

# Identifying Who Engages in Sustainable Adaptation in Large-Scale Commodity Agriculture

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## Research Article

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# Abstract

Global climate change is projected to negatively impact agriculture through increasingly severe weather. In the eastern Corn Belt of the United States, it is projected to get warmer and wetter overall, with more variability in the seasonal timing of rainfall. This will make it more difficult to get into the fields in the spring and fall due to wet conditions, while higher overall temperatures and decreased rainfall in the summer may limit crop growth. While there are multiple adaptations to reduce the vulnerability of agricultural production to a changing climate, these adaptations have varying implications for soil health, carbon sequestration and water quality. We explore the drivers of adaptations that vary in their provisioning of a variety of ecosystem services. We find that adaptation is driven in large part by self-reported past negative experiences with climate change that drive up concern about future climate change. Adaptation is also more likely among farmers that are younger, more educated, and more conservation minded, and who operate farms that are larger, more extensively insured, and will be passed on to a family member. However, increasing tile drainage will be the most common strategy in response to increased and more variable rainfall, indicating potential negative impacts for water quality. Practices that promote soil health and sequestration will be less common, and more driven by the identity of farmers as conservationists than by the weather. There will be a need to offset the potential negative impacts of increasing drainage through the promotion of edge-of-field filtration practices.

## 1. Introduction

Global climate change is projected to impact U.S. agriculture through increasingly severe weather events that will reduce crop yields and create challenges for livestock health (USGCRP, 2018). Recent analyses have suggested that the United States Corn Belt is already experiencing changing weather patterns and rainfall (Arrit, 2016). In the eastern Corn Belt, climate projections indicate that it will get warmer and wetter, but that the seasonal timing of the rainfall will become more variable (USGCRP 2017; Angel et al. 2018). Farmers may experience challenges with getting into the fields in the spring and fall due to wet conditions, while higher overall temperatures and decreased rainfall in the summer may limit crop growth and yield (Walthall et al., 2013; Challinor et al. 2014). While there are expected to be many challenges, there are also opportunities, such as the potential for double cropping as the growing season lengthens (Seifert and Lobell, 2015).

According to the IPCC, current commitments to climate mitigation are highly unlikely to limit warming to the 1.5 degrees Celsius target over pre-industrial levels. Increases above these levels will dramatically increase the necessity of adaptation strategies (IPCC, 2018). This suggests that we cannot rely on mitigation alone to reduce agricultural producers' exposure to climate impacts and must shift our focus to reducing their vulnerability to these impacts. There are a broad range of adaptation strategies available to farmers to protect their operations from the most severe impacts of climate change. These strategies might include making changes in crop types or inputs, implementing soil health or water-management practices, diversifying the farm operation to reduce reliance on crop yield for profit or changing one's crop insurance to better mitigate financial risk (Smit & Skinner, 2002; Howden et. al.,

2007). While each of these practices has the potential to reduce the vulnerability of the operation to a changing climate by ensuring continued agricultural production, they have varying implications for other important services provided by the agro-ecosystem such as climate mitigation through sequestration and the provisioning of drinkable water. For example, winter cover crops retain soil moisture and improve soil health, increasing resilience to climatic extremes in food production, while providing considerable other benefits like sequestering carbon and retaining nutrients (Kaye and Quemada 2017). On the other hand, increasing the amount of chemical inputs in a double cropping system could exacerbate water quality issues that stem from increased nutrient and pesticide runoff (Robertson and Saad 2011; 2013). Some have argued that the former list of practices can be considered truly adaptive, while the latter may be considered maladaptive (Wilson et al. 2020; Upadhaya and Arbuckle 2021).

These differences in the implications of farmer adaptations beyond the farm suggest that we need to know what influences the adoption of one set of strategies over another. Knowing more about not only who chooses to adapt to climate change and why, but also what adaptations they are likely to choose has profound implications for our ability to promote adaptation strategies that maximize benefits and reduce harms broadly defined. In this paper, we first review prior research examining farmer climate adaptation decisions, then introduce the present study, which uses a model derived from previous literature to differentiate between the factors that explain the general tendency to adapt and those that explain specific adaptations that have positive or negative externalities.

