential to address the problems of land degradation and climate change that Wyoming farmers face. Deep perennial roots sequester carbon, curtail soil erosion, and allow access to water and nutrients unavailable to annual wheat. Kernza pulls water from deeper in the soil than annual crops. In a Michigan study, Kernza used 50% more available soil water compared to wheat (Culman et al., 2013).

Additionally, Kernza grown in Kansas took up an average of 15000 lb·C·ha-1·year-1 over a period of 4 years (de Oliveira et al., 2018). Kernza especially holds benefits over the wheat-fallow rotation currently practiced in eastern Wyoming and across the High Plains region, since up to 80% of precipitation during fallow periods is lost to evaporation or runoff (Hansen et al., 2012; Kaur et al., 2015). Low-disturbance Kernza fields support a microbial community more similar to soils of native prairie than to those of annual wheat, leading to soil aggregation, enhanced microbial C stabilization, and tight nutrient cycling (Bergquist, 2019; McKenna et al., 2020; Peixoto et al., 2020). While climate change is predicted to slightly increase precipitation in Wyoming over the next few decades, increased climate variability including frequent flash droughts and high heat waves will lead to less reliable wheat harvests (USGCRP, 2018). Kernza holds promise for agricultural production in sensitive areas, and can contribute to an agricultural system resilient in the face of climate change (Duchene et al., 2019; McKenna et al., 2020).

Benefits and Profitability for Producers

Winter wheat constitutes 135,000 acres in Wyoming (*USDA-NASS*, 2019). In eastern Wyoming, wheat typically yields 30 bushels per acre. Farmers receive around $5 per bushel conventional or $9 organic ($150-270/acre every 2nd year), which is often not enough to cover input costs. As a result, the area is experiencing both land abandonment and land-use change towards CRP land and hay (USDA NASS, 2017).

Kernza can decrease input costs, save farmers time and machinery investments, and sustain profit in the long term. As a dual use grain-forage crop that grows for 3+ years, Kernza has the potential to withstand volatility in market prices and climate conditions (Duchene et al., 2019). Even in years with low yield, Kernza can be a tool for farmers looking for a perennial component of their crop rotation or for organic farmers looking for economical ways to maintain fertility. Kernza seed costs $60 per acre, and grain yields range from 100lb to 500lb per acre (kernza.org). At the Williston Research Extension Center in North Dakota, an area with similar precipitation to eastern Wyoming (12-16 in·yr-1), a Kernza trial in a dry year with weed problems yielded 100-150 lbs/acre (pers. comm., Clair Keene, WREC Extension). Kernza sells for $3.50-5.50/lb conventional and $4-$6/lb organic ($350-$900/acre).

This project will focus on testing Kernza's viability in a new region, and not on marketing, since markets have already been identified. Farmers in the project have already been approached by Kernza buyers, and other groups are making considerable efforts to expand markets. Kernza has attracted big players including General Mills: Cascadian Farms, Patagonia Provisions, and numerous small bakeries and grocers. The recent $10 million USDA-CAP grant "Developing and deploying a perennial grain crop enterprise to improve environmental quality and rural prosperity" ensures that demand will continue to increase as work goes into developing markets and increasing yields. Additionally, this project will benefit from knowledge gained in the current SARE funded project on growing and marketing ancient grains in Wyoming (OW19-340), and from the grain de-huller purchased under that grant.

Kernza is a crop in development, and as yields increase, interest is growing around the US. Until now, Wyoming farmers have mostly been ignored in efforts to increase awareness and production of perennial grains. This grant addresses that problem, and acknowledges that though Wyoming does not produce as much grain as the Midwest, its agricultural challenges mean that perennial grains could eventually prove to be the most viable crops for this region.

Stakeholder Needs and Support (5% of review criteria)

Letters from long-time Wyoming wheat producers demonstrate their interest and support. The PIs have been working with dryland wheat farmers, including those on the project team, since 2008 on projects funded by the USDA and the Wyoming Department of Agriculture. Cooperating farmers on our research team are leaders in the southeastern Wyoming farming community and are current or past members of the Wyoming Wheat Marketing Commission, Wyoming Wheat Growers Association, the Wyoming Business Council, the Farm Service Association, and other stakeholder organizations and will guide involvement of those groups in the project. Producers and other stakeholders will be included in all decision making as well as all outreach and extension activities. We see this project as a valuable opportunity for interaction among scientists, producers, and agricultural community leaders and we are motivated to involve a vibrant group of stakeholders.

The two graduate students on the project, Hannah Rodgers and Alex Fox, previously worked at The Land Institute as research interns and maintain connections with researchers there. Support and cooperation with The Land Institute is demonstrated by a letter of support from Tessa Peters, Crop Stewardship Manager at The Land Institute. Peters is a Wyoming resident and has already begun to meet with farmers over zoom to discuss management strategies and seed sourcing for Kernza.

