AGRICULTURAL ADAPTATION, MITIGATION, AND CONSTRAINED CHOICES: EVIDENCE FROM THE U.S. MIDWEST

By

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ABSTRACT

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Agriculture is simultaneously vulnerable to and a contributor to a number of environmental issues, such as water quality, soil degradation, and climate change. Agricultural management practices provide one method for both adapting to the threat of environmental problems and mitigating those same problems. However, farmers make these decisions within a broader socio-economic context which influences and sometimes constrains their choices. In this paper, I build on the existing agricultural practice adoption literature by utilizing treadmill of production theory to examine the factors that predict farmers' use of practices to adapt to or mitigate issues like climate change. My empirical analysis uses structural equation modeling with latent variables (SEMLV) to study 2019 survey data from farmers in Illinois, Indiana, Michigan, and Ohio. Results indicate that farmers' attitudes, beliefs, and environmental awareness differentially predict adaptation and mitigation practice use. These findings suggest that adaptation to protect crop yield and farm income is promoted under the current treadmill system, while mitigation to ameliorate problems beyond the scope of the farm is constrained.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION AND BACKGROUND

Over the past several decades, alarm around the forecasted impacts of climate change on agricultural production has prompted researchers to devote much attention to the resilience of agricultural producers. At the same time, concern surrounding contributions of agriculture to environmental problems such as greenhouse gas accumulation, non-point source water pollution, and soil erosion has grown. Ecological constraints are shaped by and are shaping the interactions between agricultural producers and their land, carrying profound implications. In response, researchers have turned their attention to the practices farmers adopt on their land. In the United States, a large subset of research around agriculture and the environment has focused on conservation practices. Generally, this term refers to management decisions that serve as solutions to certain environmental problems, such as nutrient loadings in waterways or soil erosion. Social science literature, include sociological literature, has focused more specifically on demographic and socio-psychological characteristics of agricultural producers that motivate or deter adoption of conservation practices.

There exists such a proliferation of conservation practice adoption research that in the past decade researchers have conducted meta-analyses of both quantitative and qualitative studies of the practice adoption literature (Knowler and Bradshaw 2007; Prokopy et al. 2008; Baumgart-Getz, Prokopy, and Floress 2012; Prokopy et al. 2019; Yoder et al. 2019; Ranjan et al. 2019). The conclusion of these meta-analyses is largely that research devoted to the study of agricultural conservation practice adoption has had mixed success at understanding farmer behavior (Knowler and Bradshaw 2007; Prokopy et al. 2019). Researchers have frequently studied a recurring set of variables relating to farmer attitudes, beliefs, identity, and demographics, as well as farm characteristics and practice characteristics. Farmers' attitudes are one of the more common variables included, specifically examining farmers' environmental attitudes, attitudes toward or perceptions of particular practices (Baumgart-Getz et al. 2012; Plastina et al. 2020), risk tolerance or aversion (Baumgart-Getz et al. 2012; Zhang et al. 2016), and stewardship attitude or orientation (Reimer et al. 2012; Zhang et al. 2016; Floress et al. 2017; Denny et al. 2019; Wang et al. 2021). So common are attitudes studied in relation to conservation practices that they are often included as a category of variables in meta-analyses (Prokopy et al. 2008; Baumgart-Getz et al. 2012; Prokopy et al. 2019). Baumgart-Getz et al. (2012) conducted a meta-analysis of the existing practice adoption literature at the time and found that out of ten attitude variables, only environmental attitudes were significantly associated with practice use. Prokopy et al. (2019) also found that environmental attitudes were a significant predictor of practice use more often than would be expected by chance, along with an other-interest identity and attitudes toward the practices themselves. However, like Baumgart-Getz et al. (2012), they found that the majority of attitudinal variables examined were not significantly related to adoption.

Another set of commonly included variables centers around farmers' perception of risks of changing weather events to their locale or operation, sometimes referred to as concern or perceived vulnerability, with many studies finding this to be associated with practice adoption (Haden et al. 2012; Arbuckle, Morton, and Hobbs 2013; Arbuckle, Morton, and Hobbs 2015; Mase, Gramig, and Prokopy 2017; Lane et al. 2018; Denny et al. 2019; Engler, Rotman, and Poortvliet 2021). Closely related to risk perceptions are variables measuring environmental awareness, again with mixed findings regarding their importance for adoption (Reimer et al. 2012; Baumgart-Getz et al. 2012; Floress et al. 2017; Ranjan et al. 2019).

Despite the plethora of work on agricultural practice adoption, many tests of variables of interest have yielded inconclusive results (Prokopy et al. 2008; Baumgart-Getz et al. 2017;

Prokopy et al. 2019; Ranjan et al. 2019). There remains a need for viable paths to facilitate agriculture's ability to adapt while also tapping into its potential to be a mitigating force for climate change. One consistent critique of research on agricultural practice adoption is the tendency to focus on individual traits while ignoring or minimizing the broader social, economic, and political context in which farmers operate (Yoder et al. 2019; Prokopy et al. 2019). In their review of quantitative literature on best management practice adoption, Prokopy et al. (2019) note that a focus on social-psychological variables may have hindered the explanatory power of existing quantitative research. Ranjan et al. (2019) similarly note the lack of qualitative studies that examine social context and call for theories and empirical research that utilize both individual and structural factors. Yoder et al. (2019) provide even more detail, indicating in their review article that 49% of included studies focused only on individual factors, 33% focused on both, and 16% examined solely institutional variables.

Given these shortcomings, further empirical research grounded in contextual-level theory is needed to advance understanding of conservation practice adoption. As a field, sociology has long sought to understand the connections between social context and individual behavior. It is impossible to fully understand decisions made by individuals without considering the broader social, political, and economic structures within which these individuals operate. In particular, many within the discipline of sociology focus on behavior within a neoliberal capitalist context. Agricultural producers in the United States occupy a unique position within this structure. Row-crop producers holding a relatively large amount of land operate as capitalists, running their own operations and making decisions around inputs and operations that profoundly affect their outputs, the local landscape, and the broader environment. Adopting a sociological lens in the study of agricultural decision-making links this process with the broader social context. Although farmers operate largely independently, their decisions are not independent from social constraints.

Agricultural production requires a weighing of inputs and outputs. These inputs and outputs can include finances, technology, products, and environmental costs or benefits. Operating within a neoliberal capitalist socio-economic structure constrains the emphasis that farmers can put on certain outputs. Input costs generally increase year over year, and markets for agricultural products are competitive (Cochrane 1958; Levins and Cochrane 1996). In order to receive a return on the investment of inputs, farmers require a certain level of yields and therefore face pressure to prioritize yields over other outcomes, such as environmental impacts. Production is often valued to the point that costs are externalized to the surrounding environment. This prioritization of production is linked to, but not the same as, the profit motive. While farmers are certainly motivated by the prospect of increasing profits, agricultural production is vulnerable to extreme weather, volatile markets, and other problems such that farmers are not guaranteed a return on investment without adequate production. For farmers, increasing production year over year is not simply a way to increase their returns; rather, it is a way to keep pace with what Cochrane dubbed the agricultural treadmill (1958). Therefore, their decisions are not independent of the forces which drive this cycle.