### 1.1 *Literature Review*

In a recent study of farmer adaptation decisions in the United States Corn Belt, Roesch McNally et al. (2017) examined farmer decisions to use cover crops, no-till and tile drainage. While both cover crops and no-till generally have positive consequences for overall environmental quality, increased tile drainage can have negative consequences by increasing nutrient runoff into local waterways (Randall & Goss, 2008). Roesch McNally et al. (2017) found that, in general, increased concern about weather variability and associated on-farm disruptions were associated with all three behaviors (e.g., concern about increased flooding and extreme rain was associated with more tile drainage, while concern about erosion was associated with more cover crops and no-till). Other research suggests that these risks are not perceived as new, but rather perceived as intensified by climate change (Schattman et al. 2016), as most farmers believe climate change is happening, they just tend to be skeptical about the anthropogenic cause (Haden et al. 2012; Arbuckle et al. 2013; Jemison et al. 2014; Chatrchyan et al. 2017). This idea that negative experiences with weather variability and concern about specific weather-related impacts is likely important for all adaptations regardless of their secondary consequences for society is supported by a wide range of farmer adaptation studies (see Haden et al. 2012; Arbuckle et al. 2015; Chatrchyan et al. 2017; Findlater et al. 2018; Upadhaya and Arbuckle 2021). However, there is evidence that perceptions of climate-related risk may be driven more by personal beliefs about climate change and ideology than by local experience (Marlon et al. 2018).

In line with this work about the relative impact of experience versus beliefs or ideology, Roesch McNally et al. (2017) also found that increasing uncertainty about the climate impacts was associated with different adaptations. Specifically, greater uncertainty about the reality of climate change was associated with less use of no-till farming practices and greater use of tile drainage. This finding about the role of uncertainty is consistent with many studies that indicate a belief in anthropogenic climate change can lead to increased support for adaptation (Arbuckle et al., 2013; Mase et al., 2017; Chatrchyan et al. 2017), while opposing beliefs can reduce adaptation (Gramig et al, 2013). The mechanism for this might be that those who are more certain that climate change is happening and caused by humans are then more concerned about future impacts on their own farm and for their community (Arbuckle et al., 2013; Niles and Mueller 2016; Mase et al., 2017; Safi et al., 2012). While these beliefs may be important, other work indicates that these beliefs may be more predictive of intentions than actual behavior (Niles et al. 2016). The authors note that this might be because farmers may run into issues of feasibility that prevent them from acting on their concern. In general, the literature does suggest that concerns about future conditions for agriculture are shaped, in part, by beliefs in anthropogenic climate change. Similarly, experiencing the effects of climate change can impact concern in different ways. For example a Midwest study showed that farmers who believed in anthropogenic climate change were more likely to notice the variable weather patterns of increased rainfall across the region (Mase et al., 2017). However, a study in Nevada showed that farmers and ranchers experiencing more severe drought than others did not identify these impacts, most likely due to the fact that continued and severe droughts, while getting worse, are already common in the region (Safi et al., 2012).

Taken together, prior literature suggests that negative experiences with climate change and concern about future weather-related challenges will increase intentions to adapt. Similarly, we expect future concern about these risks to increase if farmers see current climate variability as a signal of increasingly extreme future conditions, which they would be more likely to do if they believed that the climate was changing and that it was human caused. As a result, we pose the following research question and subsequent hypotheses.

RQ1: Does belief in anthropogenic climate change, negative climate experiences, and concern about future weather impact intentions to adapt to climate change?

H1.1: Concern about future weather conditions will impact mean inclinations to pursue a range of climate adaptation behaviors.

H1.2: Negative experiences with climate change (H1.2a) and belief in anthropogenic climate change (H1.2b) will have positive indirect effects on mean inclinations mediated through concern about future weather conditions.

H1.3: Concern about future weather conditions will have no significant effect on any specific adaptation behavior when controlling for mean inclinations.