Farmers on this project have repeatedly expressed how wheat-fallow agriculture is becoming less feasible in the area, especially as both conventional and organic prices have dropped to the point where revenue does not cover production costs. Land use is changing to perennial grasses for hay, and more and more farmers are leaving the area. Farmers need soil-building options, and many have expressed interest in Kernza not just for grain, but also as hay, forage, and as a perennial aspect of a longer rotation. For example, cooperating producer Gregor Goertz is interested in grazing Kernza stubble with his cattle, and looking into intercropping with a legume such as sainfoin, and producer Job Hellbaum is interested in Kernza for carbon sequestration and preventing soil erosion in a long-term rotation with wheat.

Many of the participating farmers were interested in Kernza before we began considering this project, and several plan to plant additional acreage beyond the 10 acres funded by this project. For example, last year, producer Clint Jessen was approached by a Kernza buyer who wanted him to plant 60 acres, but he was unable to take the risk of planting a new crop. This project will allow him to test out Kernza on a smaller plot at a much-reduced financial risk, in order to take advantage of a burgeoning new market in future years. With the dire state of agriculture in this area, Kernza could have a significant impact on the long-term viability of farming in the region.

Project Team Members

Rob Hellbaum
Gregor Goertz
Clint Jessen
Jay Norton
Brian Sebade
Tessa Peters
Thomas Foulke
Hannah Rodgers
Alexander Fox

John Watson
Newton Russell

Project Team Members' Roles (5% of review criteria)

Producers

Rob Hellbaum, farmer, Chugwater, WY will serve as the **Advisor Representative**. He has been growing winter wheat in a wheat-fallow rotation with reduced-till and organic production for his whole career as a farmer, and has planted thousands of acres of intermediate wheatgrass on CRP land and for hay (and has even harvested it for seed!). He is particularly interested in engaging youth in the project through 4H and school presentations.

Gregor Goertz, farmer, Wheatland, WY has 3000 acres of cropland, including no-till, conventional, and organic wheat production, 4000 acres of grassland, 1500 acres of CRP land, and a cattle operation. His family has been farming in this area for over 100 years, and he now works with his son.

Clint Jessen, farmer, Pine Bluffs, WY runs an extensive organic operation growing wheat and other crops. He has previously worked with Jay Norton's lab on cover crop and crop rotation projects in organic wheat. In addition to dryland, he has multiple center-pivot irrigation systems, and he has already been approached by Kernza buyers.

Newton Russell, farmer, Wheatland, WY produces both conventional and organic winter wheat in wheat-fallow systems together with his daughter and son-in-law. Newton was one of the first farmers to work with Kashi Cereals on their transitional certification programs to help farmers during transition to organic.

John Watson, farmer, Wheatland, WY operates a conventional dryland wheat-fallow operation as well as a cow-calf operation on rangelands, which has been in his family since 1918. Watson is interested in using Kernza for both grain and forage for his cattle.

Agricultural Professionals

Jay Norton, Project Director, Professor/ Soil Science Extension Specialist, **U. of Wyoming Dept. of Ecosystem Science & Management,** will oversee reporting, coordinate planting efforts at SAREC, and advise on soil sample collection and analysis. He will work with Brian Sebade on coordinating education objectives including stakeholder meetings and on-farm days (**Objectives 4+5**).

Tessa Peters, Crop Stewardship Manager, The Land Institute, will work with farmers on production matters such as acquiring seed and processing grain, and will advise on management issues such as weed control and fertilization. Peters is a Wyoming resident and so will also be involved in outreach activities.

Brian Sebade, Extension Representative, Extension educator serving SE Wyoming, U. of Wyoming, will be in charge of **Objective 5**, organizing regional outreach activities such as 4H and FFA activities, a booth at the Wyoming State Fair, and extension meetings.

Tom Foulke, Community Economic Development Specialist, U. of Wyoming Dept. of Agricultural and Applied Economics, will be in charge of **Objective 1** on economics. He will work with the team to develop effective economic data collection and analysis tools, investigate how Kernza might be managed for the

best returns to farmers, and share his findings through outreach activities and publications.

Hannah Rodgers, PhD Student in Soil Science, **U. of Wyoming Dept. of Ecosystem Science & Management**, advised by Jay Norton and Linda van Diepen (Professor of Soil Microbial Ecology, U. of Wyoming), will be in charge of **Objective 2** on Soil Health. She will be involved in outreach through yearly summaries, scientific papers, posters, extension bulletins, social media, and on-farm days. Her PhD is funded through an NSF GRFP grant.

