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Editorial

Disconnect within Agriculture and Ecosystem Climate Effects, Adaptations and Policy

Anastasia W. Thayer [1,*], Aurora M Vargas [2], Thomas E. Lacher [3,4] and Bruce A. McCarl [5]

1 Department of Applied Economics, Utah State University, Logan, UT 84322, USA
2 Agricultural Economics/College of Agriculture, Texas A&M University, College Station, TX 77843, USA; avarga5@tamu.edu
3 Department of Wildlife and Fisheries Sciences, TexasA&M University, College Station, TX 77843, USA; tlacher@tamu.edu
4 Center for Coffee Research and Education, Texas A&M University, College Station, TX 77843, USA
5 Department of Agricultural Economics, Texas A&M University, College Station, TX 77843, USA; brucemccarl@gmail.com
* Correspondence: anastasia.thayer@usu.edu

Received: 30 April 2020; Accepted: 8 May 2020; Published: 13 May 2020

1. Introduction

Frequently, agriculture and ecosystems (AE) are seen as separate entities, causing entity specific solutions in response to threats. Anthropogenic climate change simultaneously stresses both agriculture and ecosystems along with their interactions. Induced increasing surface temperatures [1], altered precipitation [2], drought intensification [3], altered ground and surface water quantity/quality [4,5], and diminished soil moisture [6] force adaptations for AE, but these adaptations fail to be efficient when interdependencies are not considered. Additional adaptations will be necessary, as future projections anticipate even greater climate change [1].

Research has quantified many AE impacts of climate change and yet greater impacts are anticipated as climate change proceeds. Thus, understanding the implications for AE systems is crucial. AE function, health, and productivity depend heavily on climatic characteristics. Typically, agriculture gets the most attention, as it feeds the world; however, an adaptation that only considers agriculture can negatively affect ecosystems and vice versa. Failure to incorporate the overlapping effects of agriculture and ecosystems could lead to maladaptation and greater long-term damages under climate change. The papers in this issue address a number of aspects of this issue.

Table 1 is adapted from Thayer et al., 2020 [7] and it provides examples of external ecological effects of agricultural focused adaptations and vice versa. Column 1 displays the general climate stressor with Column 2 showing the particular effect that has been seen in select areas. Columns 3 and 4 show either agricultural adaptations and their unintended impact on the ecosystem [termed an externality] or an ecosystem adaptation with the unintended result on agriculture [termed externality].

The examples demonstrate how an adaptation in agriculture or ecosystems can impact the other. Another factor to keep in mind is that climate change and its effects vary across the landscape geography as does AE characteristics; thus, adaptation actions must address local AE situations and cannot be spatial uniform.

This editorial will review the collective findings in the papers that are published in the *Climate* Special Issue "Climate Change in Complex Systems: Effects, Adaptations, and Policy Considerations for Agriculture and Ecosystems". We will discuss the ways the papers address climate change impacts, potential adaptations, and future policy for the continued AE prosperity. We also discuss the identified needs for research and future directions of AE interface adaptation research.

Table 1. Adaptations and externalities in response to climate stressors and effects, adapted from [7]

Climate Stressor	Climate Effect	Agricultural Adaptation	Ecosystem Service Externality
Increased temperature and drought	**Increased livestock heat stress and reduced forage and growth** [8]	Diversifying livestock species [9–11]	Altered plant biodiversity and productivity [12–14]
	Lower crop production and quality due to increased temperatures affecting growth and nutrient content [15,16]	Crop land shift to grazing [17–19]	Increased root production in upper soil levels and carbon sequestration [20,21].
Climate Stressor	**Climate Effect**	**Ecosystem Adaptation**	**Agricultural System Externality**
Increased drought	**Reduced plant growth** due to changes in temperature, precipitation, or the incidence of climatic extremes [22,23]	Shift in vegetation mix productivity and water retention [24,25]	Altered water supply and increased demand for irrigation [26,27]
Increased temperature and altered rainfall	**Disruption in Hydrological environments** that cycle nutrients, maintain water quality, and moderatelifecycle events such as spawning and recruitment [28–31]	Shifting species distribution including pest incidence [32,33]	Increased pesticide and herbicide costs [34–36]

2. Comments on Effects

Regions experience differential impacts and researchers have used diverse methods to quantify climate change effects on AE due to the complex nature of climate. Every paper in the special issue clearly identifies current and future climate change impacts on their study area.

Sinay and Carter (2020) reviewed papers that focused on climate effects on coastal communities [37]. They discussed climate change as a cause of increased occurrences of flooding and fire along with the impacts to coastlines and beaches, inland areas, infrastructure, housing, natural systems, food production, fresh and drinking water availability, and community welfare.

Changes in water availability and use is expected under climate change and has been observed to have varying impacts on AE systems within the special issue. Elijah and Odiyo show that Kenyan droughts have increased the use of groundwater to sustain rainfed agriculture, which leads to increased soil salinity due to irrigation [38]. Scholes illustrates that South Africa is also experiencing land degradation, due to high solar radiation, low atmospheric humidity and rainfall, and increased seasonality and variability of rainfall, causing a shift away from animal production and potentially to energy production [39]. Scholes (2020) further highlighted that semi-arid regions will be particularly vulnerable to land degradation and an expansion of desertification. In the paper by Ngarava et al., South Africa is also struggling to increase its livestock and energy production under climatic stressors while attempting to reduce carbon dioxide emissions [40].