It is also critical to understand what drives preferences for specific adaptation strategies that have distinct consequences for society more broadly. Here, we distinguish between intensification strategies that have potential environmental costs (e.g., potentially maladaptive practices like installing additional tile drainage or using additional fertilizer), conservation practices that have potential environmental benefits (e.g., potentially adaptive practices like cover crops or filter strips) and practices that involve leaving the profession of farming (e.g., renting out owned acreage). While all the practices have the potential to provide short-term benefits to the operation, they have profoundly different implications for the surrounding biophysical and social environment in the long-term. Intensification through more drainage and other inputs could further increase agriculture's impact on downstream water quality (Robertson and Saad 2011; 2013), while the continued loss of small farms as farmers rent out their acreage to larger operations could negatively impact dynamics in rural communities (Steele 1997). While we don't expect that one strategy would be more motivated by climate and weather concerns (in the aggregate) than another, intensification may be driven by a productivist identity, while conservation may be more driven by a conservation identity. In line with many studies from the private lands conservation literature, Roesch McNally et al. (2017) and Upadhaya and Arbuckle (2021) identified a role for a farmer's identity in shaping their adaptation choices. Using elements of the "good farmer" concept (Burton, 2004; McGuire et al. 2015); they showed that an identity oriented around stewardship was associated with the use of more adaptive (versus maladaptive) strategies, like cover crops. This is consistent with other literature that suggests that a conservation- or stewardship-oriented identity is associated with the adoption of a range of agricultural conservation behaviors (Greiner et. al., 2009; Reimer et. al., 2012). These results suggest that farmer identity has a key role to play in how adaptation decisions are made that have co-benefits for soil or water conservation more broadly. This would suggest that concern about future weather conditions may be channeled into different strategies depending on the identity of the individual farmer. As a result, we pose the following research question and subsequent hypotheses.

RQ2: Do different factors drive adaptations that involve varying positive or negative externalities?

H2.1: Conservation identity will be positively associated with intentions to engage in behaviors that have positive externalities including the use of cover crops (H2.1a) and filter strips (H2.1b), and negatively associated with intentions to engage in behaviors that have negative externalities including installing additional tile drainage (H2.1c), using additional fertilizer (H2.1d) and renting out the farm (H2.1e).

H2.2: Productivist identity will be positively associated with intentions to engage in behaviors that have negative externalities including installing additional tile drainage (H2.2a) and using additional fertilizer (H2.2b), and negatively associated with intentions to engage in behaviors that have positive externalities including the use of cover crops (H2.2c), the use of filter strips (H2.2d) and renting out the farm (H2.2e).

## **2. Material And Methods**

### **2.1 Study Area**

This study was conducted in the eastern Corn Belt region (ECBR). The population of interest was corn and soybean farmers in five target watersheds distributed along multiple land cover gradients in the five states (Fig. 1). The research instrument was a mailed survey, finalized and administered between August and October 2019. Contact information for potential respondents was obtained from the company Farm Market ID, and potential respondents were stratified by farm size within each of the five target watersheds. Survey implementation followed the Tailored Design Method (Dillman et al, 2009) with two waves of surveys sent and three waves of reminders. After filtering out invalid contacts there were 3452 farmers contacted and 918 returned usable surveys for an adjusted response rate of 27%.

## 2.2 Measurement

We measured *experience with climate change* from a bank of items assessing the past negative impacts of “changing weather patterns”. We used the language of “changing weather patterns” because we felt that the term climate change might be too politically charged. Participants were asked the extent to which they agreed or disagreed with six statements describing the potential positive or negative impacts on a scale from - 2 strongly disagree to 2 strongly agree (e.g., the amount of annual rainfall is more variable than when I began farming; see Online Resource 1 for the full list). We took the mean response of these 6 items to serve as our measure of *experience with climate change*. The reliability of all measures was assessed using Cronbach’s alpha where an alpha of .7 was considered acceptable (Gliem and Gliem 2003).