Alex Fox, PhD Student in Hydrology, **University of Wyoming Dept. of Botany,** advised by Brent Ewers (Professor of Botany, U. of Wyoming), will be in charge of **Objective 3** on Drought Response. He will be involved in outreach through yearly summaries, scientific papers, posters, extension bulletins, social media, and on-farm days.

Research Plan (30% of review criteria)

Kernza Viability: Determine Agroecological Viability of Kernza Intermediate Wheatgrass in Eastern Wyoming Under Different Farming Management Strategies.

Summary & Justification: Kernza will be planted at five dryland farms using various management strategies as well as at The James C. Hageman Sustainable Agriculture Research and Extension Center (SAREC) under irrigation. Since Kernza has never been grown in this environment, the best management practices are unknown. However, farmers in our region have extensive knowledge and experience growing both dryland wheat and intermediate wheatgrass. Therefore, farmer knowledge along with advice from Tessa Peters will guide Kernza management. Objectives 1-3 will be used to analyze Kernza viability using data from these plots.

Study Design: Research activities will take place at matched Kernza, wheat-fallow, and CRP fields on each of the 5 participating farms. Three small plots (5x30ft) will serve as replications at each field (Fig. 2). All yield, soil health, and water use analyses will occur in these plots. Additionally, two Kernza fields under different irrigation treatments will be established at SAREC. We want replicated data within each study location because each farm represents a different management strategy.

(5 farms x 3 fields) + 2 SAREC fields = 17 fields

17 fields x 3 replicate plots = **51 plots in total**

Site Description: The Central High Plains ecoregion that comprises Wyoming's wheat growing region experiences 12-17 inches annual precipitation, 100-125 frost-free days, and a mesic temperature regime (8-40°F average January min/max, 52-88°F average July min/max). Soils are mainly silty and loamy mollisols (agiustolls, haplustolls) and entisols (torriorthents, torripsamments, ustorthents) (Chapman et al., 2004).

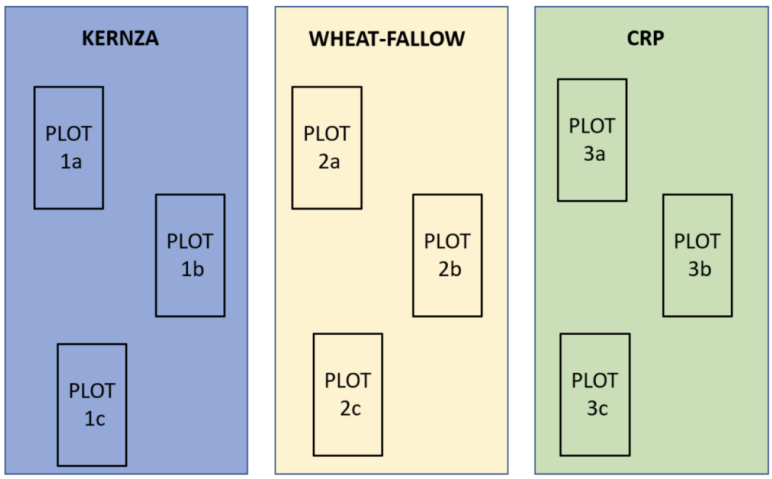

Figure 2. Each farm will include matched Kernza, wheat-fallow, and CRP fields, with 3 replicate plots per field.

Materials & Methods:

Planting & Management: In spring 2021, each of the 5 participating farmers will plant 10 acres of Kernza and manage it according to their needs and experience. The project will provide seed as well as planting costs of $50/acre. Rob Hellbaum, Newton Russell, and John Watson will manage Kernza conventionally. Gregor Goertz and Clint Jessen will manage Kernza organically. Watson and Goertz will graze Kernza after harvest with their cattle. Jessen will plant into a field previously in a crop rotation including wheat, corn, and alfalfa, and all others will plant into fields previously under wheat-fallow.

SAREC: SAREC is located in a major wheat-growing area in Lingle, Wyoming. Kernza will be planted in 6 small (5ft x 30ft) irrigated research plots. Half will be irrigated up to average precipitation monthly, and half will be fully irrigated, in order to evaluate Kernza growth with average and with non-water-limiting conditions.

Many of the participating farmers plan to plant additional Kernza acreage beyond that funded by the project. Hellbaum plans to plant a total of 31.7 acres of Kernza over 2 years (Fig. 3). Jessen has already connected with organic buyers, and plans to plant an additional 30+ acres around the research plots. If the first year goes well, John Watson is considering planting an entire 360 acre field to Kernza. Though these extra acres are not part of this research study, the project will support them however we can, including helping source seed and process grain at a lower price if possible.