Scholars within environmental sociology in particular have begun to explore the links between structures and behavior as it relates to agriculture. Environmental sociologists have a long tradition of theorizing the interactions between individuals, institutions, and resource use, dating back to Marx. One such theory that has increasingly been applied in the literature on agriculture is known as treadmill of production theory. Treadmill of production links imperatives for profit and expanding production under capitalism to growing ecological destruction (Schnaiberg 1980).

Failing to minimize costs and maximize yields is generally not a viable option, as producers will be forced out of business.

Treadmill of production and other closely related sociological theories have increasingly been applied to the agricultural context in the United States (Sanderson et al. 2019). Applied to agriculture, the treadmill of production suggests that farmers are influenced by economic and social forces to take steps to maximize their yield year after year. Treadmill of production and other related theories have also been applied more specifically to the study of practice adoption. Obach (2007) theorizes that the increase in organic agriculture in the U.S. is at least partly due to its profit potential, pursued by both individual farmers and the state. More recently, Houser and Stuart (2020) combined treadmill of production theory with O'Connor's (1988) second contradiction of capitalism to examine nitrogen fertilizer application in the Midwest and found that farmers tend to increase their nutrient applications in response to heavy rains in order to protect against yield loss while feeling restricted in their ability to act on environmental concerns. Sanderson et al. (2019) found that deployment of irrigation is linked with groundwater depletion despite increases in efficiency due to the agricultural production treadmill. Similarly, Houser (2021) found that structural pressures related to yield prioritization undermine the effectiveness of nutrient best management practices and lead to increased nitrogen application. Taken together, the existing literature suggests that farmers are generally constrained in their ability to effectively implement conservation practices for environmental outcomes.

In this paper, I apply treadmill of production theory to the adoption of conservation practices by farmers in the Upper Midwest. I build on existing literature by applying the notion of constrained choices under the treadmill of agricultural production to producers' use of two categories of practices: those used either to adapt to or to mitigate environmental effects. I focus on actual practice adoption rather than adoption intentions or willingness in order to examine real interactions between farmers and their environment.

While best management practices are often promoted as a single class of practices, some are oriented toward on-farm benefits while others are intended primarily to improve environmental conditions beyond the farm. These categories are not mutually exclusive, and there are many practices with potential for both on-farm and off-farm benefits. However, there is a need to examine differing motivating factors across practice types (Prokopy et al. 2019). Moreover, dividing practices along these lines holds theoretical interest for examining constrained choices. Farmers are often interested in implementing practices with on-farm benefits which can directly or indirectly improve their yields or cut their costs (Reimer et al. 2012; Plastina et al. 2020). Rather than examining adoption of a single conservation practice or combining a variety of conservation practices together uncritically, I take as my starting point the notion that farmers operating under the current socio-economic structure face constrained choices regarding practices for adaptation and mitigation. In particular, I posit that farmers prioritize practices that allow their own operation to adapt to negative environmental impacts, both ecologically but primarily economically, over those practices that promote mitigation of through off-farm benefits. As such, I hypothesize that adaptation and mitigation will be differentially associated with farmer attitudes and concerns, revealing the role of these external constraints on farmers' decisions.

Adaptation and Mitigation in Agriculture

Problems related to climate change, water quality, and soil erosion all present a dual problem for agriculture. First, to achieve sustainability, farmers need to be able to adjust to issues that arise relating to soil, water and weather. Second, agriculture is a source of these problems, and alleviating them will require changes to agricultural management and production. The former of these I refer to as adaptation, and the latter I refer to as mitigation. Below, I further conceptualize these two terms as they will be used in this analysis.

The United States Department of Agriculture's Natural Resources Conservation Service (NRCS) defines adaptation as "actions undertaken in response to or anticipation of changes in climatic conditions in an area" which allow for a reduction of risk or the production of resilience (United States Department of Agriculture, "Adaptation"). In the context of a farm-as-business the notions of risk and resilience often apply to production, the intersection of the concepts of yields and profits. As such, adaptation is here defined as practices which farmers implement in response to or anticipation of poor conditions with the purpose of having on-farm benefits for production, whether directly or indirectly. This can include practices with the goal of improving soil properties, aiding crop growth, or reducing losses.

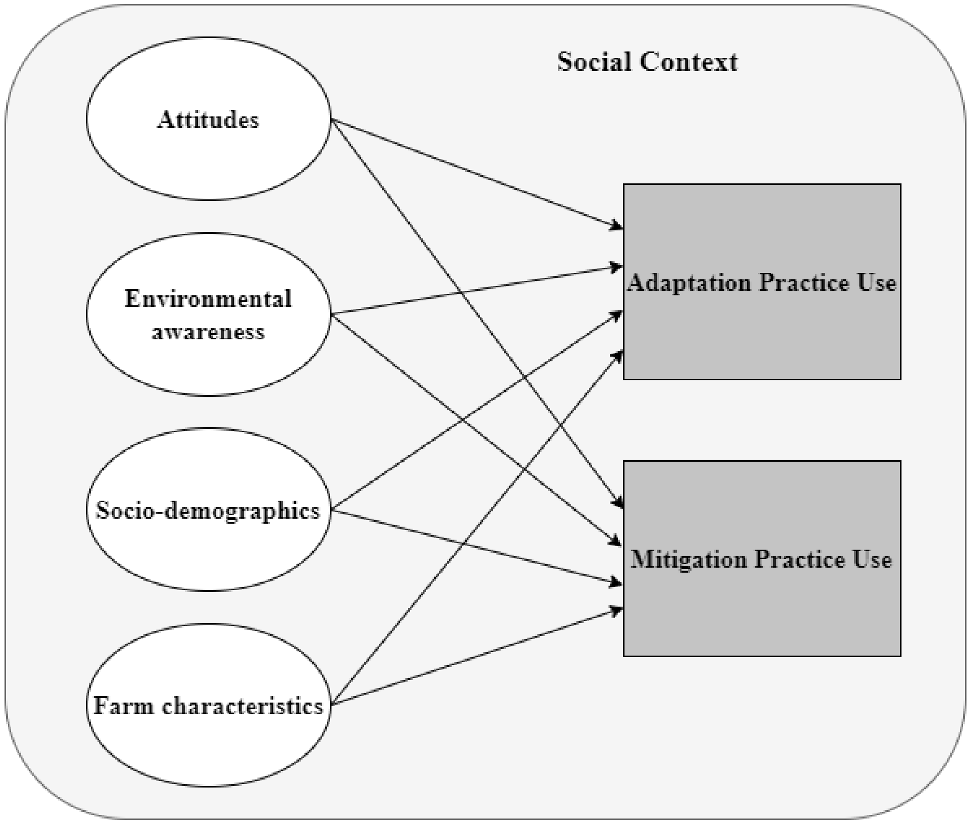
The need to understand the interplay between climatic change and agriculture has led some researchers to focus on a subset of practices which help farmers adapt to changing environmental conditions (Arbuckle et al. 2013; Arbuckle et al. 2015; Roesch-McNally, Arbuckle, and Tyndall 2017; Mase et al. 2017). These are practices which minimize farmers' risks and can be proactive (occurring before an anticipated event) or reactive (happening in reaction to an unexpected event). Knowing which strategies farmers use to adapt to change and why is especially important in the context of the corn belt in the Midwestern United States, where a large portion of the world's corn is produced along with other important crops such as wheat and soy. A limited number of studies have recently examined such adaptive practices in this region. One study found that attitudes toward adaptation, risk perception, current practice use, and confidence in current practice use influenced farmer adaptation intentions (Roesch-McNally et al. 2017). Another study of farmers in Iowa found that belief in climate change and concern about its effects influenced attitudes toward adaptation (Arbuckle et al. 2013). The same authors later found perceived risk to be associated with support for adaptation (Arbuckle et al. 2015). One of the few studies to measure actual use of adaptation strategies in the Midwest similarly found that concern for on-farm risks, climate change belief, and attitudes toward innovation were significantly associated with adapt behavior; however, this study examines strategies beyond only adoption of practices, such as financial decisions (Mase et al. 2017).