We measured *future weather concern* with a series of 8 items asking participants to identify their level of concern about the potential future impacts from changing weather patterns on a scale from 0 (not at all concerned) to 4 (very concerned) (e.g., more frequent rain events, fewer days for planting; see Online Resource 1 for the full list). We took the mean response of these 8 items to serve as our measure of *future weather concern*.

We measured *anthropogenic climate change (ACC) belief* using the single item “Which of the following statements about a changing climate comes closest to your view?” The response options were: 1) the climate is not changing, 2) the climate is changing, and it is mostly caused by natural changes in the environment, 3) the climate is changing, and it is mostly caused by human activities, and 4) unsure. To create a binary measure of ACC belief, we gave a code of zero or “no” to responses 1, 2, and 4, and a code of one or “yes” to response 3.

We measured *conservation* and *productivist identity* using a scale created by Arbuckle (2013) and McGuire et al (2015). The items are made up of a series of traits that constitute a “good farmer”. The traits are designed to reflect either an identity oriented around production (e.g., a good farmer is one who has the highest profit per acre) or an identity oriented around conservation (e.g., a good farmer is one who minimizes nutrient runoff into waterways). We took the mean response for the items associated with each identity to derive a score for each on a scale from 0 (not important at all) to 4 (very important) (see Online Resource 1 for the full list).

Our dependent variables come from responses to items about a set of 19 adaptation behaviors (see Online Resource 2 for the full list). Participants were asked to indicate if they had completed any of the 19 behaviors to adapt to changing weather conditions with a simple check box (yes/no). They were then asked to indicate their intentions to engage in those behaviors in the next 10 years to minimize the expected impacts from changing weather conditions on a scale from 0 to 4 (where 0 = not likely at all, 1 = not likely, 2 = somewhat likely, 3 = likely and 4 = very likely). Because many participants who had completed a behavior skipped the future intentions item, we combined the two measures such that participants received a score of 0–5 that reflected their stated intentions (0–4) unless they indicated that they had already completed the behavior in which case they received a score of 5. For each behavior of primary interest (i.e., cover crops, filter strips, additional drainage tile, additional fertilizer and renting out the farm), we used this *adaptation inclination* score as the key dependent variable and included the mean score on the other 18 behaviors as a control. To maintain as many responses as possible, this mean was taken if we had data for at least 2 other behaviors.

For all analyses we included a series of farm and farmer characteristics as covariates. These included age (in years), highest education level achieved (some high school to advanced degree), planned succession of the farm to a family member (binary), total farm size (in 100 acre increments), percentage of income derived from off-farm sources (in 25% increments), level of insurance coverage on the majority of the farmer's land (50–85% in 5% increments), and the amount of acreage predominantly made up of sandy soil, loam, and clay soil (in 100 acre increments). We also included the farmer's location, in the form of 4 dummy-coded variables representing each of 4 watersheds (Sugar, Maple, Macoupin and Upper Fox) and an arbitrarily chosen reference watershed (Lower Maumee).

## 2.3 Analysis

We used the lavaan package (Rosseel, 2012) in the statistical analysis program R ver. 4.0.5 (R Core Team, 2021) to analyze our data using a series of 5 path models. We chose to use path models so that we could simultaneously model mean adaptation inclination as well as the adaptation inclination for a particular behavior. By controlling for the mean adaptation inclination for all the other behaviors in the model of each focal behavior, we can highlight not only what factors drive adaptation in general, but also what factors distinctly motivate choosing one adaptation strategy over another.

The initial run of the model showed reasonable fit ( $\chi^2(15) = 69.985, p < 0.0005, CFI = 0.939, RMSEA = 0.069, p = 0.025 [0.053–0.086]$ ). Examining the modification indices identified few theoretically consistent ways to improve the model apart from the inclusion of pathways from identity to concern about future weather conditions. Given that a substantial body of research has suggested that many relevant attitudes and beliefs are shaped by important social identities including responses to hazards or threats (Dake 1991; Kahan et al. 2011), it is plausible to assume that being invested in a particular identity would shape associated concern about changes in future weather conditions. As a result, we modified the model to include these pathways (Fig. 2). For each model, all the variables were used as predictors of both adaptation inclination for the specific behavior in question but also the mean inclination for the other 18 behaviors.