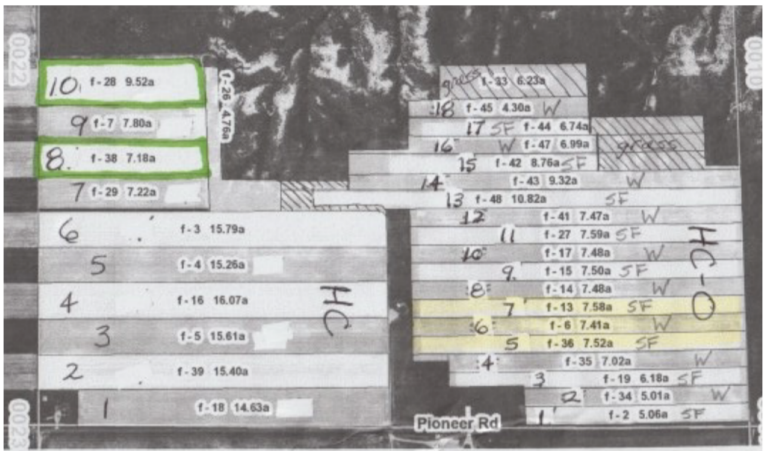

Figure 3. Part of Rob Hellbaum's farm. Proposed Kernza plots for Spring 2021 are highlighted in green.

Harvest: For yield analyses, the SAREC research combine will be used to harvest each 5x30ft plot for both Kernza (years 2 and 3) and wheat-fallow (years 1 and 3).

Expected Results: We expect Kernza yields around 100-300 lb/acre on dryland farms due to highly variable precipitation, and around 500 lb/acre under full irrigation.

Accountability: Producers will be responsible for Kernza management on their farms, and Jay Norton will be responsible for managing Kernza at SAREC. Tessa Peters will manage seed acquisition and help connect farmers with buyers. Caitlin Younquist will facilitate processing the grain at the new University-owned de-huller.

Initial on-farm planting costs will be covered by J. Norton's Soil Resource Lab at the University of Wyoming because planning and ground preparation will need to begin as early as February, 2021, before the grant is announced. In the event that we do not receive the grant award, we intend to continue with a much scaled-back project that would only estimate profitability based on yield estimates from farmers and simple cost-return calculations, and would not include SAREC, soil health, water use, or outreach objectives.

OBJECTIVE 1: Economic: Evaluate Kernza profitability under different farming strategies.

Summary & Justification: We recognize that in order to promote establishment of Kernza in this area, it needs to be competitive with wheat-fallow when considering input costs, returns, markets, and effects on soil health. We will develop effective economic data collection and analysis tools to determine the level of profitability under different management practices and uses.

Materials & Methods: Planting, growing and harvesting cost data will be transmitted to Tom Foulke for analysis and development of cost and return schedules that can be compared with traditional wheat production budgets for the region to determine relative profitability. We will estimate costs and returns for both dryland and irrigated sources and look at the economics of how intermediate wheatgrass fits into the usual rotational scheme for farmers in eastern Wyoming, including soil health considerations. We will also investigate what uses intermediate wheatgrass might best be suited for, including hay and forage, for the best returns to farmers. This

will include an estimated sale price that farmers might need in order to adopt intermediate wheatgrass on their farms. We acknowledge that the eastern Wyoming growing region is extremely variable, and we may have to adjust estimates based on yearly precipitation and growing season length during the study period.

Expected Results: We expect that despite lower yields of Kernza, profitability will be higher over time due to higher market price and lower yearly input costs.

Accountability: Tom Foulke will be in charge of all economic analyses.

OBJECTIVE 2: Soil Health: Evaluate effects of Kernza on soil health and carbon sequestration compared to wheat-fallow and CRP land.

Summary & Justification: We plan to yearly sample the soil at 2 depths at each of the 51 plots, and to analyze samples for structure, soil organic carbon, nutrients, and microbial indicators using methods based on NRCS Recommended Soil Health Indicators (Stott, 2019). Intermediate wheatgrass has been planted in this area as a primary constituent of CRP land to rebuild vulnerable semiarid soils degraded by wheat-fallow agriculture. We believe that Kernza, a domesticated intermediate wheatgrass, can supply some of the soil health benefits of CRP land, such as better water and nutrient supply and resistance to erosion, while maintaining agricultural productivity.

Materials & Methods:

Soil Sampling: Composite soil samples will be taken from each plot at 2 depths (0-5cm and 5-20 cm), along with bulk density samples. Samples will be taken around peak growth, in July of 2021, 2022, and 2023. In year 3, deeper samples (20-40cm, 40-70cm, and 70-100cm) will be taken at one replicate plot per field to use for soil characterization (soil texture and soil C and N).

Sample Analyses: Soil samples will be analyzed for the following indicators. Procedures 1-6 and 10-11 are taken from the NRCS Recommended Measures for Soil Health (Stott, 2019).

