2018

# Climate Change Adaptation in Grassland Agroecosystems.

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# Climate Change Adaptation in Grassland Agroecosystems.


## Abstract

We proposed to engage landowners and land managers (i.e., biologists and agency personnel who manage state, federal, and non-profit lands) to protect grassland and biodiversity through development of climate change adaptation strategies in the Grand River Grasslands of southern Iowa and northern Missouri, with a focus on examining how grasslands are managed. Our plan was to build on our previous research to: 1) identify priorities for the conservation of grassland ecosystems, 2) identify the vulnerability of a suite of plant species to climate change, 3) identify options that land managers can take in the present to prepare for future climate conditions, and 4) discuss and evaluate these options with land owners and land managers to determine which options are most socially and economically feasible to implement.

Title: **Climate Change Adaptation in Grassland Agroecosystems**

**Final Report**

**Feb. 17, 2019**

Proposal Code Number: XP2016-07A
Portal: Integrated Farming Systems
Focus Area: Farming Options for a More Diverse Landscape
Category: Research

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Budget:
Year 1 - $35,951
Year 2 - $29,638
Year 3 - $24,411
Total: $90,000

**Scope of Work:**
We proposed to engage landowners and land managers (i.e., biologists and agency personnel who manage state, federal, and non-profit lands) to protect grassland and biodiversity through development of climate change adaptation strategies in the Grand River Grasslands of southern Iowa and northern Missouri, with a focus on examining how grasslands are managed. Our plan was to build on our previous research to: 1) identify priorities for the conservation of grassland ecosystems, 2) identify the vulnerability of a suite of plant species to climate change, 3) identify options that land managers can take in the present to prepare for future climate conditions, and 4) discuss and evaluate these options with land owners and land managers to determine which options are most socially and economically feasible to implement.

In brief, the objectives defined in the grant were as follows:

1) From a *climate perspective*, we will assess historic variability in weather patterns over the past 120 years to document change. We will evaluate these data to determine specific weather indices that relate to grassland resilience from a biological and economic perspective. We will evaluate these indices under weather conditions expected to occur during 2020 – 2040. We will also create presentations on topics ranging from weather trends to sources of variability in climate projections. These presentations will be shared with landowners and land managers.
2) From an *ecological perspective*, we will assess how habitat suitability will change for particular key grassland plants and how best to manage for these changes. We will expand on our previous research to develop recommendations for future grassland management including: 1) selection of seed mixes and planting sites relative to soil moisture, soil type, and flooding potential, 2) use of grazing and/or grass banking as management tools, and 3) managing to mitigate for woody encroachment. We will survey managers to evaluate the strategies that they have found to be most effective during extreme climate conditions and collaborate with them to develop effective strategies for the future.
3) From an *economic & policy perspective*, developing adaptation strategies to climate change requires a thorough understanding of the social-economic context of land use changes. We will focus on "macro-drivers" (i.e., policies and market environment) and "micro-drivers" (i.e., community level interactions and characteristics of landowners/fields) to examine the effectiveness of different conservation strategies and policies (e.g., Conservation Reserve Program, Environmental Quality Incentive Program, and conservation easements).
4) From an *integrated analysis perspective*, we recognize that it is very important to consider interactions and feedback among the climatic, biological, and economic components of the project. Linkage will occur via development of research questions, data sharing, interpretation of analysis results, and the dissemination of project findings to land managers and land owners.

The major events that occurred in year three focused on 1) writing up the results of the climate models for publication, 2) analyzing the results of the survey instrument, and 3) meeting with partners, collaborators, and stakeholders to report on our findings. Debinski and graduate student Nick Lyon collaborated with climatologist Dr. Imtiaz Rangwala (of the University of Colorado and the North Central Climate Science Center) to write a paper summarizing how climate change would affect plant species responses. Feng, Miller, and Debinski collaborated on the development of the survey tool, which was sent out to farmers in January 2018. The survey went to farmers with 50 acres of grass/hay/pasture or 50 heads of animals in Ringgold and Decatur Counties of IA, and Harrison and Mercer Counties in MO. The three PIs held a meeting in the Grand River Grasslands in May, 2018 to report out on their findings. Below we summarize the results of our work relative to each of the four objectives listed above.

**Project Summary**

*Climate Perspective*
We used two approaches to model current and future climatic conditions in the Grand River Grassland region. Our initial approach involved the use of four global climate models to allow for comparison among species and among possible futures, yielding 56 species distribution models (four models for each of 14 modeled species). We were concerned that this would prove difficult to explain to lay audiences. We therefore narrowed our focus to facilitate robust comparisons among species within a single future condition. We chose the Met Office Hadley Center (United Kingdom) HadGEM2-ES global climate model predicted for 2050 at Representative Concentration Pathway (RCP) 8.5 because this model has a low error rate (Rupp *et al.*, 2013), and we believe management informed by the most extreme possible emissions pathway will, at worst, do more than is strictly necessary for the preservation of these species and habitats.

*Ecological Perspective*
From the ecological perspective, our focus was to develop species distribution models using the climate data described above. Our approach included predicting habitat suitability for representative grassland plant species under the current conditions and under each of the four future climate scenarios. Our goal was to analyze responses of 14 grassland plant species representing a broad range of functional groups (forbs, warm-season grasses, cool-season grasses, and legumes). All species distribution models were trained with data from the WorldClim Global Climate Dataset at a 2.5 min resolution using the modeling software MaxEnt version 3.3.3k (Elith *et al*., 2011), as described above. Our plant species distribution models were constructed using uncorrelated BIOCLIM variables from a set of 8 candidate variables: mean temperature for the wettest (BIO8), driest (BIO9), warmest (BIO10), and coldest (BIO11) quarter-year periods (quarters) averaged from 1960 to 1990 as well as the mean precipitation for the same quarters (BIO16 through 19 respectively), though when variables were found to have a Pearson correlation coefficient of greater than 0.7 (or -0.7) one of the correlated variables was excluded from model construction. We assumed that elevation and climate parameters alone would be sufficient in model creation due to the convention that at macro-ecological scales, they are all that is needed to predict species distributions (Pearson & Dawson, 2003).

We originally started by developing species distribution models (SDMs) for our 14 grassland plant species representing a broad range of functional groups (forbs, warm-season grasses, cool-season grasses, and legumes). We then shifted to focus on a comparison of models among species and functional groups. To streamline interpretation, we created "delta maps" where the present distribution model for each species is subtracted from the predicted distribution model. This allows a single map to show areas of changing suitability (both increasing and decreasing) for each species. Consistent with hypotheses, suitability for many species shifts to the north and east under all future conditions, with the loss of suitability in current ranges and the amount of movement both becoming greater under progressively hotter and drier conditions. While these general themes hold across species, variation within functional groups was less than variation among functional groups; this indicates that species within the same functional group will respond to changing climate more similarly to one another than to presently co-occurring species of different functional groups. These relatively conserved suitability changes within functional group lend credence to managers making restoration and conservation decisions for locally rare species based on the modeled response of species that are generally within the same functional group.

