BIOAG PLANNING GRANT FINAL REPORT

KRISTEN JOHNSON, PRINCIPAL INVESTIGATOR

TITLE:

Flexible Farming (FlexFarm) Production Systems: Integrating Crops and Livestock for Diverse, Resilient, and Sustainable Agricultural Landscapes

CO-PRINCIPAL INVESTIGATOR(S):

Research Team:

Kristen A. Johnson, Ph.D. (Ruminant Nutrition, Beef and Dairy Cattle, Animal Systems and Environmental Impact); Scot H. Hulbert, Ph.D. (Cropping Systems Pathology); William L. Pan, Ph.D. (Cropping Systems, Soil-Plant Relationships); Lynne Carpenter-Boggs, Ph.D. (Organic Farming Systems); Vicki McCracken, Ph.D. (Agricultural Economics); J. Shannon Neibergs, Ph.D. (Economics of Livestock Production and Marketing); David R. Huggins, Ph.D. (Agroecology, Land Management, Water Conservation); Haijing Tao, Ph.D. (Nutrient Management, Statistics, GIS); Ian Burke, Ph.D. (Weed Science); Margaret Benson, Ph.D. (Ruminant Nutrition, Sheep), Dennis Roe (Retired NRCS, Conservation Agronomist, Leslie Michel (Soil Scientist and Conservation Planner, Okanogan County), Dave Crowder, Ph.D. (Entomology), J.D. Wulfhorst (Rural Sociology, UI).

Extension Team:

Don Llewellyn (WSU Extension Specialist, Benton & Franklin Counties), Sarah Maki Smith (WSU Extension Specialist, Grant & Adams Counties), Tip Hudson (WSU Extension Livestock Grazing Specialist, Kittitas County), Karen Sowers (Extension and Outreach Specialist, Richland), Steve Van Vleet (Extension Specialist, Whitman County), Steven Fransen (WSU Forage research agronomist and Extension specialist, WSU Prosser), Ken Hart (UI Extension Educator, Lewis County), Jim Church (UI Extension Educator, Idaho County), Doug Finkelnburg (UI Extension Educator, Nez Perce County).

COOPERATOR(S)

Ranchers/Growers:

John and Debbie Pearson, John and Cory Aeschliman, David Lange, Stephen and Fran Maki, Gary Monson and Sons, Kim Weerts, Jon Link, Rodger Zaring, and several others from Lincoln, Douglas, Grant, and Okanogan counties.

Industry Stakeholders:

Pacific Coast Canola, Shepherd's Grain, Country Natural Beef, WA Cattlemen's Association, PNW Grain Growers Cooperative.

KEY WORDS:

Integrated crop-livestock farming systems, Land-use efficiency, Sustainable food production, Ecosystem services, Soil erosion, Water quality

ABSTRACT:

Our overall research goal is to contribute to global, national, and regional food security and the ecological and economic sustainability of the inland Pacific Northwest's (iPNW) agricultural landscape. Specifically, the project aimed to study the potential of integrated crop-livestock (ICL) production systems as resilient and sustainable alternatives to the iPNW's existing, rainfed agricultural landscape dominated by intensive, small-grain monoculture systems. Factors that signal the timing is right for transitioning toward regional

ICL systems include: (1) shift in consumer preferences and demand toward healthier, sustainable, and locally produced food; (2) increasing societal emphasis on ecosystem services and environmental protection in response to greater awareness of the carbon, nitrogen, and energy footprints of food and fuel production; (3) advances in mobile grazing and forage production technologies such as low cost, portable, and flexible animal fencing and watering systems; (4) need for crop diversification and intensification for improved agronomic, environmental, and economic sustainability and to feed a growing human population; and (5) more stringent government regulations and environmental pressures on animal and crop nutrient management. We designed on-farm, ICL research sites—in cooperation with several farmers and ranchers—under a range of dryland (rainfed) conditions within the iPNW agricultural landscape. We anticipate that future implementation of "real" ICL production systems will result in the following outcomes: (1) sustainable agricultural intensification that increases food quantity, quality, and diversity; (2) a more balanced portfolio of agricultural products that are consumed regionally, nationally, and internationally; (3) regional resource use optimization and an internally reliant and resilient production system that is responsive to global climate and societal change; and (4) tightened and reconnected nutrient, energy, and carbon cycles that protect the environment and improve the supply of ecosystem services. The BIOAg Planning Grant helped us create interdisciplinary teams and links that had never worked together before for future research proposal submission to an appropriate funding agency.