1. **Aggregate Stability** using a Yoder-style wet sieving apparatus.
2. **Bioavailable Nitrogen** using autoclaved citrate extractable (ACE) protein analysis.
3. **Short-Term Carbon Mineralization** by quantifying CO2 concentration after a 4-day incubation in a closed container.
4. **Active Carbon** by reacting with a potassium permanganate solution.
5. **Gravimetric Moisture** by oven-drying.
6. **Total Carbon and Nitrogen** by combustion analysis on air-dried ground samples on a Leco TruSpec CN Analyzer.
7. **Soil Inorganic Carbon** by pressure calcimeter (Sherrod et al., 2002).
8. **Nitrate and Ammonium** by extraction using potassium sulfate solution and quantification on a microplate reader (Doane & Horwáth, 2003; Weatherburn, 1967).
9. **Bulk Density** using soil cores. Bulk density will be used to calculate porosity and to estimate carbon and nitrogen stocks in kg ha-1.

Microbial Analyses:

1. **Enzyme Activities** using assays for β-glucosidase, N-acetyl-β-D-glucosaminidase, Phosphomonoesterases, and Arylsulfatase
2. **Microbial Biomass and Community Composition** using Phospholipid Fatty Acid (PLFA) analysis.

Data will be analyzed using 2-factor ANOVA in R to compare: 1) Kernza under different farming strategies and 2) Kernza to wheat-fallow and CRP land.

Expected Results: We expect to see soil health indicators, especially microbial activity and labile carbon pools, to be intermediate in Kernza compared to wheat-fallow and CRP land. Though SOM can be slow to change, responsive indicators such as labile carbon pools and microbial activity can show significant effects in only the first few years.

Accountability: Hannah Rodgers will be responsible for soil collection and analyses. She will be advised by Professor Jay Norton for all soil analyses except the microbial analyses (10 and 11), for which she will be advised by Professor Linda Van Diepen.

OBJECTIVE 3: Drought Response: Predict and compare Kernza and wheat-fallow yields across the Central High Plains ecoregion using a model for water use.

Summary & Justification: Water is the limiting resource in eastern Wyoming, and precipitation is highly variable, so understanding how Kernza reacts to drought stress beyond the three years of our study is crucial. Prior studies have shown promise for Kernza's water use efficiency (Culman et al., 2013; de Oliveira et al., 2018), but it is unknown how Kernza's deep roots will impact yields in a climate this dry. We will use the Terrestrial Regional Ecosystem Exchange Simulator (TREES) model to characterize differences between Kernza and wheat-fallow in this region. TREES is a process-based ecophysiological model that describes carbon, nitrogen, and water cycling in a variety of plants (Mackay et al., 2015; Mitra et al., 2016; Wang et al., 2019), and will provide a framework to predict how Kernza will respond to increasingly unpredictable climate conditions in the Central High Plains.

Materials & Methods:

Hellbaum Farm: We will first test the model using data from the Hellbaum farm, which is among the driest of the five farms. TREES requires the following parameters as one-time inputs (Mackay et al., 2015), which we will collect in year 2 for Kernza and in year 1 for wheat. Parameters 1-5 will be measured for 10 plants per plot.

1. **Leaf Water Potential** at predawn and midday in spring using a PMS-610 Pressure chamber.
2. **Transpiration** at midday in spring using a LI-COR-6400 Portable Photosynthesis System.
3. **Hydraulic Vulnerability Curves** using the bench-drying method (Resco et al., 2009).
4. **Nonstructural Carbohydrate Content** analyzed in above- and below-ground biomass using a spectrophotometer (Guadagno et al., 2017).
5. **Specific Leaf/Root Area** using images of leaves and roots taken at harvest time.
6. **Soil Texture** taken from Objective 2 analyses.

To provide continuous input data for the model, we will use existing lab equipment to establish a meteorological station near field 10 (Fig. 3) to measure wind speed, net radiation, precipitation, air temperature, and relative humidity.

To validate our model, we will install thermocouples and soil moisture sensors at 10, 20, 40, 60, 80, and 100cm in April 2021 at all Kernza and wheat-fallow plots. We will analyze below- and above-ground carbon and nitrogen content at the UW stable isotope facility for wheat (year 1) and Kernza (year 2) at harvest time. This data will be used to calibrate the soil water budget and total yearly carbon and nitrogen budgets predicted by TREES.

To evaluate yield, we will correlate modelled carbon, nitrogen, and water uptake in harvest years with spatial yield data collected at each plot using the SAREC research combine.

Central High Plains Ecoregion: We will expand the model to use publicly available NRCS soil data and PRISM climate data as inputs (*PRISM Climate Group, Oregon State U.*; *Web Soil Survey*). We will corroborate this data using tipping bucket rain gauges on all five farms and soil texture and gravimetric moisture data from Objective 2. We will validate the model by comparing predicted yields at all five farms with observed yield data collected using the SAREC combine.