Here we present the delta maps of the legume *Amorpha canescens* (Leadplant), and the forb *Asclepias tuberosa* (Butterfly Milkweed), to facilitate comparison across functional group (Figures 1–2). Initial suitability predictions are made in the logistic output format such that predictions can range from 1 (100% probability of presence) to 0 (0% probability of presence) on a continuous scale (Phillips & Dudík, 2008), so delta maps report the percent difference between future and present conditions, expressed as a decimal.

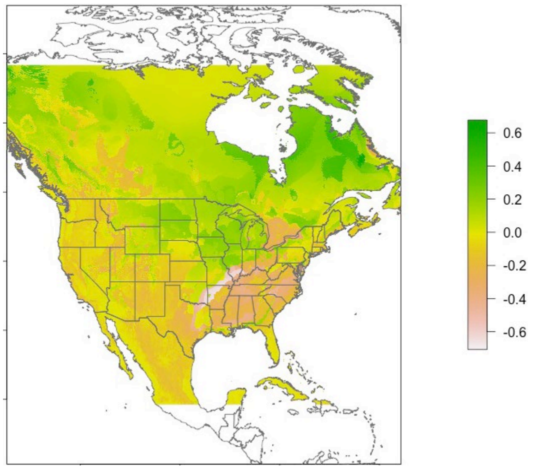



**Figure 1.** Delta map of predicted change in *Amorpha canescens* bioclimatic suitability between the present and 2050. Legend shows percent change in decimal form where positive values indicate increasing suitability in the future relative to present conditions and negative values indicate decreasing suitability.

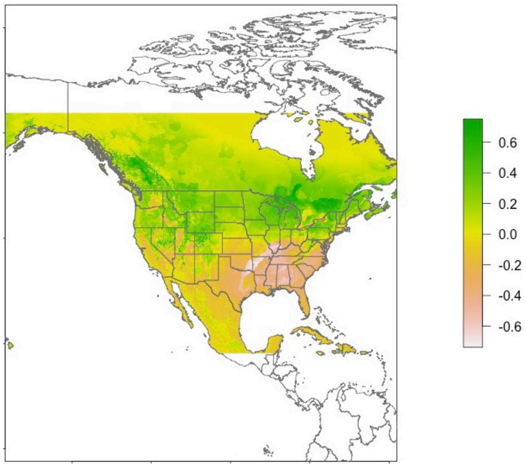



**Figure 2.** Delta map of predicted change in *Asclepias tuberosa* bioclimatic suitability between the present and 2050. Legend shows percent change in decimal form where positive values indicate increasing suitability in the future relative to present conditions and negative values indicate decreasing suitability.

These models illustrate that 1) northward shifts are common to virtually all species and 2) inter-species and inter-functional group variation exists in the amount and area of changing suitability. *Amorpha canescens* for instance, demonstrates its highest suitability (darkest green) in Northern Canada (Figure 1), while *Asclepias tuberosa* has highest suitability in both the western United States and just north of Ontario (Figure 2). Additionally, while both species current distributions are similar in the American Southeast, *Asclepias tuberosa* only loses suitability in that area while *Amorpha canescens* has some areas in Florida, Georgia, and Texas where suitability either remains unchanged or actually increases. While not presented here, the response of other forbs is relatively similar to *Asclepias tuberosa*, and the responses of both cool season ($C_3$) and warm season ($C_4$) grasses are conserved within their respective functional groups. Only the legumes *Amorpha canescens* and *Petalostemon candida* (White prairie clover) had sufficient occurrence data to produce models, so true consensus for the forb functional group is difficult to assess.

The results of this work are included in a manuscript entitled "Evaluating the Utility of Species Distribution Models in Informing Climate Change-Resilient Grassland Restoration Strategy" which is in press with *Frontiers in Ecology and Evolution*, in the Biogeography and Macroecology section (Lyon et al., 2019). This manuscript will be appended to the report.

*Economic & Policy Perspective*

The Co-PIs (Debinski, Feng, Miller) met in May, 2016, to discuss the landowner survey. The original project plan was to conduct a survey during fall/winter of 2016-17. However, Miller's graduate student, Jaime Coon, presented an outline of a separate survey of Grand River Grassland (GRG) landowners that she was preparing to send to landowners during the winter of 2017. Coon and Miller's survey was meant to be a follow-up to a 2007 survey funded by LCSA (Leopold Center for Sustainable Agriculture) grant (to Morton, Miller, and Engle) that focused on the use of prescribed fire and encroachment by eastern redcedar (*Juniperus virginiana*) in the GRG region. The Coon and Miller survey was to include some questions from the 2007 survey, but the focus will be more on the invasive grass tall fescue (*Schedonorus phoenix*). At the May 2016 meeting, we decided to delay the survey associated with the current LCSA grant until winter 2018, to better integrate it with the Coon survey. This would allow us to derive synergy from two surveys in the same study region with the same landowner population. Feng, Miller, and Coon had several subsequent meetings, culminating in a review of Coon and Miller's survey by Feng and further discussion of ways the two surveys could complement one another. Miller and Coon developed a list of landowners and contact information to serve as the sampling universe for both surveys. Feng was granted access to the Miller survey formally through the IRB process and considered data gathered through the Miller survey in designing the survey instrument for the LCSA project.

Miller and Debinski had been conducting research in the GRG since ~2006, and as such the LCSA research built on that previous work. Feng had previous experience in Midwestern agroecological systems, but was not familiar with the GRG. In order to familiarize herself with the region, Dr. Feng made trip to the GRG in 2016 to meet with landowners and state agency employees and toured the ecosystem. Feng had extensive meetings with Randy Arndt, the manager of the Dunn Ranch (owned by The Nature Conservancy (TNC)) about grassland management and grassland easements. The take home messages from Arndt included: (1) Landowners could convert grassland to native grassland at almost no costs because of available incentives offered by the Natural Resource Conservation Service (NRCS), state agencies, and TNC. (2) As to participation in incentive programs, those who are willing to convert to native grassland have already converted. However, those who have not converted will never convert. These people tended to be older, had been doing the same thing all throughout their life, and were less willing to try new things. Even field demonstration did not help in this regard. (3) There are different programs supporting native grasses. People can get more points with native cover in Conservation Reserve Plan (CRP) application. To protect the monarch butterfly, the U.S. Fish and Wildlife Service (FWS) has initiated programs to enhance habitat. Also within CRP, there is CP42 pollinator seed mix. CRP is very competitive—most counties in the area are at their acreage cap.