Related to agricultural adaptation, and just as important, is the capacity of the agricultural sector to mitigate environmental problems, like climate change, through practice adoption. Mitigation is here conceptualized as practices whose benefit primarily occurs off-farm. This does not preclude the practice from having some on-farm benefits, both in the short-term via immediate payoffs and in the long-term via complex ecological processes. Indeed, few if any practices could be conceivably defined as purely mitigative. In scientific literature, a variety of practices have been examined for their contributions and/or reductions to environmental degradation and climate change via various biophysical processes, such as crop management (Kaye and Quemada 2017), nutrient management (Robertson and Vitousek 2009; Xie and Ringler 2017; Bowles et al. 2018), pest management (Mahmood et al. 2016), and tillage (Mehra et al. 2018; Powlson et al. 2014). Less effort in the social sciences has been devoted to measuring corn belt farmers' actions to mitigate climate change, despite much praise around the potential for the agricultural sector to reduce greenhouse gas emissions and act as a sink for atmospheric carbon dioxide (Bellarby et al. 2008). Some research has examined this category, however. Arbuckle et al. (2013) examined the effect of farmer beliefs and concern on their attitudes toward adaptation and mitigation distinctly; however, attitudes toward mitigation were measured via support for government action rather than agricultural practice adoption. Haden et al. (2012) similarly studied the effects of concern and beliefs on willingness to adopt adaptation and mitigation practices, finding that the two types of practices are motivated at separate cognitive levels. Houser and Stuart (2020) take a similar approach but divide practices into conservation adaptive practices and quick-fix adaptive practices, finding that farmers often felt pressure to apply quick-fix adaptive practices in order to maximize yield. Engler et al. (2021) similarly divide adaptation into proactive and reactive categories, linking use of these practices to both farmers' perceived vulnerability and structural factors.

Despite the growing number of studies conceptualizing these two categories of practices, little research has examined the distinct characteristics, attitudes, and beliefs associated with actual measures of adoption of adaptation as opposed to mitigation. As research increasingly suggests, it is tenuous to claim that all conservation practices, both adaptive and mitigative, are motivated by the same factors. Support for the idea of separating adaptation and mitigation comes from Arbuckle et al.'s (2013) empirical study in Iowa, in which farmers' attitudes toward adaptation and mitigation were shown to have not only different predictors, but in some cases the same predictor would significantly influence adaptation and mitigation in opposite directions. Relatedly, Houser and Stuart (2020) draw on qualitative data to theorize that Midwestern farmers adapt to extreme rainfall by increasing their nitrogen applications and therefore increasing their negative environmental impact; in other words, adaptation is found to be antithetical to mitigation. Such a conclusion provides additional theoretical support for the idea of separate categories and predictors for adaptation and mitigation practices. However, despite their at times opposing nature, there is also much potential and realized overlap between adaptation and mitigation (Lal et al. 2011). Part of this is due to unclear or unstated definitions, but there is also room for mutual benefit and synergy between farms-as-businesses, farms-as-environment, and the surrounding landscapes (Smith and Olesen 2010). However, current evidence suggests that this synergy may be undermined by the political-economic forces which constrain producers' management decisions and set practices that benefit yields and practices that benefit the environment at odds (Houser and Stuart 2020; Houser 2021; Lane et al. 2018).

In order to explore the potential for distinct or contradictory predictors of adaptation and mitigation, I examine adoption of management practices by agricultural producers in the Eastern corn belt of the United States using structural equation modeling. My research questions are: 1) What attitudes and characteristics of farmers affect adaptation? 2) What attitudes and characteristics of farmers affect mitigation? 3) In what ways are adaptation and mitigation distinctly influenced by farmers' attitudes, perceived vulnerability, environmental awareness, and socio-demographic characteristics, and 4) what does that reveal about the constraints placed on practice adoption? Figure 1 shows a conceptual model of the ideas to be tested. Consistent with existing literature on practice adoption, I hypothesize that productivist attitudes will have a positive effect on use of adaptation practices and environmental awareness will have a positive effect on use of mitigation practices. Additionally, in keeping with theory on constrained choices under the treadmill of production, I hypothesize that the factors affecting conservation practice use will differ across the categories of adaptation and mitigation practices.

Figure 1: Conceptual Model Relating Categories of Predictors with Outcomes



DATA AND METHODS

Survey Methods and Questionnaire

Data for this analysis come from a 2019 mail survey of row crop farmers in the states of Illinois, Indiana, Michigan, and Ohio. It features a self-administered questionnaire including questions on agricultural practices, farm characteristics, farmer attitudes, and farmer demographics. Only counties with at least 15% of land in agricultural production were included in the sampling frame, and of those only farms operating at least 100 acres and growing corn and/or soybeans were eligible to be sampled. Sampling was stratified according to total operation size, by farms operating between 100 and 499 acres and those operating 500 acres or more, with larger farms being oversampled. The survey followed a modified Dillman protocol (Dillman, Smyth, and Christian 2014). Multiple waves of surveys and postcards were mailed to farmers over a six-week mailing schedule that included a survey packet postcard survey protocol, yielding 1,080 usable responses, a response rate of approximately 26%. The survey is distributed annually to a returning panel of farmers as well as a newly drawn sample, with each new sample being representative cross-sectionally on its own. For this analysis, I use only the 2019 new sample, with listwise deletion across all included variables yielding a final sample size of 452 farmers across the four states.[1]