PROJECT DESCRIPTION:

The iPNW offers a unique location for testing new research ideas toward creating an integrated, diverse, and sustainable agricultural landscape. These ideas extend from understanding the biophysical domain of animal, soil, and plant health through the social domain of risk management and rural community sustainability. A fair amount of research has been conducted in other more humid regions of the US and in other countries worldwide. However, little is known about the feasibility of ICL systems under lower rainfall, rainfed agricultural production regions. Successes and lessons learned in the iPNW will be transferable to other regions in the country and the world with a similar combination of climate and agriculture.

The intent of our research is not to return to low productivity agriculture, but rather consider innovative opportunities that maintain needed high outputs to feed a growing population and optimize production per unit of natural resource (Lemaire et al., 2015). Thus, a grain producer can work with a livestock producer to mutual benefit. Soil organic matter and nitrogen use can be altered with cropping strategies, grazing strategies, forage production, or combinations of each system (Mobley et al., 2014). We plan to examine these alterations to optimize social, economic, and ecosystem benefits.

We have identified several barriers to adoption of ICL systems, which will also be addressed in our research project. These barriers include 1) livestock management issues (timing, water, fencing, transportation), 2) grazing efficiency issues (stocking rate and density, timing), economic issues (economic risks and uncertainties, lack of local markets, supply chain management, alternative markets, hidden costs), and policy barriers (CRP grazing restrictions and inflexibility of government subsidy/crop insurance programs). We propose several options that could make ICL very attractive to growers and ranchers. One is an entrepreneurial opportunity for a service that can match forage to the livestock needs and create and coordinate grower-rancher partnerships. Another option is to create tools based on real data that allow prediction of forage production early in the year for planning purposes.

Specifically, our research objectives include the following:

Socio-economic:

1. Understand opportunities, constraints, and barriers to adoption of ICL systems in the iPNW through engagement with diverse stakeholder groups.
2. Evaluate the economic risks and benefits of selected, regionally appropriate ICL systems.
3. Assess the social implications of selected, regionally appropriate ICL systems.

Biological:

1. Identify and examine existing, successful ICL systems in the iPNW; investigate novel ICL systems with potential for success; and seek opportunities to facilitate expansion of these systems in the region.
2. Quantify the productivity and environmental impacts (e.g., water, greenhouse gas, and nitrogen budget analyses) of the selected ICL systems and their capacity to improve the diversity, resilience, and sustainability of farming, ranching, and rural communities in the iPNW.

Extension:

1. Use successful models as guides to create extension programs and learning materials that teach methods for implementing ICL systems and communicate the economic and environmental risks and benefits of implementing ICL systems.
2. Develop and evaluate online, self-directed tools that help growers and ranchers determine and manage risk associated with various ICL systems.
3. Initiate and test a web-based decision support and communication system that allows farmers and ranchers to spot potential beneficial relationships and set up pasture/cover crop-grazing exchanges based on need, timing, and location.

The objective of this planning proposal was to create an interdisciplinary team to: (1) understand the potential to re-diversify the iPNW's agricultural landscape through identifying farmer/rancher cooperators and potentially viable ICL systems; (2) examine the preliminary implications of these systems from a social, economic, and biological perspective; and (3) use this information to draft several parts (e.g., logic model, background/rationale, stakeholder involvement, etc.) of a larger funding proposal, which would then be submitted to the National Institute of Food and Agriculture (NIFA) and USDA: Agriculture and Food Research Initiative Competitive Grants, Food Security Program in June 2016. However, the Priority Area, Agricultural Production Systems - Integrated Crop and Livestock (ICL) Management Systems, that was a focus in 2015 was not a focus in the 2016 solicitation. Thus, we are currently investigating other funding opportunities. At this date we would like to return the balance of the grant to the program so it can be used by others. The people who have been a part of the project have already begun to submit other projects together sucha as a NIFA SARE grant (Michel, Carpenter-Boggs, Tao, Hulbert, Burke and Johnson).

OUTPUTS:

Work Completed:

1. Hired Proposal Planning Coordinator: Linda Klein.

2. Core Team Meetings*:

Primary team (all meetings): Kris Johnson, Scot Hulbert, Linda Klein.