We will use this validated, expanded model to predict annual carbon uptake and yield of wheat-fallow and Kernza cropping systems in different microclimates and years within the Central High Plains ecoregion, and we will produce maps to inform potential growers.

Expected Results: We expect that Kernza's extensive root system and its ability to improve soil water holding capacity will provide it with more water compared to annual wheat, which will allow it to produce yield even under prolonged drought conditions.

Timeline and accountability: Alex Fox will be responsible for data collection, maintenance, analysis and presentation of results. He will be advised by Professor Brent Ewers and assisted by technicians from the Ewers Lab.

Educational Plan (30% of review criteria)

Summary & Justification: Our outreach plan was formed based on conversations between producers and professionals. Producers shared where they get their agricultural information, what outreach they find most effective, and what activities they personally would like to be involved in. Outreach will be highly participatory, and include many opportunities for peer-to-peer education. Research has shown that participatory applied research fosters farmer inquiry, peer-to-peer learning, and lasting relationships that can lead to social change necessary for adoption of conservation practices (Hall & Fleishman, 2010; Hawkins & Southard, 2001; Licht & Martin, 2007). Our outreach will focus on building relationships between producers, researchers, and professionals at The Land Institute and extension who can support the adoption of perennial crops in this region.

Outreach will be tailored to different groups in the community, including younger students, agricultural producers, the general public, and the scientific community. Much of the outreach will be focused on years two and three, and will focus on the value of perennial crops or grassland in dryland systems as well as on Kernza

specifically. Interest in Kernza is growing around the US, and until now, the Wyoming agricultural community has mostly not been included in efforts to increase awareness and production of perennial grains.

During the COVID-19 pandemic, outreach activities will be held remotely or outdoors and distanced, with all meetings and presentations over Zoom.

1. Maintain stakeholder engagement and cooperation.

A. Stakeholder meetings.

These meetings will serve to maintain lines of communication between all stakeholders using a co-innovation, co-design approach (Dogliotti et al., 2014). At meetings, stakeholders will share their experiences and findings, and will develop scientific and agronomic plans and goals for the following months. Regular meetings, including sharing of phone numbers and emails, keep lines of communication open, demonstrate that on-farm plots are important, and allow for shared observations and problem solving among researchers and cooperators.

Timeline and accountability: Our first project meeting will be held December 2020, before the grant period, in order to discuss plans for the growing season. If we are granted funding, researchers will meet with each cooperator at least three times per year, and meetings with all stakeholders will be held each December to present annual research summaries and make plans for the upcoming season.

B. Annual research summaries.

Each winter, the research team will analyze data from the previous growing season and communicate their findings with stakeholders and other interested groups, such as the Wyoming Wheat Growers Association, by sending out a brief summary before the winter project meeting. This will give stakeholders time to make fully-informed decisions about the coming year. These summaries will also be used in other outreach activities such as articles, posters, and social media.

Timeline and accountability: Tom Foulke will report economic findings, Hannah Rodgers will report soil health findings, Alex Fox will report water usage findings, and Jay Norton will report on the overall state of the project.

2. Host events to engage with the local community about perennial crop agriculture.

A. Youth engagement (4H, FFA, School Presentations, and Lab Days)

Stakeholders from all aspects of the project have emphasized the importance of youth engagement on the project's lasting sustainability. FFA and 4H chapters help youth conduct experiments each year related to some aspect of agriculture. We will connect youth interested in conducting their own Kernza experiments with farmers in the project, who will share seed and provide mentorship.

We will also organize presentations in local schools on perennial grains as an alternative to annual wheat farming. We will use materials geared towards a younger audience, such as a "MinuteEarth" video about perennial grains produced in collaboration with The Land Institute (*Why Farming Is Broken (And Always Has Been)*, 2017). Farmers on the project have experience giving presentations in schools and working with 4H and FFA youth.

Through these agricultural youth groups and schools, we will invite interested students to participate in "Lab Days," where they can spend a day helping with sample collection and lab analyses to learn about the research process and scientific method.

Timeline and accountability: Extension Agent Brian Sebade will be in charge of youth engagement activities. He works with both 4H interns and FFA science projects, and he will coordinate school presentations and publicize "Lab Days." Graduate students Hannah Rodgers and Alex Fox will each host a "Lab Day" annually to involve interested students in sample collection and analyses.