Dr. Feng met employees of the Farm Services Agency (FSA) and NRCS in Ringgold, IA, and Worth and Harrison counties in MO. Several things were learned: (1) There are both state and federal cost share programs. On the federal side, it is mostly Environmental Quality Incentives Program (EQIP). (2) Most common practices are terraces and structures. (3) There is cost-share program for seeding from crop to grass. (3) There are more applications than the funding can support. (4) EQIP is also a competitive program, whereas the equivalent state program is not and is on a first come first serve principle. (4) There is support for burning, seeding, and brush removal. Dr. Feng traveled to Worth county, MO to meet with Ann Gillard and Kris Lyle, FSA and Soil and Water Conservation Districts (SWCD) agents. Points learned were (1) For the last CRP signup, there were 35 applications, but none were accepted because the points were not high enough. (2) CRP rent has become more competitive, increasing from $100-125 per acre to $152/acre. (3) When CRP expires, 75% of the land looks good but 25% does not. (4) Warm season grasses are perceived to hold soil less well, and are expensive to seed. (5) Land can still be accepted through State Acres For wildlife Enhancement (SAFE), which is a new continuous CRP conservation practice, also known as CP38, and there is funding for pollinator and buffer strips. Farmers are not interested in government programs for the following reasons: time restrictions; the process is not user-friendly, and landowners are too bogged down in paper work (e.g., matching of physical year and project period); for absentee land owners (often nearby wealthy urban people) land is just an investment. Worth county is only two hours from big cities and it attracts urban investors. Most people who participate in conservation programs participate more than once. There are many people who never participate.

Dr. Feng met officials working at the USDA and FSA in Bethany office, MO. She heard a similar message: demand for CRP is high now and it is hard to get into the program. There are several programs that support grass/native grass. They talked about barriers to adopt new practices: farmers' age and farm size (operators managing large acreages can be too busy to have time to try new things). Still, there were more applications than the available funding in EQIP.

Dr. Feng also had meetings with three local farmers (two work at the Dunn Ranch) who have experience with government programs. One couple had very positive experience with EQIP. They said they just followed the advice/suggestion of a relative to take up livestock insurance, a government sponsored program. Two of them talked about the poor quality of land—basically, you can grow corn on some land for two years, but after that, you have to stop because of erosion. One couple mentioned a practical difficulty of using native grassland—the grass would be too tall for them to keep an eye on their young livestock. Some general points from the meetings are as follows: There are multiple incentives available for grass/native grass covers. Some farmers do not seek out such incentives and are not willing to adopt. Non-adopters are hard to convert even with incentives—there might be some other underlying reasons. Funding for conservation practices is limited in the sense that it does not meet demand.

From the economic perspective, our preliminary economic data showed that Ringgold County showed a decrease in CRP by almost half since the 1990s (Fig. 3), average land rent had not changed much since 1990 (Fig. 4). Corn and soybean acres increased from about 80K acres to over 120K acres in 2014 in Ringgold county but declined in 2015 (Fig.5). The trends in corn price affected trends in acres, but the increases in acreage seemed have leveled off in recent years (Fig. 6).