Secondary participants (selected meetings): Bill Pan, Dennis Roe, and Leslie Michel:

- 10/16/15
- 10/26/15
- 11/6/15
- 11/20/15
- 11/24/15
- 1/25/16
- 4/13/16
- 5/14/16

3. Full Team Meetings*:

- 11/03/15

Handouts of the agenda, proposed project summary, and potential ICL system descriptions were sent out prior to the meeting. This initial 2.5-hour "in-person" meeting focused on a) introducing potential team members and their unique contribution to the proposed research project, b) reviewing the proposed FlexFarm project idea and objectives and the elements and constraints of the target RFA, c) discussing the potential integrated crop-livestock (ICL) systems for the iPNW, d) brainstorming tentative research questions/hypothesis and experimental design options, and e) deciding on which ICL systems to pursue further. Meeting minutes and assignments for providing additional information for the proposal were sent to all participants and those interested, but unable to attend the meeting in person.

4. Rancher/Grower/Stakeholder Meetings*:

- 12/1/15: Colfax, WA area growers/ranchers
- 12/17/15: Dusty, WA area growers/ranchers
- 3/7/16: Okanogan area, WA growers/ranchers

***In addition to the planned meetings listed above, communications and information sharing between various project team members were frequent via phone, text, or email through the planning period.**

5. Test plots – We conducted a simulated grazing experiment at the Wilke Farm in Davenport, WA and at the Lind Research Station to examine the role of late winter forage removal (simulated grazing) on yield, test weight and water use. Eight plots per site were designated as test plots. Four plots serve as control (unharvested) plots and four as treatment (forage removal). The data collected at harvest indicated there were negative effects on wheat yield with simulated grazing.

<u>Publications, Handouts, Other Text & Web Products</u>:

In addition to documenting all meetings, the team completed several informational documents, including the following:

1. Research Definitions, Problem, and Scope:

<u>Definitions</u>

Integrated Crop-Livestock (ICL) System: Crops and livestock interact in such a way that products or by-products of one component are resources for the other. In ICL systems, *recycling* is key for maximizing use and efficiency of available resources. For example, cropping provides feed as crop residue, grass, weeds, or legumes, while livestock excreta provides nutrients to improve soil fertility and reduce use and dependence on external inputs. In contrast, diversified agricultural systems also consist of multiple components such as crops and livestock, but components co-exist separately, without interaction. Diversified systems function primarily to reduce economic risk, but not to recycle resources.

Within the context of this project, ICL systems are defined for three spatial scales:

- **On-farm ICL:** Integrating livestock and crops within a single farm (landowner maintains and manages own livestock). These systems can include perennial forage/pasture-based operations.
- **Among-farm ICL:** Nearby producers and growers exchange crop-livestock resources. Livestock graze crops or crop residue while cropland receives an application of "free" nutrients through a coordinated timing system of supply and demand. This strategy requires knowledge of nutrient cycling; animal nutritional needs; awareness of plant and soil conditions; and livestock transport, fencing, water, and management services. Livestock management services could be provided by one of the cooperating producer-grower pairs or by an independent third party.
- **Landscape-scale ICL:** The combined effects of on-farm and among-farm ICL systems on land-use efficiency, sustainable intensification, and biodiversity can be visualized and

experienced at the larger, agricultural landscape scale. Furthermore, the biological and physical processes and interactions that contribute to many of the negative impacts (environmental degradation) and humankind benefits (ecosystem services) of agricultural systems transcend landownership boundaries. Thus, impacts of the spatial arrangement, compositional structure, and temporal interactions of land ownership units on phenomena such as soil erosion, water quality, air quality, and biodiversity can only be adequately measured and realized at larger scales. The degree of these impacts is also dependent on the topographical, hydrological, and ecological contexts of any given agricultural setting. Additionally, a regional analysis is necessary to understand the socio-economic and political incentives, barriers, and implications of diversifying/intensifying the agricultural landscape via ICL systems.

Problem

Issues addressed by studying the feasibility of ICL systems in the iPNW

- Soil erosion (e.g., fallow/low residue land is planted to cover crops or stubble is maintained for grazing, rather than plowing/discing into soil and leaving soil exposed during winter and early spring when erosion risk is the highest).
- Water quality (e.g., maintaining cover reduces runoff and increases water infiltration).
- Dependence on external chemical inputs (e.g., grazing livestock naturally apply "free" soil nutrients via manure and urine, improving soil fertility and reducing the amount (and cost) of fertilizer inputs).
- Livestock forage limitations in late summer and fall (e.g., allowing grazing on grain stubble or cover crops on nearby cropland can help close livestock feed gaps and reduce supplemental feed and transportation costs).
- Persistent cycles of weeds, insects, and disease (e.g., diversifying crop rotations and integrating livestock grazing can break weed, insect, and disease cycles to reduce crop damage and subsequent yield loss).
- Agricultural land-use efficiency, sustainable intensification, and natural resource protection (e.g., growing crops for multiple purposes and converting marginal lands (low productivity or expiring CRP) to permanent grassland/pasture/forage for year-round, sustainable grazing operations—rather than using/converting them for annual grain crop monocultures that, in turn, create soil conditions that are highly susceptible to erosional processes).