Dependent Variables

There are multiple factors to consider in conceptualizing adaptation and mitigation. Practices which set off certain biophysical processes that could be considered mitigative may be

[1] Missing data occurs when a respondent chooses not to respond to some questions on the survey. This could occur for a variety of reasons, including (but not limited to) that the respondent found the question unclear, felt the question was too personal, or felt the response options presented to them were inaccurate. Considering that both environmental issues and governmental regulation are highly politicized in the United States and perhaps especially for farmers, additional investigation is needed to examine the patterns of missing data and what effect they may have on this analysis.

widely viewed by farmers as adaptive, or vice versa. For example, Kaye and Quemada (2017) write that cover crops have the potential to mitigate a substantial amount of warming if widely adopted, yet they are typically presented as having benefits for soil health on-farm. As such, cleanly identifying practices as either adaptation- or mitigation-oriented is difficult. Looking at the biophysical properties and processes associated with practices is contentious enough on its own[2]; sorting through the marketed, perceived, or socially constructed characteristics of a practice is even harder. I argue it is meaningful to categorize a practice based on dominant perception, while attempting to remain grounded in the empirically demonstrated properties of the practice where possible.

Conceptualizing and operationalizing adaptation.

With the above considerations in mind, four practices are chosen to operationalize adaptation: use of pest-resistant crop varieties, use of drought-tolerant crop varieties, use of reduced tillage, and increased nitrogen application in response to wetter springs. The first two fall under crop management, pest-resistant crop variety use can also be seen as pest management, increased nitrogen application falls under nutrient management, and reduced tillage fits within the category of tillage. Use of modified crop varieties is a management decision that, at least at the individual level of adoption, has little effect outside of the farm itself and may primarily be performed as a proactive adaptive choice to minimize risk of crop loss in case of adverse events. Climate change is predicted to have effects that are beneficial for insect pests and plant diseases, increasing the need for farmers to adjust management decisions to adapt to an increasing number of pests in their fields (Delcour et al. 2015). With regards to tillage, conventional tillage refers to

[2] An example of contention over inherent mitigative benefits of a practice comes from the literature on no-till, a practice which is often lauded as a major source for carbon sequestration but which Powlson et al. (2014) argue has limited potential as a carbon sink.

a business-as-usual approach, in which tillage is used to prepare for planting while also controlling pests. In contrast, reduced tillage is defined via an increased amount of crop residue remaining on the surface. Reduced tillage has been shown to be beneficial for crops and soil health on-farm (Busari et al. 2015) but does not provide the carbon sequestration benefits of no-till. Finally, increased nutrient application is used as a strategy for farmers to adjust to increased rainfall under climate change (Houser and Stuart 2020). Applying excess nitrogen as insurance against anticipated rainfall reduces risks to farmers' profits, but also increases runoff to waterways and greenhouse gas emissions (Houser and Stuart 2020). In summary, each chosen practice in this category has potential on-farm benefits especially with regard to yield, while the off-farm effects range from only secondarily beneficial to neutral or even harmful.

The scale of practices measuring adaptation in the analysis consists of the four practices listed above[3]. Each measure is adjusted to binary coding, with 0 indicating no use of the practice and 1 indicating at least some use. To create the outcome variable used in the SEMLV model, the scores across all four practices are combined in an additive scale. Scores range from zero to four with a mean of 2.50 and a standard deviation of .90. Table 1 displays use of the individual measures as well as a brief summary of some of the on- and off-farm effects of each practice. Table 2 contains descriptive statistics for the scale outcomes of practices.

[3] For pest-resistant and drought-tolerant crop varieties, responses are drawn from a table with the instructions "For the following, please indicate your current, past, or likely future use of these practices anywhere on your farm operation" and options for responses ranging from "yes, regularly (most fields and/or most years)," "yes, sometimes do this (some fields and/or some years)," "used to, but no longer do," "never used, but might," and "never used, don't want to." From this, I selected two variables to include in my measure of adaptive practices: "use crop varieties with resistance to a certain pest(s)" and "use drought tolerant crop varieties." The measure of reduced tillage comes from a similar question table, with instructions reading "Did you use any of the following practices on your operation in 2018?" and five options ranging from "yes, on all/most of my operation," to "did not use." The row for this measure reads "Reduced tillage (e.g., chisel plow) 15-30% remaining on surface." Finally, the measure for increased nitrogen application comes from a table with instructions reading, "In the last five years, have your management practices changed due to wetter springs, more extreme rain events, or more frequent droughts?" The response options ranged from "decreased a lot" to "increased a lot" and the measures "Due to wetter springs, the amount of N I apply after crop emergence has…" and "Due to wetter springs, the amount of N I apply before crop emergence has…" were combined.

Table 1: Adaptation and Mitigation Practice Use and Effects (n=452)

	Mean	Std. Dev.	On-farm effects	Off-farm effects
Adaptation Practices				
Pest resistant crop varieties	0.914	0.281	Protect against pest risks	Resistance in pests, harm to other species
Drought tolerant crop varieties	0.728	0.446	Protect against drought risks	Reduce irrigation
Reduced tillage	0.593	0.492	Improve yield, reduce erosion, improve soil health	Reduce runoff
Increased N use	0.268	0.443	Increase N available to crop	Increase nutrient runoff
Mitigation Practices				
Perennial vegetation use	0.283	0.451	Promote biodiversity	Sequester carbon, regulate water quality
No till	0.723	0.448	Reduce erosion, improve soil health	Reduce runoff, sequester carbon
Variable rate nitrogen application	0.398	0.490	Decrease total fertilizer input	Reduce nutrient runoff
Cover crops	0.429	0.496	Fix nitrogen in soil, reduce soil erosion	Sequester carbon

Conceptualizing and operationalizing mitigation.

Four practices are chosen to measure farmers' climate change mitigation. These are perennial vegetation use, no-till, cover crop use, and variable rate nitrogen application. Perennial vegetation use is a method for sequestering carbon in soil, preserving biodiversity, and regulating water quality (Asbjornsen et al. 2013), but in the context of row crop agriculture indicates land that is taken out of production of the operation's main crops. Likewise, no-till has been lauded for its carbon sequestration potential (Mehra et al. 2018; but see also Powlson et al. 2014), and though it is presented as benefitting soil health its on-farm benefits as far as crop production are somewhat limited (Busari et al. 2015) and benefits to crop yield and soil water availability take fifteen years or longer to manifest consistently (Cusser et al. 2020). Cover crops have been found to have a wide array of benefits both on and off farms, including reducing soil erosion, improving soil quality, fixing nitrogen, and sequestering carbon (Kaye and Quemada 2017). While often perceived as having a long-term positive impact on yields and a reduction on input costs, some preliminary research has suggested that the net economic impact of cover crop use is actually negative (Plastina et al. 2020). Finally, variable rate nitrogen application is a nutrient best management practice meant to improve nitrogen use efficiency. While this can decrease the total nutrient input cost of farmers, one key benefit of variable rate application is that it minimizes nutrient loss to the surrounding environment, which in turn helps to mitigate issues like hypoxia, algal blooms, and greenhouse gas accumulation (Robertson and Vitousek 2009).