### 3. Results

The effects of the modeled variables on each focal strategy (Table 1), and the indirect and total effects of negative experiences with climate change and belief in anthropogenic climate change (Table 2) are presented below for easy comparison between models. Because the only difference between the models is the primary dependent adaptation, and the model includes a relationship between every variable and that adaptation, the fit statistics for each model are nearly identical. Fit statistics are provided for each model as they vary slightly due to small amounts of missing data leading to the inclusion of a small number of cases in some analyses and not others. All coefficients are presented fully standardized.

#### 3.1 Mean adaptation inclination results

While the coefficients for the pathways predicting mean adaptation inclination are slightly different across all 5 models due to the focal behavior not being included in the mean inclination metric, they are very similar to one another. As a result, we just present the model used as a control for cover crops as it is archetypical of the other models (Fig. 3). This model includes, but does not show, pathways from all variables to cover crop intentions.

Overall the model fits extremely well ( $X^2(13) = 14.401$ ,  $p = 0.346$ ; RMSEA = 0.012,  $p = 0.941$  [0.000-0.039], CFI = 0.998,  $n = 767$ ). The coefficients for the pathways suggest that both *experience with climate change* and *anthropogenic climate belief* are positively associated with concern about future weather conditions. Consistent with hypothesis 1.1, the pathway from weather concern to mean adaptation inclination is positive and significant. Consistent with hypothesis 1.2, the indirect effect of both *experience with climate change* and *anthropogenic climate belief* are positive and significant. This suggests that mean adaptation inclination is a function of concern about future weather conditions, and that the impact of negative experiences and climate beliefs on concern carries through in creating mean adaptation inclinations. With respect to Hypothesis 1.2 it is worth noting that the total effect of belief in anthropogenic climate change is not significant. This suggests that while we can trace the impact of belief in anthropogenic climate change on mean adaptation inclination through its positive impact on concern, it is also having a negative impact through some other unobserved mechanism, rendering the overall effect essentially 0. Further, it is also worth noting that there is a positive, significant direct effect of negative experience with climate change on mean adaptation inclination. This suggests that concern about future weather events is not entirely sufficient to explain the impact of negative experiences from climate change on intentions to adapt. As such, while we have some support for hypothesis 1.2, it is tempered by these additional findings.

We also see positive effects from conservation identity ( $B = 0.159$ ,  $p < 0.0005$ ), education ( $B = 0.162$ ,  $p < 0.0005$ ), planned succession to a family member ( $B = 0.062$ ,  $p < 0.05$ ), farm size ( $B = 0.251$ ,  $p < 0.0005$ ), and extent of insurance coverage ( $B = 0.127$ ,  $p < 0.0005$ ), as well a negative effect of age ( $B = -0.151$ ,  $p < 0.0005$ ). This suggests that, in general, younger, more educated farmers with stronger conservation

identities and larger, more extensively insured farms that they plan to pass on to a family member, tend to have stronger adaptation inclinations when considering all the adaptations together.

## 3.2 Specific adaptation inclination results

For all subsequent models in this section, the coefficients for the relationships predicting weather concern will be identical. However, because the impact of concern about future weather conditions has different impacts on each specific adaptation inclination, the coefficients for the direct and total effects of both negative experiences with climate change and belief that climate change in human caused will be different between models. Also note that the total effects for experience with climate change and anthropogenic climate belief do not include the effect that these variables have through mean adaptation inclination. This portion of the total effect was omitted to highlight when the climate and weather variables have an impact on a specific adaptation inclination that cannot be accounted for by its impact on mean inclinations.