Scope

Region: Inland Pacific Northwest dryland farming region (focus is on non-irrigated systems)

Multi-state:

- Washington
- Idaho

Multi-scale:

- On-Farm (Experimental Plots)
- Among-Farms (Experimental Plots)
- Landscape/Regional-scale (Modeling)

2. Existing versus Potential ICL Systems:

We have developed detailed information about the potential ICL systems, including timing, locations, rotations, crop species, tillage management, experimental design, and research comparisons. We consider this proprietary information because we have yet to secure funding for the research. Thus, we are respectfully withholding this information and, instead, provide the following summary:

Existing Common Cropping Systems:

- Winter Wheat-Spring Cereal-Legume (WW-SC-L). Continuous grain cropping in areas of high rainfall, 500–600 mm (~ 20–24 inches).
- Grain-Fallow (F) rotations in areas of intermediate rainfall, 380–490 mm (~ 15–19 in.) (WW-SC-F) and areas of low rainfall, 200–360 mm (~ 8–14 in.) (WW-F)
- Perennial forage/pasture/grassland (all rainfall areas) - lands used solely for livestock grazing and/or hay/silage production.

Alternative ICL Systems: The two dual-purpose systems are defined in general and can be implemented in any rainfall area using the same basic systems/cropping rotations above. However, plant species and timing and duration of rotations and grazing will vary according to rainfall and tillage system.

- **Dual-Purpose Grain/Oilseed ICL System**: Crop is used for both livestock forage and grain or oil production. Animal waste products provide soil and plant nutrients. In our context, forage is supplied by stubble grazing post harvest, unless fall-planted crops produce enough early growth to graze.
- **Dual-Purpose Cover Crop ICL System:** Spring- or fall-planted cover crop is used for both livestock forage and green manure/soil cover (cover crop is plowed under during late-spring seedbed prep in conventional or reduced till operations, but sprayed out in no-till). Animal waste products provide soil and plant nutrients.
- **Perennial/Permanent Pasture ICL System:** Pasture/forage provides livestock fodder; animal waste products provide soil and plant nutrients. Beyond the traditional "ranch" environment, a sustainable, pasture-based ICL system requires a high-level of active livestock management (e.g., intensive, high-density, rotational grazing on small paddocks) to realize uniform distribution of animal nutrients; consistent, regeneration of high quality forage; and maintenance of a productive and health soil resource. Opportunities for this system include expiring CRP lands (previously set-aside for conservation purposes), existing CRP lands with relaxed restrictions that allow limited grazing, and marginal lands (low grain productivity land such as areas of steep slopes, shallow soils, or otherwise unsuitable for cultivation). Flexibility can allow harvesting some acreage for hay/silage or producing a cash crop if doing so provides weed or pest cycle disruption and creates minimal adverse environmental impacts.

3. Local grower/producer feedback, issues, and questions in response to FlexFarm ICL ideas:

- Some of the complexities of integrating cattle are timing and coordination with weather, available forage, and existing cropping systems. Cow and calf feed is needed at the end of the summer (August) to mid-November and yearlings need feed in July, August, and September. Dry cows can graze grass; pregnant cows and yearlings need higher quality feed.
- Most crop-only growers do not have the knowledge or desire to manage cattle on their land, nor do they have the supplies and equipment (fencing, water) or the extra time. Doing so would require navigating a steep learning curve and a large outlay of cash.
- If wheat/cereal crop value is high, why would growers want to convert land to livestock and then deal with the management issues?
- Grazing limitations on CRP and riparian areas (in other words, it would be nice to figure out how to use these resources sustainably). Grazing CRP lands is enticing for some producers, particularly given the past summer's fire damage on grazing lands in ID/WA forests and the restoration time required before grazing can resume. A big issue is how to get water on CRP

lands. Relative to riparian areas, WA Department of Ecology (DOE) has strict regulations. Would DOE loosen the regulations if a grazing plan was designed in a novel way to protect the resource while allowing limited grazing for research purposes?