For the mitigation practice outcome scale, measures of the four practices listed above were used[4]. As with adaptation, all measures for mitigation are recoded so that 0 indicates no use and 1 indicates at least some use. As above, all four measures are then added to create the scale for mitigation. The scale variable ranges from zero to four with a mean of 1.83 and a standard deviation of 1.16. The scales for adaptation and mitigation have a low positive correlation (r=0.014).

Table 1 shows counts for practices included in the adaptation and mitigation scales, while Table 2 displays descriptive statistics for all observed variables (also see Appendix A for a correlation matrix of practices). The most commonly used adaptation practice is pest-resistant crop varieties, with over 91% of respondents indicating they used the practice. Drought tolerant crop varieties are also popular, with almost 73% reporting use. Reduced tillage was used by about 59% of respondents. Increasing nitrogen applications was the least frequently used practice, with only 27% using this practice. No-till was the most frequently used practice included in the mitigation

[4] The first three come from the same table in the questionnaire as the crop variety questions listed above, from the rows labeled "Use perennial vegetation in unstable or low yield areas of my operation," "plant a cover crop over winter," and "variable rate Nitrogen application." The final measure comes from the same table as the reduced tillage option above, and the row is labeled "No-till (minimal soil disturbance) all residue left on surface."

Table 2: Descriptive Statistics for Variables in Empirical Model (n=452)

	Mean	Standard Deviation	Range: Min	Range: Max
Adaptation Practice Scale	2.502	.900	0	4
Mitigation Practice Scale	1.834	1.160	0	4
Perceived vulnerability				
Concern about impact on my farm: warmer temperatures	2.903	1.161	1.000	5.000
Concern about impact on my farm: extreme weather events	3.392	1.211	1.000	5.000
Concern about impact on my farm: climate change	2.692	1.334	1.000	5.000
Concern about impact on my farm: floods	3.038	1.319	1.000	5.000
Concern about impact on my farm: droughts	3.345	1.203	1.000	5.000
Productivist orientation				
Importance to you: build up wealth and family assets	3.914	0.941	1.000	5.000
Importance to you: earn a high income	3.617	0.989	1.000	5.000
Importance to you: maximize farm/company profit	4.301	0.803	1.000	5.000
Importance to you: be among the best in the industry	3.889	1.017	1.000	5.000
Belief in climate change (1=yes)	0.832	0.374	0.000	1.000
Risk Averse (1=yes)	0.097	0.297	0.000	1.000
Education (1=at least some college)	0.595	0.491	0.000	1.000
Farm size (1=at least 500 acres)	0.471	0.500	0.000	1.000
Proportion of income from farming (1=>50%)	0.639	0.481	0.000	1.000
Years of experience farming	31.856	14.481	2.000	69.000

scale, with nearly three quarters (72%) using it. Cover crops were the next most popular mitigative practice, with about 43% use. Variable rate nitrogen application was used by about 40% of farmers surveyed, while perennial vegetation was used by about 28%.

Some comparisons can be made between the measures for adaptation and mitigation. Less than two percent of farmers report using none of the adaptation practices included here, but over thirteen percent report using none of the mitigation practices. The mode for the scale of adaptation practices used is three, while for mitigation it is only one. While practice use is combined here across all four surveyed states, there are differences in practice use by state due to varying local climate and policies.

Independent Variables

Confirmatory factor analysis (CFA) was used to create two latent variables for inclusion in the final structural model. The first construct, perceived vulnerability to environmental issues, is measured via five indicators asking farmers to rate their concern about various issues' impact on their farm. The environmental issues included are warmer temperatures, extreme weather events, droughts, floods, and climate change. The second construct measures the extent to which a farmer is oriented toward farm productivity. Respondents were asked to indicate the importance to the management of their operation of being among the best in the industry, building up wealth and family assets, earning a high income, and maximizing farm/company profit. Full question wording of each measure can be found in the footnotes[5]. CFA results indicate that all individual measures and both latent constructs display acceptable fit. Appendix B contains the factor loadings and fit measures for the latent constructs in the model.

Additional exogenous variables in the model are all observed measures. The first is climate change beliefs, measured on the survey through six categorical options. These categories are

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[5] Full questions for included measures are:

a. Perceived vulnerability: "Below are some potential environmental issues related to agriculture. How concerned are you about their impact on your farm?: Warmer temperatures; extreme weather; climate change; floods; droughts."
b. Productivist orientation: "When you think about being a farmer and managing your operation, how important are the following to you?: Build up wealth and family assets; earn a high income; maximize farm/company profit; be among the best in the industry."

recoded for the sake of the analysis into two: belief that climate change is not happening and belief that it is happening, regardless of whether the cause is anthropogenic or natural. Risk aversion in a binary measure based on whether farmers report being willing to take more or fewer risks on introducing new crop production practices to improve yield; those who indicated they were a lot less or slightly less willing are coded as being risk averse. Experience is measured in years, calculated from year respondent became the primary decision maker for their farm. Education is recoded here to two categories, indicating whether or not the respondent completed at least some college.[6] Farm size is a binary measure, dividing farms into those operating less than or greater than five hundred acres. Finally, proportion of income from farming measures whether farmers get at least half of their income from farm activities.

Statistical Modeling Approach

Structural equation modeling with latent variables (SEMLV) is used to assess the effects of all exogenous variables on adaptation and mitigation practice use. SEMLV is a modeling technique which allows for multiple endogenous variables to be examined at once. Latent variables are unobserved variables that capture underlying constructs measured via indicator variables included in the survey. The SEMLV analysis consists of two parts: the measurement model, used to evaluate the fit of the latent variables (completed using confirmatory factor

[6] Full questions for included measures are:

1. Years of experience: "In what year did you become the primary decision-maker for crops on this farm?"
2. Education: "Which category below best describes your formal years of education? Less than high school; high school diploma; some college (include associate's degree); bachelor's degree or higher"
3. Climate change beliefs: "Which of the following statements do you personally believe? Climate change is happening now, caused entirely by human activities; climate change is happening now, caused mainly by human activities; climate change is happening now, caused equally by human activities and natural forces; climate change is happening now, caused mainly by natural forces; climate change is happening now, caused entirely by natural forces; climate change is not happening now."
4. Risk aversion: "Compared to other farmers, would you say that you are willing to take more or less risks on introducing new crop production practices to improve yield?"
5. Proportion of income from farming: "What portion of your household's adjusted gross income was earned through farming activities?"

analysis—see Appendix B), and the structural model for the relations between all specified paths in the model. I used Stata 16 to conduct the analyses.