*Cover crops.* The model fit statistics show excellent fit and were provided previously. As noted earlier, while the model of cover crop adaptation inclination (Fig. 4a) includes pathways from all the other variables to the mean adaptation inclination, they are not shown in this figure (for reference to the values of those pathways see Fig. 3 above). In contrast to the pathways predicting mean adaptation inclination, here we see no significant impact of the weather and climate beliefs or demographics on the inclination to use cover crops, partially supporting hypothesis 1.3. Rather, it is the identity variables that appear to distinguish cover crops from the other adaptations. Specifically, we see a strong positive effect of conservation identity ( $B = 0.274$ ,  $p < 0.0005$ ), supporting hypothesis 2.1a. Similarly, we see a strong negative effect of productivist identity ( $B = -0.152$ ,  $p < 0.01$ ), supporting hypothesis 2.2c. In addition, we see a further negative effect of age ( $B = -0.103$ ,  $p < 0.01$ ) beyond the influence that age exerts on adaptation in general. Finally, we see significant negative effects for the Sugar ( $B = -0.161$ ,  $p < 0.0005$ ), Macoupin ( $B = -0.194$ ,  $p < 0.0005$ ) and Upper Fox ( $B = -0.177$ ,  $p < 0.0005$ ). This model suggests that, on average, a farmer is more likely to choose cover crops as an adaptation strategy if they identify more strongly as a conservationist and less strongly as a productivist, if they are younger, and if they live in the Lower Maumee (reflecting something unique about that local context).

*Filter strips.* In the model explaining the inclination to use filter strips (Fig. 4b), the fit remains excellent ( $\chi^2(13) = 15.120$ ,  $p = 0.300$ ; RMSEA = 0.015,  $p = 0.993$  [0.000-0.040], CFI = 0.998,  $n = 0.767$ ). The significant pathways broadly mirror the relationships observed in the model of cover crops, with the identity variables carrying most of the influence beyond the impact of the mean adaptation inclination. Specifically, both conservation identity ( $B = 0.225$ ,  $p < 0.0005$ ) and productivist identity ( $B = -0.098$ ,  $p < 0.01$ ) significantly impact inclinations to use filter strips, supporting hypothesis 2.1b and 2.2d. There are also no significant effects of the climate and weather beliefs beyond the influence on mean adaptation inclinations, further supporting hypothesis H1.3. We also see a significant positive effect of succession ( $B = 0.063$ ,  $p < 0.05$ ). However, unlike cover crops, we see a significant negative effect of education ( $b = -0.069$ ,  $p < 0.05$ ). Finally, we see significant effects for all the watershed variables suggesting that those in the Sugar ( $B = -0.133$ ,  $p < 0.0005$ ), Maple ( $B = -0.079$ ,  $p < 0.05$ ), Macoupin ( $B = -0.118$ ,  $p < 0.0005$ ) and

Upper Fox ( $B=-0.188$ ,  $p < 0.0005$ ) are all less inclined than those in the Lower Maumee to install filter strips as a form of adaptation. This model suggests that, on average, a farmer is more likely to choose filter strips as an adaptation strategy if they identify more strongly as a conservationist and less strongly as a productivist, if they are less educated, if they plan on passing their farm on to someone in their family when they retire, and if they live in the Lower Maumee (reflecting something unique about that local context).

*Using additional fertilizer.* In the model explaining the inclination to use additional fertilizer (Fig. 5), the fit remains excellent ( $\chi^2(13) = 15.029$ ,  $p = 0.306$ ; RMSEA = 0.014,  $p = 0.994$  [0.000-0.040], CFI = 0.998,  $n = 767$ ). Similar to the previous models, we see significant effects from the identity variables and not from the climate and weather beliefs, only in this instance, the signs are reversed with a positive effect from productivist identity ( $B = 0.161$ ,  $p < 0.0005$ ) and a negative effect of conservation identity ( $B=-0.176$ ,  $p < 0.0005$ ), supporting hypotheses 1.3, 2.1d and 2.2b. We also see a significant positive effect for age ( $B = 0.076$ ,  $p < 0.05$ ) and a marginal positive effect for farm size ( $B = 0.068$ ,  $p < 0.01$ ) and off-farm income ( $B = 0.068$ ,  $p < 0.01$ ). We also see significant negative effects for the number of acres in predominantly loam soil ( $B = 0.101$ ,  $p < 0.05$ ) and the extent of insurance coverage ( $B=-0.091$ ,  $p < 0.05$ ). Finally, we see significant positive effects of all 4 watershed variables suggesting that those in the Sugar ( $B = 0.228$ ,  $p < 0.0005$ ), Maple ( $B = 0.197$ ,  $p < 0.0005$ ), Macoupin ( $B = 0.265$ ,  $p < 0.005$ ) and Upper Fox ( $B = 0.236$ ,  $p < 0.0005$ ) watersheds are all more likely to use additional fertilizer than the Lower Maumee. This model suggests that, on average, a farmer is more likely to choose additional fertilizer as an adaptation strategy if they identify more strongly as a productivist and less strongly as a conservationist, are older, have larger farms, have off-farm income, have less acres in loam soil, have less insurance coverage and do not live in the Lower Maumee (reflecting something unique about that local context).