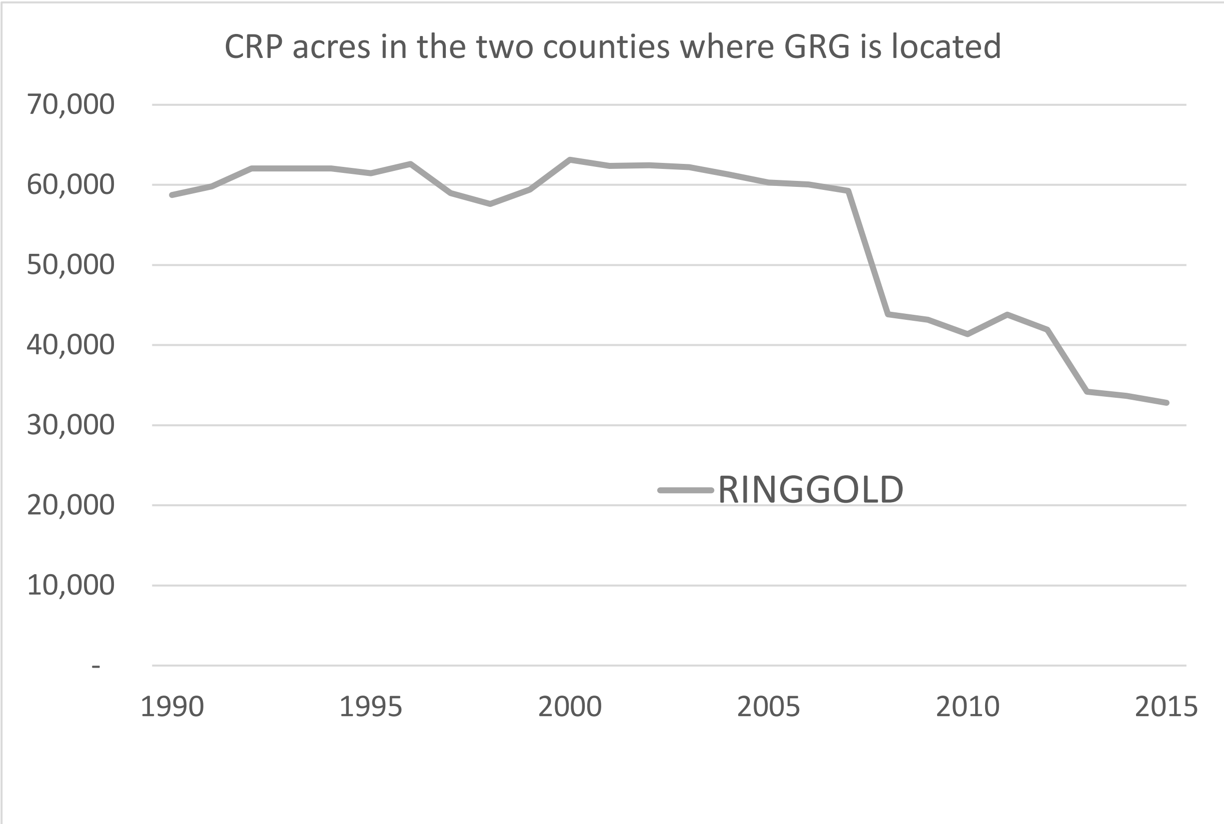



**Figure 3.** CRP acres decreased by almost half from the 1990s in Ringgold County, IA.

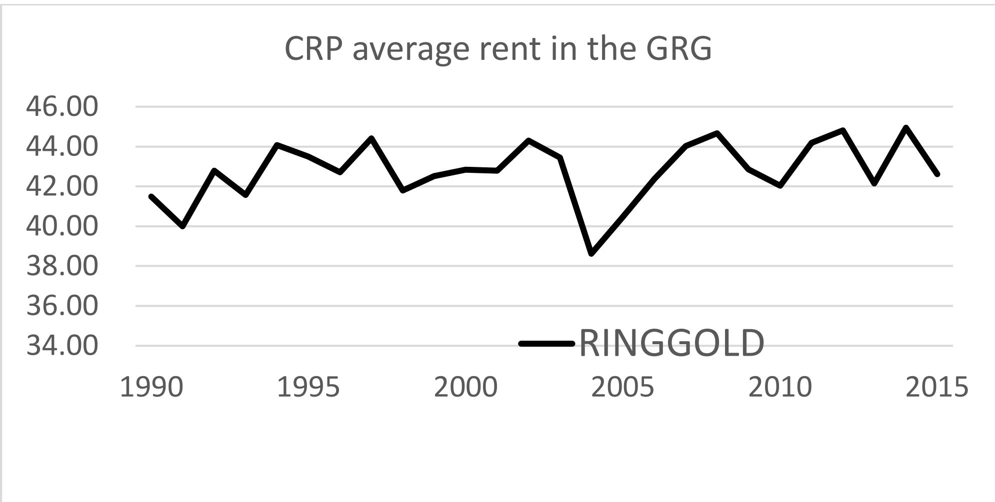



**Figure 4.** Average CRP rent in Ringgold County has not changed much.

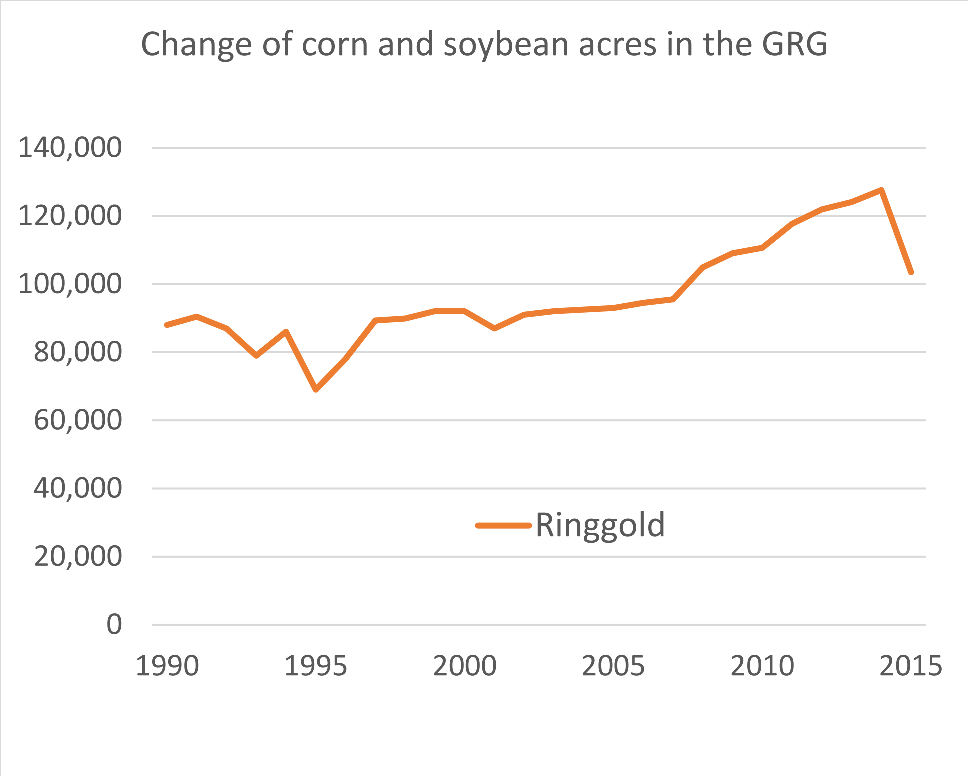



**Figure 5.** Corn and soybean acres increased from about 80K acres to over 120K acres in 2014 in Ringgold county. The planted acres for corn and soybean declined in 2015.

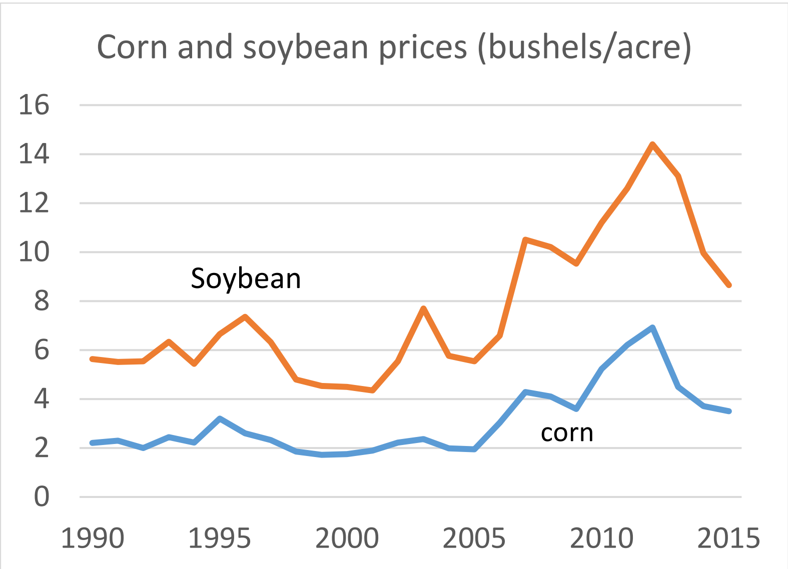



**Figure 6.** The trends in price affected trends in acres (in previous slide). The increases in acreage seemed have leveled off in recent years.

In December 2017, Dr. Feng acquired program data on the use of the two largest working land conservation programs: the Conservation Stewardship Program (CSP) and EQIP from 2007 to 2017. She found that both programs offered incentive payments to encourage practices that protect natural habitats and enhance grasslands. However, the use of these practices did not seem to be as extensive as the use of some other practices.

With LCSA funding combined with the funding from another project that was focused on North and South Dakota and funded by The U.S. Department of Agriculture (USDA) National Institute of Food and Agriculture (NIFA), during the second year of the project, Dr. Feng implemented a survey, with input from the PI, Dr. Debinski and co-PI, Dr. Miller. The questionnaire was designed to obtain information on farmers' participation of conservation programs and the role of different decision factors that affect the use of these programs. The questionnaire also had a section on climate related information so that she could specifically evaluate how farmers view changing weather patterns and the importance of projected future weather patterns in their land use decisions. This survey enabled us to test several hypotheses. One hypothesis was that, among the factors that affect farmers' land use decisions, projected future climate is ranked less important than other factors such as crop and livestock prices. Another hypothesis was that some farmers do not participate in conservation programs like CSP and EQIP because they are concerned about the excessive paperwork. The survey was sent out in early January, data collection was completed in April, 2018. Results are summarized below.