B. Regional presentations (Wyoming State Fair and Extension Meetings)

We will set up a booth next to the hay show at the Wyoming State Fair in Douglas, and bring posters and bulletins, a sample of Kernza, and information to help farmers connect with growers and seed suppliers. At both the State Fair and at Extension Meetings, we will distribute general information about perennial grains taken from Kernza.org as well as data from our study. By winter 2023, we will have written up posters and bulletins summarizing the outcomes of Kernza grown under different management strategies which can be shared.

Timeline and accountability: Brian Sebade will be in charge of organizing the booth at the State Fair in August of 2022 and 2023. Tom Foulke, Hannah Rodgers, and Alex Fox will attend to educate the public about soil health, water use, and perennial crops. Jay Norton and Brian Sebade will be responsible for extension meetings. All stakeholders will be encouraged to attend these events to share their experiences.

C. On-farm visits and SAREC field days

On-farm events, organized and publicized by UW extension educators, will focus on farmer-to-farmer experience sharing and will support farmers interested in trialing Kernza on their own farms. We will use the SARE Farmer Field Day Toolkit, and we think that there will be excellent turnout if planned to avoid busy times of the year for area farmers. These short, focused, on-farm sessions have become very popular among producers in Wyoming. We will work within existing structures such as the annual SAREC field day.

Timeline and accountability: Brian Sebade and Jay Norton will be responsible for

organizing and promoting these on-farm days, which will take place in years 2 and 3 of the project. Producers on the project will attend to share information about their experiences with Kernza.

3. Publish our findings on Kernza profitability, soil health, and drought response.

A. Scientific research papers.

We plan to publish papers in journals such as the "Agronomy Journal" and the "Soil Science Society of America Journal" detailing our findings on the viability of Kernza in eastern Wyoming from the perspectives of water usage, soil health, and agroeconomics.

Timeline and accountability: We will write up our findings during the winter of 2023, and submit papers for publication before the end of the grant period in April 2024. Hannah Rodgers, advised by Tom Foulke, will be responsible for a paper on soil health and the economic potential of Kernza, and Alex Fox will be responsible for a paper on predicting Kernza water use and yield in a changing climate.

B. Extension bulletins.

We will publish a small series of four peer-reviewed bulletins on Kernza agronomy, economics, soil health, and water use/ yield predictions in eastern Wyoming. We will use data from our yearly research summaries and research papers. We will distribute them around the University of Wyoming and to regional agricultural groups

Timeline and accountability: The same 4 people responsible for the yearly summaries will be responsible for these bulletins.

C. Other media forms (radio, social media, newspaper)

We will work with the University communication office, Wyoming Public Radio, social media platforms, and regional agricultural publications to present information about perennial agriculture and our study and to publicize events. We will reach out to commercial and public radio programs to produce interviews about the project. We will publish articles in popular agricultural publications, such as the Wyoming Livestock Roundup, the Prairie Star, and the Fence Post.

For social media, we will establish and update a linked blog and Instagram account dedicated to the project to be shared through local schools, agricultural groups, and existing social media accounts such as those associated with The Land Institute. We will share research updates, general information about perennial agriculture, virtual farm tours, and short videos of planting, harvesting, sample collection, and lab work.

Timeline and accountability: Graduate students Hannah Rodgers and Alex Fox will be in charge of social media outreach. Jay Norton and Brian Sebade will be in charge of coordinating publications and broadcasts with local newspaper and radio, and getting other stakeholders involved. Tom Foulke will write and publicize articles on the economic potential of perennial crops in the Central High Plains.

Timeline (5% of review criteria)

Year 1 will focus on the establishment of Kernza on five farms as well as taking baseline soil and water use data. In Years 2 and 3 of the project, we will continue gathering agroeconomic, soil, and water use data, which will be sent out to all stakeholders in yearly reports and discussed in stakeholder meetings. Other outreach activities will begin in Year 2 and will be the focus of Year 3. From winter 2022 onwards, we will organize outreach through 4H groups, the Wyoming State Fair, extension meetings, and other media forms including radio, local newspaper, and social media. After data collection is finished in fall of 2023, we will spend the winter and spring of 2023-2024 producing and distributing educational materials.

As stated above, initial on-farm planting costs will be covered by J. Norton's Soil Resource Lab at the University of Wyoming because planning and ground preparation will need to begin as early as February, 2021, before the grant is announced. In the event that we do not receive the grant award, we intend to continue with a much scaled-back project without soil health, water use, or outreach objectives.

Milestones

1. Kernza planting.
2. Begin community outreach activities (youth engagement, field days, state fair, extension meetings).
3. First Kernza harvest.
4. Begin building expanded drought response model.
5. End of data collection for Objectives 1-3.
6. Finish publishing all materials.