*Installing additional tile drainage.* In the model explaining the inclination to install additional tile drainage (Fig. 5), the fit remains excellent ( $\chi^2(13) = 15.552$ ,  $p = 0.274$ ; RMSEA = 0.016,  $p = 0.992$ , CFI = 0.997,  $n = 770$ ). In contrast to the previous models, for tile drainage we see no significant effect of identity (failing to support H2.1c and H2.2a, though there are small positive indirect effects of both through weather concern). However, we do see a significant effect of weather concern ( $B = 0.108$ ,  $p < 0.01$ ) on inclination to install additional tile drainage beyond the impact of mean adaptation inclinations (failing to support H1.3). We also see significant indirect effects of both negative experience with climate change ( $B = 0.061$ ,  $p < 0.05$ ) and belief in anthropogenic climate change ( $B = 0.012$ ,  $p < 0.05$ ), though neither total effect is significant suggesting that both beliefs may also be contributing to reducing intentions through an unobserved mechanism. We also see significant negative effects of age ( $B=-0.086$ ,  $p < 0.05$ ) and the proportion of income derived from off-farm sources ( $B=-0.063$ ,  $p < 0.01$ ), as well as a positive effect of farm size ( $B = 0.128$ ,  $p < 0.05$ ). Finally, we see significant negative effects for the Macoupin ( $B=-0.175$ ,  $p < 0.0005$ ) and Upper Fox ( $B = 0.150$ ,  $p < 0.0005$ ) watersheds. This model suggests that, on average, a farmer is more likely to choose tile drainage as an adaptation strategy if they have greater concern about future weather conditions (driven by beliefs in climate change and past negative experiences), larger

farms, and when they are younger, have less off-farm income, and live in the Lower Maumee (versus the Macoupin or Upper Fox).

*Renting out the farm.* In the model explaining the inclination to rent out the farm (Fig. 6), the fit remains excellent ( $X^2(13) = 15.872$ ,  $p = 0.256$ ; RMSEA = 0.017,  $p = 0.991$  [0.000-0.042], CFI = 0.997,  $n = 764$ ). Here we see the weakest effect of mean adaptation inclination ( $B = 0.181$ ,  $p < 0.001$ ) suggesting that renting out the farm may be the most dissimilar to the other adaptations. We do not see a significant effect of concern or identity, supporting H1.3, but failing to support H2.1e or H2.2e. We do see a significant positive effect of age ( $B = 0.254$ ,  $p < 0.001$ ) and belief in anthropogenic climate change ( $B = 0.083$ ,  $p < 0.05$ ), as well as negative effects of succession ( $B = -0.135$ ,  $p < 0.001$ ), farm size ( $B = -0.143$ ,  $p < 0.001$ ) and the extent of insurance coverage ( $B = -0.104$ ,  $p < 0.01$ ). We also see significant positive effects for the Sugar ( $B = 0.134$ ,  $p < 0.001$ ) and Maple ( $B = 0.150$ ,  $p < 0.001$ ) watersheds. This model suggests that, on average, a farmer is more likely to rent out the farm as an adaptation strategy when they are older, believe in anthropogenic climate change, do not have a succession plan, and live in the Sugar or Maple.