**Survey Approach and Results**

The survey was sent to a few selected counties in Iowa and Missouri and counties in eastern North and South Dakota. The relative sample size in IA/MO versus the Dakotas was determined by funding level of the relevant projects. The IA/MO counties, illustrated in the following chart, were selected based on the criteria that they cover the GRG while also allowed us to have adequate responses to conduct a rigorous analysis. The charts show that Ringgold and Decatur counties were chosen for Iowa and Harrison and Mercer counties were chosen for Missouri. The green bar in Figure 7 represents the location of GRG area.

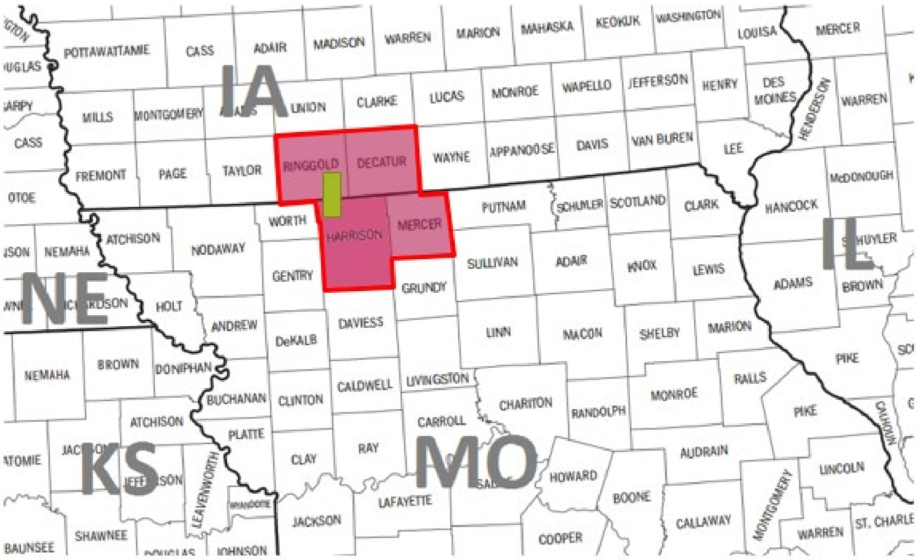



**Figure 7.** LSCA Survey region. Counties are highlighted in pink, GRG is highlighted in green.

**Table 1.** Response rates for LCSA Survey.

| | **Iowa/Missouri** | **Total** |
|---|---|---|
| **Sample** | **600** | **2084** |
| **Not Eligible** | **66** | **178** |
| **Eligible Sample** | **534** | **1906** |
| **Returned by USPS** | **11** | **25** |
| **Refused** | **21** | **47** |
| **No Response** | **322** | **969** |
| **Completed Surveys** | **180** | **865** |
| **Response Rates** | **33.7** | **45.4%** |

## Survey Results

### A. Participation in government conservation programs

One question in the survey asked about participation in major federal conservation programs: "Have you used or participated in any of the following government incentive programs? If not, please indicate your awareness of and interest in using the programs." From the table, it is clear that CRP had the highest participation rate (about 44%) whereas WRP had the lowest participation rate (9%). The two largest programs for working land only had a participation rate of 16% (for CSP) and 19% (for EQIP). What is more interesting is that 30% of the respondents were aware of the programs but had no interest in participating in the programs. For CSP, there is need to get the word out given that about 32% of the respondents were not aware of the program. This is an important issue given that CSP offers support for habitat enhancement practices. For example, in 2018, CSP supports "Conservation cover to provide food habitat for pollinators and Beneficial insects," "Enhanced field borders to increase wildlife habitat continuity along the edge(s) of a field," "Range planting for improving forage, browse, or cover for wildlife," and "Establish and maintain wildlife habitat continuity by providing early successional, naturally occurring vegetation in ditches and ditch bank borders." (https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/csp/?cid=nrcseprd1388686 )

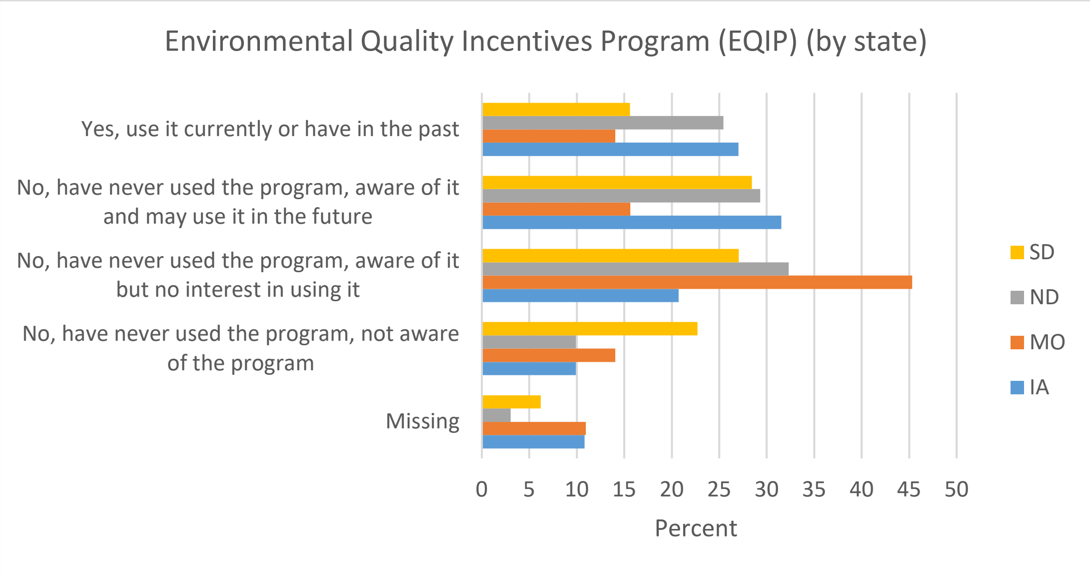
Table 2. Results of survey regarding participation in government conservation programs

| | Q15a--CRP | | Q15b--CSP | | Q15c--EQIP | | Q15d--WRP | |
|---|---|---|---|---|---|---|---|---|
| *Value* | *Frequency* | *%* | *Frequency* | *%* | *Frequency* | *%* | *Frequency* | *%* |
| 1 | 380 | 43.88% | 141 | 16.28% | 169 | 19.52% | 79 | 9.12% |
| 2 | 138 | 15.94% | 125 | 14.43% | 245 | 28.29% | 161 | 18.59% |
| 3 | 298 | 34.41% | 264 | 30.48% | 252 | 29.10% | 480 | 55.43% |
| 4 | 10 | 1.15% | 281 | 32.45% | 144 | 16.63% | 90 | 10.39% |
| 9 | 40 | 4.62% | 55 | 6.35% | 56 | 6.47% | 56 | 6.47% |

The abbreviation for the programs are: Conservation Reserve Program (CRP); Conservation Security Program (CSP); Environmental Quality Incentives Program (EQIP); Wetland Reserve Program (WRP).
1 = Yes, use it currently or have in the past
2 = No, have never used the program, aware of it and may use it in the future
3 = No, have never used the program, aware of it but no interest in using it
4 = No, have never used the program, not aware of the program
9 = MISSING

There are some differences among the states, as shown in Fig. 8 and Table 2. For example, for EQIP, Iowa seemed to have the highest interest in terms of current use or potential use.