- Moisture limitations: cover crops are a great idea, but they currently do best in areas with summer rain, which the Palouse doesn't experience. Also, how would cover crops impact yield of subsequent cash crops?
- Planting canola in the summer for grazing in fall can work, but income is lost by forfeiting the wheat crop. High evapotranspiration is also an issue with canola - i.e., canola has high water requirements.
- Economics centers around comparing the economics of wheat production versus economics of forage grazing on the same land. Growers are also concerned about potential reduced yields, post grazing.
- Interest in the potential to graze barley in the dough stage. Among wheat, barley, triticale, and oats, the focus seems to be on wheat and barley for grazing.
- What's the potential for grazing alfalfa and brassicas other than canola (e.g., turnips, kale, cabbage?) in the Palouse?
- When grazing stubble, consider nutrition supplied by plant vs. nutrition needed by class of livestock.
- Livestock are typically wintered elsewhere than the Palouse due to rain and mud.
- Constraints to establishing forage crops in summer is lack of rainfall and to grazing livestock in winter is compaction problems on wet soils.
- A large proportion of cropland in Whitman County (and Palouse?) is leased. Farmers who lease the land are less likely to be concerned with conservation measures that require time and money ~ because they don't own the land and won't benefit in the long-term.
- How will subsequent crop yields be affected by grazing stubble? If yields go down, how will that affect my subsidy payments? What about weeds? Will weeds increase? What about compaction by hooves - will my soil be adversely affected?
- If I have a water source (creek), EPA regulates cattle in the water - this will be an annoyance to crop growers who currently do not have to deal with this issue. Some growers expressed fear/irritation relative to the potential of more government regulations and scrutiny.
- How to provide livestock with water while temporarily grazing stubble on crop-only lands? Labor and management issues.
- Managing livestock is a 24/7 commitment - need great passion to do so.
- How would the agreements be worded between the livestock producer and the crop grower for a temporary grazing arrangement (e.g. fall stubble) - who would be responsible for accidents, unintentional damages, etc.? What are the legal implications?

4. Research questions/hypotheses, justification, experimental design, methods, anticipated outcomes, and relationship to other components of the potential ICL systems (*selected example drafts from Entomology and Animal Science team members*):

ENTOMOLOGY

Research Question(s)/Hypothesis(es):
(1) How do ICL systems impact the population dynamics of wireworms and their impacts on wheat cropping systems?
Hypothesis: Wireworm population abundance will decrease in wheat-based cropping systems that incorporate livestock into rotations, as will subsequent damage to wheat crops
(2) Can incorporating grazing, cover crops, or different rotations affect aphid dynamics and the incidence of aphid-transmitted viruses in wheat?

Hypothesis: Grazing will help reduce the amount of available resources for aphids, resulting in declines in aphid populations and helping to disrupt disease cycles in wheat.

Justification:

(1) Wireworms are soil dwelling insects that are extremely economically damaging to cereal, potato, legume, and canola crops. To date, 100% of wheat growers used prophylactic treatments with seed-applied neonicotinoids to control wireworms. However, research by Crowder's lab and others have shown these treatments are not particularly effective at controlling wireworms because neonicotinoids cause intoxication but don't kill wireworms. Thus, there are no good insecticide-based strategies are available to manage these insects.

Wireworms, however, are extremely impacted by soil conditions and crop rotations. We have found that soil pH, moisture, texture, and temperature all influence wireworms, and these factors might be influenced by grazing. Moreover, rotations also impact wireworms. For example, winter-wheat fallow rotations have 50% lower abundance of wireworms than continuous spring wheat rotations. It is unclear, however, whether livestock would affect wireworms. Livestock grazing could reduce the abundance of weeds and other resources used by wireworms for food, thus indirectly impacting populations. Livestock could also affect soil conditions with direct impacts on wireworms. Therefore, understanding how different cropping systems impact this major insect pest may provide clues for developing viable control strategies.

(2) As the climate has warmed, there has been a trend for growers to plant winter wheat earlier and earlier. In turn, late season generations of aphids have found a green bridge into winter wheat that may not have previously existed. This new green bridge has increased problems associated with aphid-transmitted viruses in winter wheat crops. Therefore, understanding aphid response to ICL systems, cover crops, and alternative rotations may provide clues for developing viable strategies to disrupt this climate-induced green bridge.