RESULTS

Figure 1 displays the empirical model estimated, and results of the structural model are presented in Table 3. Both adaptation practice use and mitigation practice use are regressed on perceived vulnerability to environmental issues, productivity orientation, climate change beliefs, risk aversion, education, large farm status, proportion of income from farming, and years of experience.

Overall model fit in the context of SEM is determined via a number of fit indicators. The most important of these is the chi-square test, which compares the covariance matrix of the observed data to that of the theorized model. If the two do not differ, then the chi-square test is insignificant; a significant value here indicates poor fit. The chi-square figure for this model is highly significant, suggesting that the fit of the model is poor. While chi-square tests do not adjust for sample size, the root mean squared error (RMSEA) is a fit measure which does adjust for sample size. Lower values of RMSEA are considered indicators of good fit, with acceptable levels of RMSEA falling below a threshold ranging from .05 to .08 (Schumacker and Lomax 2016). The RMSEA of this model falls within that range. Comparative fit index (CFI) and Tucker-Lewis index (TLI) are two additional measures of fit. Values for both these measures range from 0 (no fit) to 1 (perfect fit), with values close to and above .90 indicating acceptable model fit (Schumacker and Lomax 2016). For this model, both CFI and TLI meet that threshold, indicating acceptable overall model fit. Still, this model may require additional modifications according to considerations around theory and data collection to improve overall fit.

Adaptation

Of the eight exogenous variables included in the model, only two are significantly associated with adaptation practice use. The first is the latent variable for perceived vulnerability

Figure 2: Empirical Model of Adaptation and Mitigation Practice Use

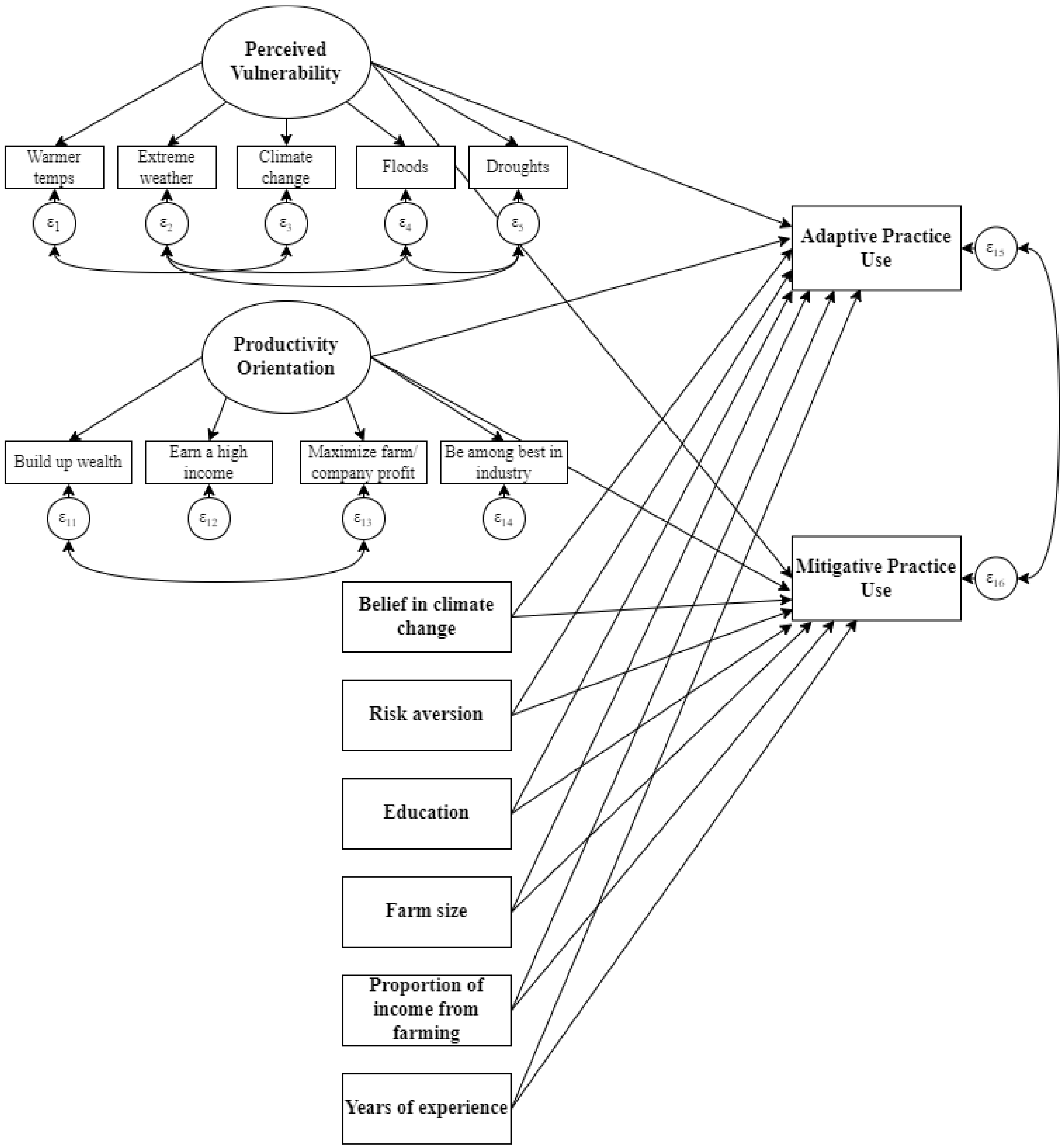

Table 3: Parameter Estimates for Structural Model (n=452)

	Endogenous Variables			
	Adaptation practices		Mitigation practices	
	Coef.	(S.E.)	Coef.	(S.E.)
Perceived vulnerability (latent)	0.139*	(0.054)	-0.139*	(0.066)
Productivity orientation (latent)	0.054	(0.060)	-0.052	(0.077)
Belief in climate change	0.037	(0.117)	0.263†	(0.145)
Risk aversion	-0.081	(0.142)	-0.995**	(0.176)
Education (at least some college)	0.056	(0.086)	0.361**	(0.107)
Farm size (>500 acres)	-0.008	(0.089)	0.124	(0.111)
Proportion of income from farming (>50%)	0.259**	(0.091)	0.014	(0.113)
Years of experience	0.001	(0.003)	-0.005	(0.004)
			Chi-square	153.21**
			RMSEA	0.046
			CFI	0.959
			TLI	0.936
			†p<0.1 *p<.05 **p<.01	

to the environment. A farmer's perception of their farm's vulnerability to the impacts of environmental events is positively associated with adaptation practices (p=0.010). This is consistent with prior findings on perceived risks and conservation practices (Arbuckle et al. 2013; Mase et al. 2017) and adaptation intentions (Roesch-McNally et al. 2017). Likewise, earning a majority of one's income from farming is positively associated with the use of adaptation practices (p=0.004). This is consistent with Prokopy et al.'s (2019) review article, which found that variables for income from farm were more often positively than negatively associated with conservation practice use.