Figure 8. The participation or awareness of Environmental Quality Incentives Program (EQIP) (by state).




### B. Factors affecting participation decisions on government programs

We also asked "Please indicate how much impact each of the following issues had on your decisions whether or not to participate in the programs listed in Question 15 above." The numbers suggest that weather and climate factor had no or only slight impact on farmers' participation decisions regarding conservation programs.

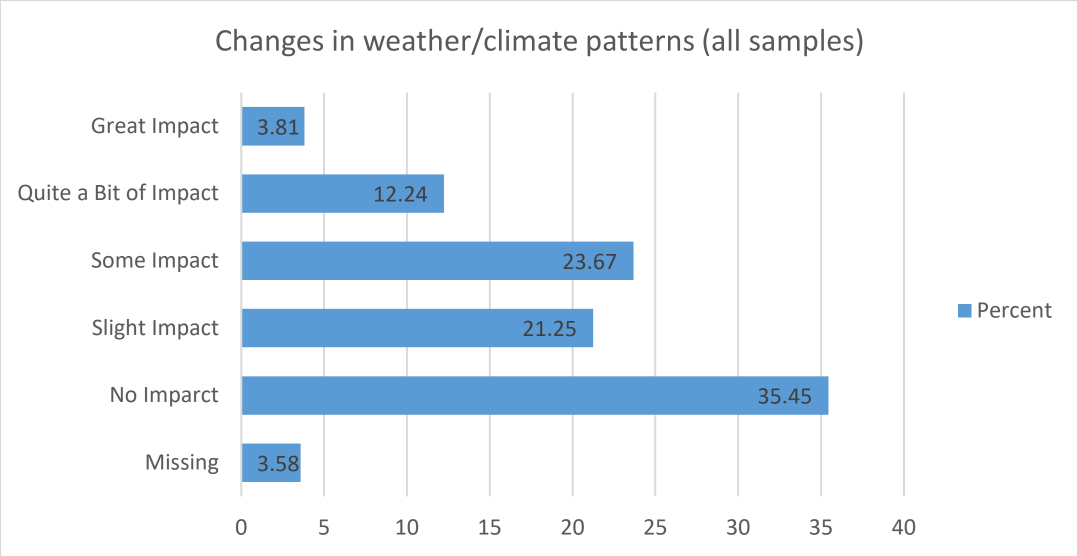
Table 3. Impact of weather vs. other issues on participation in conservation programs by state.

| State | Q16a | Q16b | Q16c | Q16d | Q16e | Q16f | Q16g | Q16h |
|---|---|---|---|---|---|---|---|---|
| 19 (IA) | 3.54 | 3.40 | 3.68 | 2.82 | 2.64 | 3.11 | 3.45 | 3.16 |
| 29 (MO) | 3.11 | 2.94 | 3.30 | 2.56 | 2.27 | 2.42 | 3.33 | 2.64 |
| 38 (ND) | 3.31 | 3.16 | 3.13 | 2.47 | 2.43 | 2.72 | 3.03 | 2.55 |
| 46 (SD) | 3.35 | 3.09 | 3.13 | 2.69 | 2.51 | 2.75 | 3.19 | 2.50 |
| Grand Tot | 3.35 | 3.14 | 3.22 | 2.64 | 2.49 | 2.77 | 3.19 | 2.61 |

a. Payments or cost share amounts
b. Requirements of government policies (e.g., Conservation Compliance)
c. Soil health (e.g., erosion control)
d. Wildlife or other environmental benefits
e. Changes in weather /climate patterns
f. The ease of the application process
g. Output and input prices
h. Issues concerning work-life balance

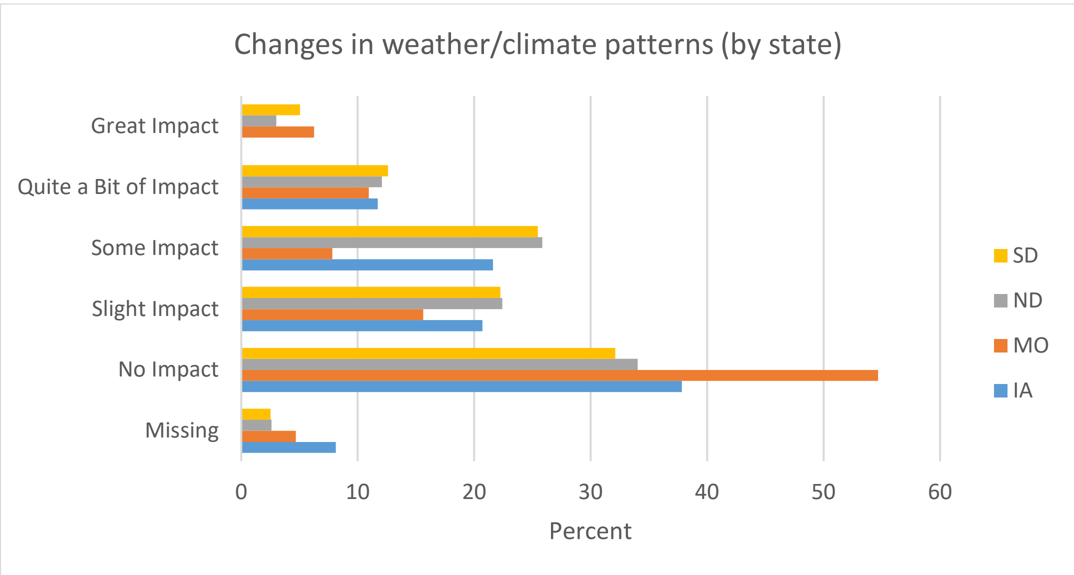
Figure 9 shows the distribution of respondents based on their ranking of the importance of weather/climate patterns on farmers' decisions to participate the government incentive programs (all samples).

Figure 9. Importance of weather on participation in incentive programs.




The by state data shows that over a third of the respondents deem weather/climate not important at all in their decisions to participate in government programs. The distribution is similar for three states, ND, SD, and IA. Missouri respondents stood out in that a much larger percentage of them (about 55%) indicated that weather climate had no impact on their program participation decisions.

Figure 10. Importance of weather on participation in incentive programs with state comparisons.



## C. The importance of weather/climate in land use decisions

The survey questionnaire included a question: "Q8. How much impact has each of the following issues had on changes in your own agricultural land use?" The percentage of respondents checking each category of impact is presented in the following chart. The chart shows that more than 45% of respondents think weather/climate patterns had either no impact at all or only slight impact.

Figure 11. The importance of weather/climate in land use decisions.