Methods/experimental design:

(1) Conduct long-term sampling of wireworm and aphid populations on paired farms that incorporate grazing or do not. Explore whether long-term declines in population abundance can be detected in farms that integrate livestock. Explore whether the incidence of wireworm damage (which can be scored in the field) and incidence of aphid-transmitted pathogens (like Barley yellow-dwarf virus) differ on farms with and without livestock integration.

Basically, our insect work can easily be integrated into the broader study. The experimental design is basically to implement grazing or not, and then monitor the insects over time. This might require several years to detect differences. It would also be good to look at whether we can estimate yield reduction caused by insects in farms with/without grazing.

Anticipated outcomes (*defined as a change in participant/stakeholder knowledge or behavior or when a societal condition is improved because of actions taken by the participant/stakeholder*):

If livestock grazing is shown to significantly reduce problems associated with insect pests, this would be a strong incentive for growers to adopt this practice as a cultural control for insects.

Potential interactions/relationships of entomology research with other ICL system components and processes across multiple scales:

Wireworms and aphids, as with almost all insect pests, are affected by soil conditions, plant quality, and cropping rotations. Understanding how these populations are changing based on rotations is important. Moreover, we can easily integrate data with insects with scientists studying soil properties or plant quality traits in our study systems, to try and figure out the mechanisms by which livestock integration might influence insect populations. Finally, wireworms and aphids affect farmer's bottom lines and their decision making processes, so there is a natural link between our work and work on the economics/social dimensions of this system.

ANIMAL SCIENCE

Research Question(s)/Hypothesis(es):

1. For a given ICL system and location, what are the optimal ranges for stocking rates, densities, and timing and duration of grazing?
2. What are the nutritional benefits/risks associated with the livestock components of the ICL systems?
3. How do the cattle/sheep components of the ICL systems impact the environment, e.g., greenhouse gas emissions, soil fertility, soil compaction, weed suppression?
4. What information do livestock producers/livestock managers need to make decisions, i.e., what is needed for use of a risk management tool?

Justification:

1. Animals can both positively and negatively impact the landscape and information is needed to assist producer in enhancing the positives and protecting against the negatives. Animals, if used correctly as a tool, can enhance and repair an ecosystem.
2. Animals move nutrients around the landscape and change the form of nutrients that can benefit the soils.
3. Food production needs to be a sustainable system and an adaptable one. Grain and livestock producers need options to use that are economically sound, socially appropriate, and enhance ecosystem services. Resilience and adaptability will be the key to economic sustainability.

Methods/experimental design:

- Collect livestock data including body weights, body condition scores, weaning weight.
- Stocking density, stocking rate.
- Collect and analyze plant composition data for N, protein, ash, anti-quality factors (if any), digestibility (energy).
- Measure GHG by use of a mobile collection system designed at WSU.
- Use satellite imagery and laser systems to determine stocking rates.
- Graze or no graze plots…..different animal densities.

Anticipated outcomes (*defined as a change in participant/stakeholder knowledge or behavior or when a societal condition is improved because of actions taken by the participant/stakeholder*):

- Outreach tools based on research findings will be developed to educate grain and livestock producers on options to integrate the two.
- Risk management and other economic tools will be developed for use by the grain and livestock producers.
- Recommendations of stocking rate and density factors for integrated projects.

Potential interactions/relationships of animal science research with other ICL system components and processes across multiple scales:

- Livestock and plant composition data and analyses can be shared with researchers responsible for other systems components.
- GHG emissions for larger modeling efforts.
- Livestock data to be shared with the economics modelers.
- Data on grazing intensity and soil compaction or other soil specific measures.
- Water usage for budgets.

Outreach & Education Activities: NA

IMPACTS: NA

- Short-Term:
- Intermediate-Term:
- Long-Term:

ADDITIONAL FUNDING APPLIED FOR / SECURED:

The intention of this project was to apply for funding for an integrated project in the NIFA Food Security program. Unfortunately, the newly released 2016 RFA was changed from the previous year and the FlexFarm project did not fit the new focused priority areas. We have examined all of the RFAs that have been released and have found no opportunity to apply. We wish to return the balance of the planning grant funds. We believe that we have created a highly competitive team, have engaged stakeholders, and have developed solid experimental designs for the purpose of submitting a competitive proposal in the future. We intend to continue searching for appropriate funding programs. A part of the team did recently apply for a USDA Western SARE grant using some of the ideas in this project.

GRADUATE STUDENTS FUNDED: NA

RECOMMENDATIONS FOR FUTURE RESEARCH: NA

REFERENCES CITED:

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