Further, water stress and increased temperatures were discussed in various regions in Korea and the United States. An et al. report increased insect populations as a result of rising temperatures and decreased tree health due to water stress are affecting the growth of the Korean Oak and, in turn, the country's lumber industry [41]. In addition, Ding and McCarl show that, under increased drought, a region of Texas with competing interests in water rights is expected to experience crop losses and a shift from expensive irrigated land to grasslands [42]. Further, as groundwater pumping for municipal and industrial water increases, lower pumping limits might be imposed, which could jeopardize the ecosystems that rely on the spring levels fed by the groundwater systems.

As discussed, climate effects may have common aspects across the landscape, but their solutions will require localized attention and they are subject to available resources, magnitude and knowledge of current and future impacts, as well as the community's response. Thus, a collection of viable adaptations must be outlined to facilitate and lessen the expected damage as a result of climate effects.

3. Comments on Adaptation

Identifying appropriate adaptations was a key goal in designing this special issue. However, few papers in this collection suggested specific AE adaptation strategies. Only Sinay and Carter exclusively focused on identifying and synthesizing the best practices in adaptation strategies [37]. Other papers were able to make adaptation suggestions specific to the system such as Scholes argument for the adoption of sustainable land use [39] or Ding and McCarl's suggested changes to current water use [42].

However, none of the studies were able to fully discuss adaptations in the context of both ecosystems and agriculture.

Despite a lack of concrete adaptations for each system, other take-aways from the literature might be relevant when suggesting future productive directions for adaptation research. In general, Sinay and Carter suggest that adaptation strategies should be flexible and multiple strategies might need to be considered in order to respond to the magnitude of effects [37]. Identifying a range of possible adaptations or a time frame where one adaptation might be more effective could be productive. Several of the papers cited here were also able to identify adaptations that might not be useful [37–39,41]. While the scope of study areas and methodologies suggests that adaptations discussed in these papers are difficult to summarize, it might be helpful for future research to discuss adaptations that are likely to lead to maladaptation or worse outcomes just as much as suggest adaptations.

It is known that identifying adaptation strategies is difficult and their role to combat the effects of future changes is complex [43]. Despite this difficulty, climate change impact studies have insights into the study region, knowledge of the drivers, which impact the magnitude of effects, and an understanding of system feedbacks. These factors will be critical in estimating the magnitude of future effects and identifying best adaptation practices that benefit, or do not worsen, the agriculture and ecosystems. Thus, future research studies must extend their scope to consider adaptation strategies for the effects that they present as key findings. This could include drawing on literature from other similar study areas, as did Scholes [39], or attempting to extend the analysis and discussion to explicitly extend the findings from one system (agriculture or ecosystems) to discussing adaptations that will be necessary in other systems [7].

4. Comments on Policy

While papers that were included in this special edition fell short of providing concrete adaptation strategies that addressed AE simultaneously, studies were more successful in identifying policy recommendations to respond to current and future climate change effects; however, papers fell short of calling these policies adaptation strategies.

Policy recommendations were generally specific to the particular study area and they emphasized the need for local solutions and investments in human capital, such as the recommendation of several papers on education for success [37–39]. It was also clear that, if properly designed, financial incentives and economic support mechanisms could be useful in a number of study areas [40,41]. Ding and McCarl were able to point to specific policy recommendations and their impact on the community and discuss the effects of a policy on both humans and the ecosystem [42].

The contrast between authors' ability to make policy recommendations and suggest adaptation strategies suggests a possible important disconnect in researchers' ability and confidence in discussing the future impacts of climate change. In general, the distinction between policy recommendations and adaptations seemed to be arbitrary and only delineated by the timeframe the policy would be put in place. In many cases, policy recommendations were framed as such and not as adaptations to climate change. This might highlight the need for education of climate change researchers to adaptation scenarios and their ability to restructure research topics in order to explore adaptations. In many cases, with slight augmentation of research or extensions, policy recommendations could be easily tested as either successful or unsuccessful adaptations to climate change effects. Extending research to include a formal explanation and discussion of adaptation strategies reduces the risk to the study area and provides tested best-responses.

5. Conclusions

This special edition attracted a diverse selection of papers that were focused on climate change effects, adaptations, and policy recommendations with the goal of exploring agriculture and ecosystems impacts and interdependencies. As noted, the broad range in scope made it difficult to make concrete conclusions across each area of focus: effects, adaptations, and policy. Further, while the authors attempted to blend ecosystems and agriculture into a holistic sphere of research, largely, this remains a difficult and incomplete objective. This suggests that the field of climate change research in the AE arena needs additional support, funding, and ways to prioritize and incentivize integrated research and interdisciplinary teams in order to generate findings that will be applicable and accurate to the complex systems that define reality [7].

From the wide scope of articles included in this collection, it is clear that how humans and ecosystems respond to climate change effects will have a large influence on the eventual impact of changes. In all papers, land use changes in the coming decades, resource use, and conservation efforts, as well as energy use and efficiency efforts will define the ultimate failure or success of governmental and institutional responses to climate change as we transgress into the Anthropocene [44].

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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