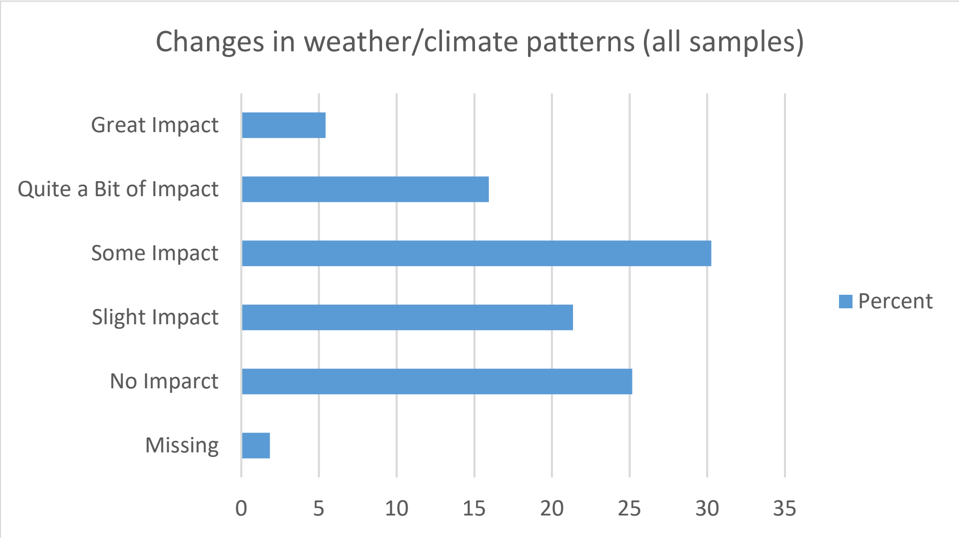
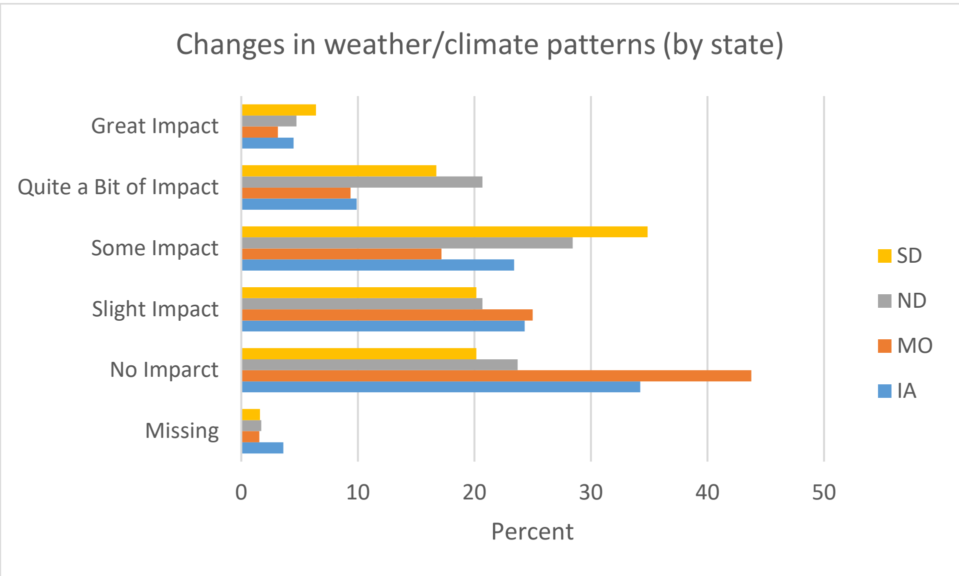



Figure 12. The importance of weather/climate in land use decisions with state comparisons.




Q9. Which one of the issues in the previous table, also listed below, would you say has had the greatest impact on changes in your own land use?

The ranking of changes in weather/ climate patterns is #3 among all samples. The ranking of changes in weather/ climate patterns in Iowa, Missouri, North Dakota and South Dakota is #5, #4, #3 and #3 respectively.

Figure 13a. The greatest impact of the issues on changes in farmers' own land use (all samples).

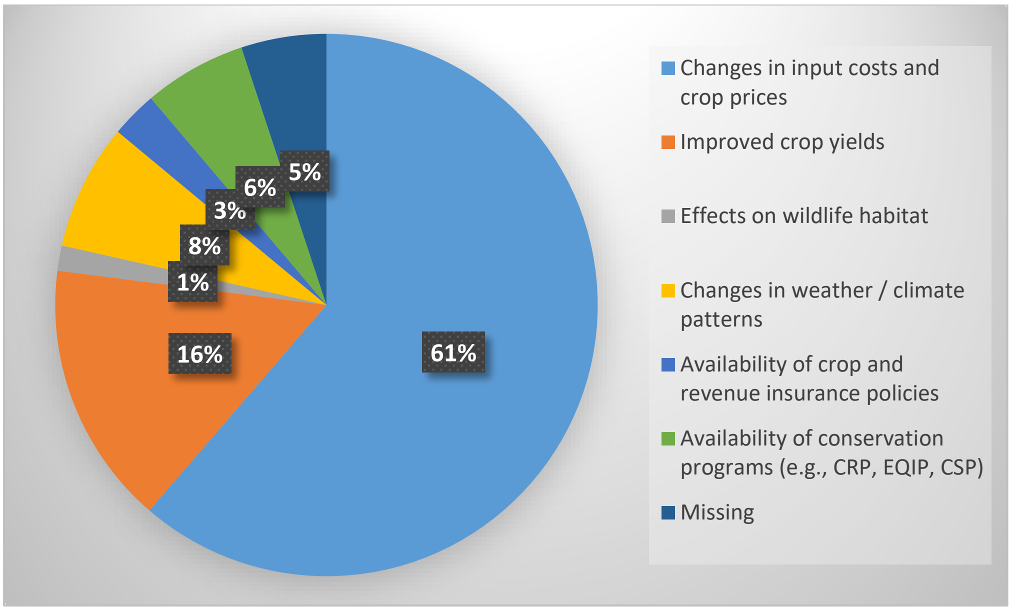
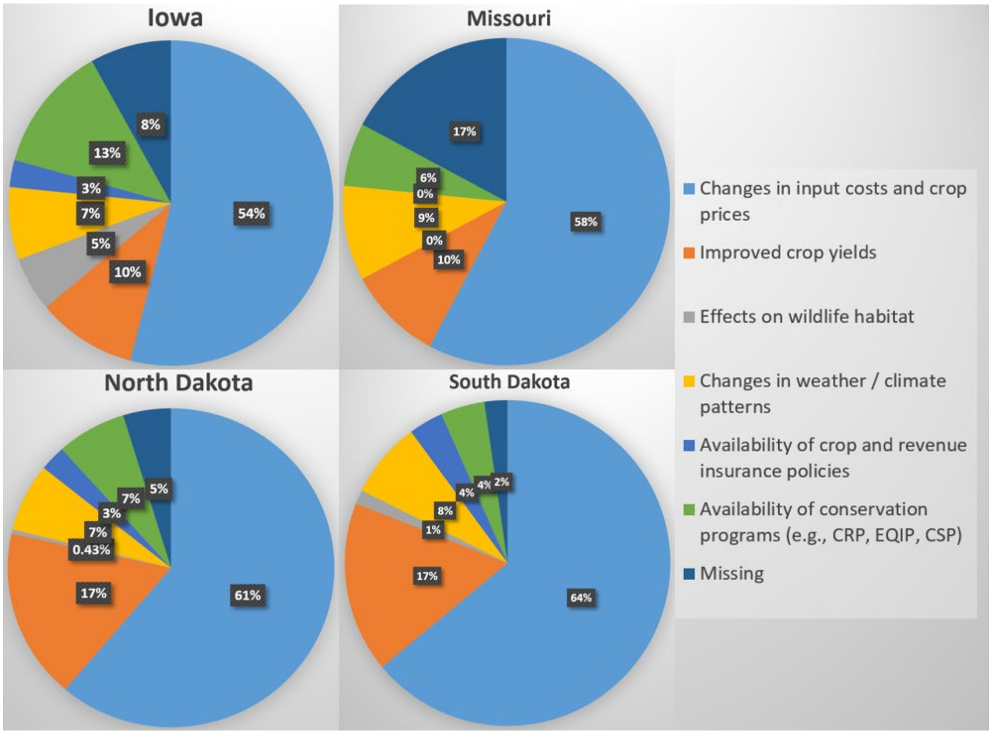