The remaining variables were not significantly associated with adaptation. The R-squared values indicate that this model only explains about five percent of the variation in adaptation practice use, suggesting there is still much room for improvement in understanding factors influencing farmer adaptation practice adoption.

Mitigation

Three exogenous variables are significantly associated with use of mitigation practices. The first is the latent variable for perceived vulnerability, which is negatively associated with mitigation (p=0.036). The measure of risk aversion was also significantly and negatively associated with mitigation practice use (p=0.000). This finding is inconsistent with Prokopy et al.'s (2019) review article, which found neither risk aversion nor risk tolerance to be significant in more quantitative articles than would be expected by chance. Education is the only variable positively and significantly associated with mitigation practice use (p=0.001). This association is consistent with prior findings (Prokopy et al. 2019; Mase et al. 2017; Denny et al. 2019). Belief that climate change is occurring approaches, but does not reach, significance (p=0.069), and the association is positive. The remaining variables in the model did not significantly affect the use of mitigation practices. Only about eleven percent of the variation in mitigation practice use is explained by variables in the model, again suggesting that additional variables need to be included for fuller understanding of farmer decision-making around mitigation practices.

Comparisons

As shown in Table 3, perceived vulnerability to environmental issues significantly predicts both adaptation and mitigation practice use (p=0.010 and 0.036, respectively). Notably, perceived vulnerability is *positively* associated with adaptation practice use, but *negatively* associated with mitigation practice use. As stated above, the positive association of perceived vulnerability with adaptation is consistent with prior work (Arbuckle et al. 2013; Roesch-McNally et al. 2017; Mase et al. 2017). However, the negative association of perceived vulnerability with mitigation is distinct from both the effects of perceived vulnerability on adaptation in this analysis and others (Mase et al. 2017), but indicates there are important differences in predictors between these distinct categories of practices. Productivity orientation is not found to be significantly associated with either adaptation or mitigation practice use. While a review of the literature did not find this to be a commonly significant predictor, farmer orientation toward others (as opposed to self/profit) was recently found to have a statistically positive effect on BMP adoption (Prokopy et al. 2019). Risk aversion is a strong negative predictor of mitigation but is not significantly associated with adaptation. This finding contradicts Prokopy et al.'s (2019) and Baumgart-Getz et al.'s (2012) findings that risk tolerance and risk aversion were not predictors of practice use. Belief in climate change was not a significant predictor of adaptation but approached significance for mitigation ($p=0.069$). This is an intuitive result, as belief in climate change may be a prerequisite for adopting practices with broad environmental benefits but little immediate on-farm impact. However, belief in climate change may not be a prerequisite for practices that allow for adaptation to changing environmental conditions (such as drought-tolerant crops), as farmers do not necessarily need to connect these changes to broader patterns to experience their effects.

Other predictors included in the model also suggest different motivators for adaptation and mitigation. Education is positively and significantly associated with mitigation practice use ($p=0.002$), though it is not significantly related to adaptation practice use. Earning a majority of one's income through farming was significantly and positively associated with adaptation practice use ($p=0.004$) but not with mitigation practice use. These distinct effects between adaptation and mitigation practice use again suggest that the effects of certain variables differ in the context of practices as divided between the categories of adaptation and mitigation.

DISCUSSION AND CONCLUSION

The association shown in this analysis between perceived vulnerability to environmental issues and adaptation is consistent with findings in some existing literature. Mase et al. (2017) found a positive relation between perceived risk from weather and climate threats and adaptive practices like adding new technology or purchasing crop insurance. Similarly, Arbuckle et al. (2013) found perceptions of climate risks to be a key influence on adaptation attitudes. However, Prokopy et al. (2019) do not identify perceptions about the climate as a consistent predictor of conservation practices in their review of the literature. It is possible that perceived vulnerability emerges as a significant predictor only when examining particular categories of practices, and that examining individual practices or general groupings of conservation practices may obscure the effect of perceived vulnerability on practice adoption.

The effect of perceived vulnerability on mitigation practice use coincides with findings from some prior research. For example, Haden et al. (2012) found that perceived changes in water availability influence willingness to adopt adaptation and mitigation practices in California, and Arbuckle et al. (2013) observed that concern about potential negative impacts of climate change positively predicts attitudes toward mitigation. However, the findings of the current study are distinct in that they examine actual practice use rather than intentions and find that practices with primarily off-farm mitigative benefits are negatively associated with perceived vulnerability. While perceiving their farming operation to be vulnerable to environmental issues may positively influence farmers' beliefs around what others (e.g., government) should do to reduce those risks, farmers who feel their operations are most vulnerable may also be the ones who most feel the pressures, exerted by a variety of actors under the treadmill of production (Houser and Stuart

2020), to prioritize their own yield over off-farm benefits. Such a prioritization may explain the negative association seen here.

The relationships between perceived vulnerability, adaptation and mitigation reinforce the core ideas of the treadmill of production as applied to agriculture. Farmers who perceive their farms to be most vulnerable to environmental problems likely view their productive capabilities as at risk. In turn, this risk to productivity has implications for their sales, income, and ability to continue farming in the future. My analysis suggests that farmers who feel most at risk are also most likely to use practices that are adaptive or potentially maladaptive. Prioritizing yield is crucial for producers who do not want to be left behind by a political-economic structure that requires not only stable but increasing production, since farm input costs (land, labor, chemical) tend to rise year over year (Levins and Cochrane 1996). As such, farmers face a constrained choice regarding whether to adapt (Houser and Stuart 2020). On the other hand, farmers who feel most vulnerable are significantly less likely to take measures to mitigate agriculture's effects on the surrounding environment. Despite the potential long-term payoffs of these practices, the same political-economic structures that motivate producers to adapt in order to protect their yield also work to prevent them from sinking costs into mitigation. Farmers who feel their livelihoods are immediately at risk will have little freedom to invest time, money, or labor into practices which may not have immediate benefit for them.

The finding that risk aversion is negatively associated with mitigation practice use reinforces the theorized relationship between practice use and treadmill forces. Those who are unwilling to take risks are probably unwilling to sink costs into practices that may not be immediately beneficial for them, and perhaps especially those practices which require collective adoption to make an impact, implying that farmers may find themselves in a situation similar to the tragedy of the commons (Hardin 1968). This finding nuances Baumgart-Getz et al.'s (2012) argument that the risk associated with practice adoption has diminished over time. The current study demonstrates that risk aversion is still an important factor in farmer decision-making with regards to some, but not all, practices. Although increasing adoption may make a practice appear less risky to some, it may not be enough to override farmers' caution surrounding the challenges of practices geared toward mitigation of environmental harm.