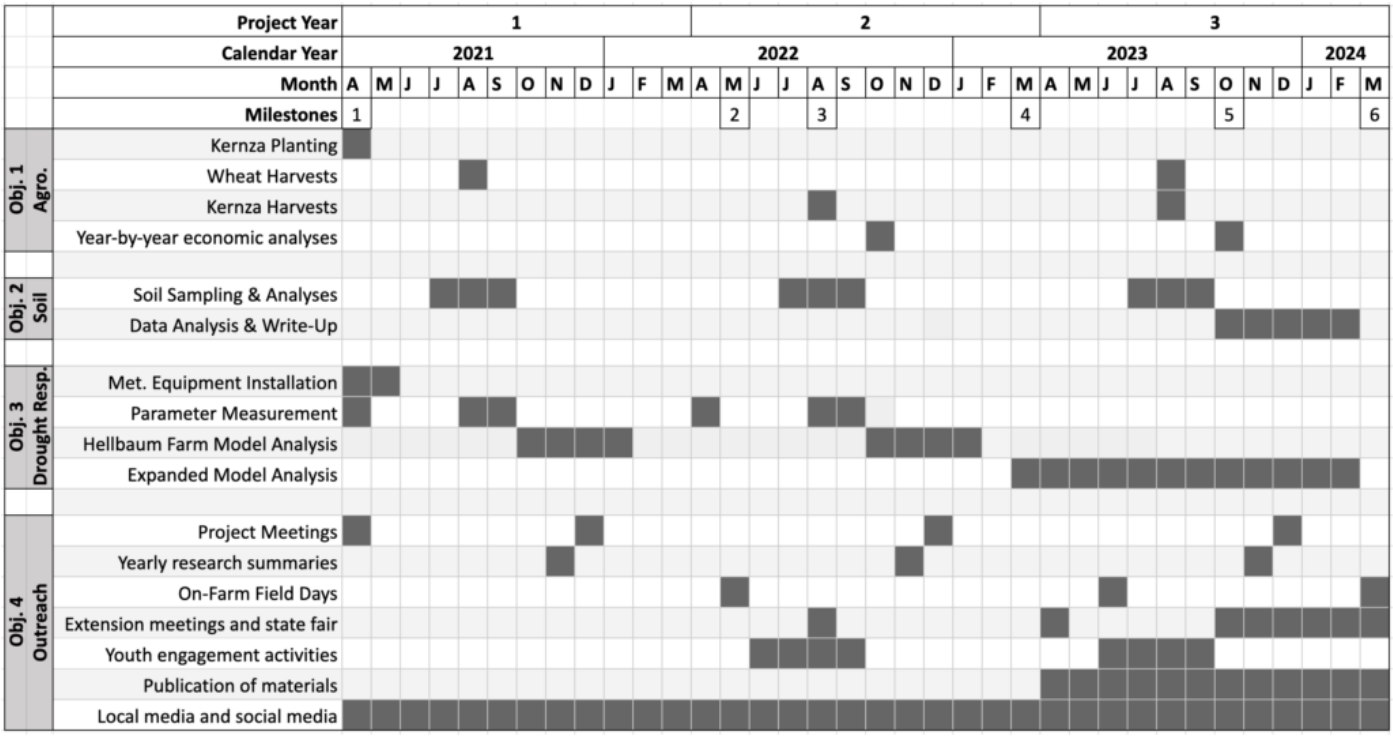

Table 1: Project Gantt Chart

Evaluation and Producer Adoption (5% of review criteria)

We will use the Western SARE evaluation tool, or a similar tool developed by UW Extension, to assess how outreach events impact participants' knowledge, awareness, attitudes, and practices. We intend to survey attendees at field days, extension meetings, youth engagement activities, and other outreach events. Active engagement of producers along with frequent communication between all stakeholders will facilitate information on adoptability of perennial grains.

We will use information from these evaluations to assess impacts based on our outreach objectives, and to revise our approaches. We particularly plan to have to adjust our youth engagement in order to tailor activities to different age groups. Survey results will be included in the annual and final project reports, discussed at project meetings, and used to inform future work on this project.

Budget and Justification

Total Budget

$74804

Budget Worksheet for Awarded Institution

SARE Budget Worksheet Kernza Grant

Sub-awards to Other Institutions

No

Authorized Organizational Representative

Diana Hulme

Supporting Documents

Signature Page
WSARE-Signature

Current Vita
Norton CV
Sebade CV
Rodgers CV
Fox CV
Foulke CV
Peters CV

Letters of Producer Cooperation
Jessen Letter of Support
Russell Letter of Support
Watson Letter of Support
Goertz Letter of Support
Hellbaum Letter of Support

Current and Pending Support
Sebade C&P Support
Norton C&P Support
Foulke C&P Support
Peters C&P

Animal Welfare Assurance Statement
WSARE_Institutional-Animal-Care-and-Use-

Letters of Stakeholder Support (Optional)
Peters Letter of Support

Citations
Citations

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