Figure 13b. The greatest impact of the issues on changes in farmers' own land use (by state).



Q22. Please indicate the extent to which you agree or disagree with each of the following statements. (1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree.)

| | Variable | N | Mean | Std Dev |
|---|---|---|---|---|
| It is important to take good care of farmland for future generations. | **Q22a** | 861 | 4.695703 | 0.659699 |
| The next generation of farmers will have to deal with more extreme weather, especially drought. | **Q22b** | 859 | 3.242142 | 0.988061 |
| Long-range weather predictions, for 30 years or more, are important for my current land use decisions. | **Q22c** | 859 | 2.623981 | 1.018218 |
| I have confidence in weather and climate predictions that are for 30 years into the future. | **Q22d** | 858 | 2.051282 | 0.963599 |
| Technology will help me cope with any changing weather and climate patterns. | **Q22e** | 861 | 3.101045 | 0.920193 |
| It is important to adjust land use now to be prepared for changes in weather patterns in the future, say 30 years from now. | **Q22f** | 860 | 2.85 | 1.013098 |
| I am not concerned about what may happen with farmland in the long term (30 years) because I will be retired by then. | **Q22g** | 859 | 2.309662 | 1.172544 |
| I believe my state is being impacted by climate change. | **Q22h** | 859 | 2.910361 | 1.140532 |

**Summary**

Our climate and species projection models illustrated that northward shifts are common to virtually all of the plant species we examined but that inter-species and inter-functional group variation exists in the amount and area of changing suitability. The responses of forbs, cool season ($C_3$), and warm season ($C_4$) grasses were conserved within their respective functional groups. As such, we expect the plant community of the Grand River Grasslands to show changes over the next several decades. One way to prepare for this change would be to modify the seed mix used in conservation plantings. Our results provide insights on which species would be best to use in the future. However, the utilization of conservation programs may have cultural limitations as described by the findings of our landowner survey results.

The landowner survey provided valuable information about how landowners are expected to respond to this climate change, but it also identified some significant barriers. We found that weather and climate factors had little or no impact on farmers' decisions regarding land use and their participation in conservation programs. Missouri was the state that showed the strongest opinion in that regard. South Dakota and North Dakota respondents were much more likely to have their land use or incentive programs decisions affected by weather. Our findings suggest that residents of the Grand River Grassland (Iowa and Missouri) will be slow to respond to climate change in the context of conservation plantings. Importantly, 30-55% of the respondents were aware of program such as CRP, CSP, EQIP and WRP, but had no interest in participating in the programs. When comparing the four prairie states examined here (ND, SD, IA and MO), Missouri had the largest percentage of respondents that were aware but uninterested in these programs. The one possible opportunity may lie in education regarding CSP programs. About 32% of the respondents were not aware of the program. Perhaps unsurprisingly, we found that the two most important variables affecting farmers' land use decisions were 1) the availability of crop and revenue insurance policies and 2) improvements crop yields. This response was relatively consistent across all four states.

Overall, our results are not promising in terms of expecting farmers to respond to climate change in a proactive way using conservation programs. Even if conservation planting seed mixes are modified to include plant species that are expected to do well under future conditions, the reticence of farmers to become involved in such programs or to change their land use practices as a result of changing environmental conditions will be a barrier. Our findings indicate that that there could be benefits if landowners and land managers use this information to prepare for future climate changes. However, our economic and social science analyses indicate that land use decision makers do not see a need to respond, and that even the use of economic incentives may not bring desired responses.

**Budget Assessment**

The expenditures for the climatological and biological portion of the project have been slightly lower than expected due to our good fortune that graduate student Nick Lyon was awarded a one year graduate fellowship in YR1 and he opted to get some teaching experience in YR3, which provided some TA support.

The expenditures for the economic portion of the project funding were incurred mostly in YR3 because the survey was postponed to January 2018.

**Works Cited**


Elith J, Kearney M, Phillips S (2010) The art of modelling range-shifting species. *Methods in Ecology and Evolution*, **1**, 330–342.

Elith J, Phillips SJ, Hastie T, Dudík M, Chee YE, Yates CJ (2011) A statistical explanation of MaxEnt for ecologists. *Diversity and Distributions*, **17**, 43–57.

Lyon, N.J., D.M. Debinski and I. Rangwala. 2019. Informing Climate Change-Resilient Grassland Restoration Strategy with Species Distribution Models. *Frontiers in Plant Science*. Vol 7 Article 33 doi: 10.3389/fevo.2019.00033

Pearson RG, Dawson TP (2003) Predicting the impacts of climate change on the distribution of species: are bioclimate envelope models useful? *Global Ecology and Biogeography*, **12**, 361–371.

Phillips SJ, Dudík M (2008) Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. *Ecography*, **31**, 161–175.

Rupp DE, Abatzoglou JT, Hegewisch KC, Mote PW (2013) Evaluation of CMIP5 20th century climate simulations for the Pacific Northwest USA. *Journal of Geophysical Research: Atmospheres*, **118**, 2013JD020085.

Soley-Guardia M, Gutiérrez EE, Thomas DM, Ochoa-G J, Aguilera M, Anderson RP (2016) Are we overestimating the niche? Removing marginal localities helps ecological niche models detect environmental barriers. *Ecology and Evolution*, **6**, 1267–1279.