Belief in climate change is hypothesized to be a positive predictor of mitigation, and this analysis comes close to supporting that hypothesis. Climate change belief did not predict adaptive practices. Arbuckle et al. (2013) similarly found that belief in specifically anthropogenic climate change was positively related to attitudes in support of government mitigation of greenhouse gases but was not related to attitudes toward adaptation. Likewise, Mase et al. (2017) failed to show an association between climate change and adaptive strategies. The results of the current analysis suggest that belief in climate change may be a factor motivating mitigation but is not a factor that broadly promotes or discourages adaptation. A possible explanation for this finding is that farmers feel pressure to maximize their yields and profits regardless of their beliefs about the origins of those challenges. For example, regardless of whether an extreme weather event is perceived by the farmer as being entirely natural or linked to anthropogenic climate change, under a paradigm of constant economic growth the negative impacts to yield must be minimized. Belief in climate change may not be enough to override constraints directly relating to adaptation, but this analysis implies it may have some impact on farmers' use of mitigation. Future research should make efforts to introduce additional complexity to the ways in which farmers' beliefs and attitudes regarding climate change and other forms of environmental degradation are assessed and modeled.

A farmer's orientation toward productivity and profit is found here to be unrelated to their use of adaptation or mitigation practices. This appears to contradict the treadmill of production theory as applied here. Since yield maximization is key to the adaptation practices included in this analysis, it was hypothesized that productivity orientation would be positively associated with adaptation practice use and negatively associated with mitigation practice use. While the signs of the coefficients do match this hypothesis, neither association is significant. Farmer orientation or identity is often divided into productivity or business orientation as opposed to conservation or stewardship orientation. While Prokopy et al. (2019) likewise did not affirm the hypothesis that farmers who identified as self-interested were less likely to adopt best management practices, they found that farmers who identified as other-oriented were more likely to adopt those practices. Therefore, future research may benefit from focusing more on farmer other-identity as a predictor of practice use than productivity identity.

Despite the lack of association between productivity orientation and practice use in the current analysis, other variables still support the notion of distinct predictors for adaptation and mitigation as conceptualized. These differences suggests that there is something captured by the division of practices along lines of adaptation and mitigation, and treadmill of production theory still holds explanatory power for those differences. Future research should continue to explore these and other categorizations of practices, applying both micro- and macro-level theories to further understand farmer decision-making within a neoliberal socio-economic structure.

In addition to providing insight into farmer behavior, the current results also elucidate the relationships between individual behaviors and social structures more generally for actors who directly impact the environment. It is important to understand not only which actors choose which behaviors but what constraints are at play in those decisions and from where those constraints emerge. Farmers, like all social actors, are both objects and agents of social change. While individual characteristics like attitudes, beliefs, and education are found to be important influences on decision-making for mitigation, agriculture in the United States has largely failed to become a mitigative force for environmental issues like climate change. Therefore, these findings strengthen the idea that social structures are necessary pieces of social movements geared toward protecting the environment, since individuals face constrained choices in how they choose to interact with the environment.

More specifically, these results imply that voluntary adoption of individual practices may be insufficient to make agriculture a force for positive environmental impact under a 'treadmill' system that prioritizes growth. Under increasing competition and input costs, agricultural producers are rewarded for prioritizing yield and externalizing costs to the environment (Levins and Cochrane 1996). On the other hand, an inherent contradiction in such a paradigm means that voluntary adaptive measures may be insufficient to foster agricultural resilience in the face of volatile climates and markets. The fundamentals of agriculture need to change in order to create a truly sustainable food system. Currently, agricultural decision-makers walk a tightrope of management, attempting to balance economic and ecological stability. Notions like sustainable intensification may be inherently contradictory—the choice may instead be *either* sustainability *or* intensification. Results of this study join a growing body of literature (Sanderson and Hughes 2019; Houser and Stuart 2020; Houser 2021) that indicates that the two are at odds with each other. While many studies examining the farm and farmer characteristics associated with practice use often conclude with recommendations for increased education on best management practices, cost-share policies, or technical assistance, the current study joins the mounting call for a critical examination of the social and economic systems that prioritize growth and rely on ecological modernization as the dominant force for social and environmental change (see Prokopy et al. 2020; Sanderson and Hughes 2019). Under the threat of the fast-approaching climate crisis, urgent actions need to replace moderation in all industries. Both adaptation and mitigation in agriculture will need to look drastically different as the climate continues to change. A new way of doing agriculture (and indeed structuring the entire food system) needs to be implemented, one which will be *both* environmentally beneficial in its capacity to mitigate harm *and* resilient to the changes already guaranteed based on current levels of global warming and environmental degradation.

APPENDICES

APPENDIX A: Correlation Matrix of Practices Included in Scales for Adaptation and Mitigation

Table 4: Correlation Matrix of Practices Included in Scales for Adaptation and Mitigation

	1	2	3	4	5	6	7	8
1. Pest resistant crop varieties	1.000							
2. Drought tolerant crop varieties	0.219*	1.000						
3. Reduced tillage	0.050	0.060	1.000					
4. Increased N application	0.079	-0.023	-0.028	1.000				
5. Perennial vegetation use	0.106*	0.075	-0.129*	0.008	1.000			
6. No till	0.057	-0.000	-0.180*	0.072	0.213*	1.000		
7. Cover crops	-0.004	0.018	-0.055	0.021	0.348*	0.186*	1.000	
8. Variable rate nitrogen application	0.057	0.061	-0.034	0.110*	0.071	0.139*	0.080	1.000
								*p<0.05

APPENDIX B: Confirmatory Factor Analysis (Measurement Model) Results

Table 5: Factor Loadings for Latent Variables in SEMLV Model

Overall Model Fit	Chi-sq	p	CFI	RMSEA
Perceived vulnerability	1.558	0.459	1.000	0.000
Productivist orientation	1.447	0.229	0.999	0.031

Component Fit	Unstandardized Factor Loadings	R-squared
Perceived vulnerability		
Concern about impact on my farm: warmer temperatures (scaled)	1	0.546
Concern about impact on my farm: extreme weather events	1.260	0.797
Concern about impact on my farm: climate change	1.026	0.435
Concern about impact on my farm: floods	1.041	0.458
Concern about impact on my farm: droughts	1.144	0.666
Productivity orientation		
Importance to you: build up wealth and family assets	1	0.684
Importance to you: earn a high income	1.037	0.667
Importance to you: maximize farm/company profit	0.664	0.413
Importance to you: be among the best in the industry	0.649	0.247

Table 5 displays the results of the measurement model for perceived vulnerability to environmental issues and productivity orientation. Each construct was scaled to the first indicator in the model. The factor loadings listed in Table X denote the change in each indicator for a one-unit change in the factor. For example, an increase of one unit of perceived vulnerability to environmental issues corresponds with an increase of 1.260 in the score for concern about the impacts of extreme weather events. All R-squared values were sufficient to indicate that the indicators were good measures of the factors. All factor loadings are statistically significant.

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