## 4. Discussion

In this paper, we examined the differential impact of concerns about climate and weather related impacts versus farmer identity on adaptation inclinations. We also identified the extent to which these drivers of adaptation are unique to a particular adaptation strategy, or just a reflection of a general tendency to adapt. We find that adaptation in general is driven in large part by self-reported past negative experiences with climate change (e.g., heavy rain in the spring that delays planting), and that these experiences drive up concern about future climate change, and in turn, increase the tendency to adapt. This finding is consistent with prior work that finds that increased experience with and concern about weather events increases multiple adaptations from those that have co-benefits to society and the environment at-large (e.g., cover crops) to those that do not have benefits beyond short-term crop production (e.g., tile drainage) (Haden et al. 2012; Arbuckle et al. 2015; Chatrchyan et al. 2017; Roesch McNally et al., 2017; Findlater et al. 2018; Upadhaya and Arbuckle 2021).

We also find that adaptation is generally more likely among younger, more educated farmers with stronger conservation identities and larger, more extensively insured farms that will be passed on to a family member. There are several interesting points to note here. One, there is significant overlap between what explains future adaptation inclinations and what is generally identified as drivers of conservation in agriculture. For example, we often see that conservation is more likely among younger, more educated farmers with strong conservation identities, who operate larger farms (Prokopy et al. 2008; Baumgart-Getz et al. 2012). The overlap may be because several of the recommended adaptations (and those we measured in this study) are already promoted as beneficial conservation practices (e.g., cover crops, limited tillage, buffers). As a result, those interested in these practices for adaptation purposes, may be like those interested in these practices for conservation purposes more generally. It might also be that individuals who have the capacity to engage in conservation are the same as those who have the capacity to adapt (e.g., larger farms with more resources, or more educated farmers who better

understand the problem and the potential solutions). When looking at studies conducted with farmers in South Africa, larger farms and smaller farms were equally concerned and aware of the climate and weather challenges, but the lower adaptive capacity of the small-scale farms decreased their adaptation frequency (Wilk et al., 2013). Small-scale farms also tended to focus more on the immediate impacts than the longer term climate driven impacts focused on by large-scale farms (Findlater et al., 2019). Larger farms may also be more likely to adapt due to the greater personal investment made in their farms (Jin et al. 2020) or because they feel more susceptible to loss (Jemison et al. 2014). In terms of education, Jin et al. (2020) also found that higher levels of education among farmers in China was associated with greater adaptation. While a study in Indiana showed that farmers with higher education levels (and larger farms) were less likely to believe that climate change was real, and as a result were less concerned about the potential impacts and less likely to adapt (Gramig et al., 2013). These results point to the potential complexity of the adaptation decision process and the importance of context-specific studies that account for why a particular decision is being made.

Two, prior research has noted that federally subsidized crop insurance might “crowd-out” other adaptations (Chatrchyan et al. 2017) or promote more maladaptive actions (Upadhaya and Arbuckle 2021). In other words, that having insurance might be considered a sufficient adaptation, without having to change one’s land management practices. However, we do not see evidence of this issue here with our measure of the degree of one’s insurance coverage, indicating that having greater coverage may just be viewed as one of several necessary adaptations (or the adaptation necessary to cover the worse-case weather challenges). One explanation for these differences might be that prior studies often focus on having insurance versus or beliefs about the sufficiency of crop insurance to manage risk versus the degree of coverage.

Three, contrary to prior studies (Upadhaya and Arbuckle 2021), we see some evidence of legacy effects promoting adaptation, or the idea that thinking about one’s legacy may increase the tendency to engage in more sustainable behaviors (Zaval et al. 2015; Wickersham et al. 2020). Specifically, the human tendency is to place less value on future outcomes than those occurring today (Frederick et al., 2002). This discounting of the future has important consequences for decisions that involve costs and benefits that accrue over time, such as those common in climate adaptation. In some cases individuals’ discount rates can run so high that the future benefits of acting today are worth practically nothing in the present (Frederick et al., 2002; Wade-Benzoni, 2002; Van Lange et al., 2013). Private landowners often hold discount rates that range from 28–43%, and these higher discount rates are more common among the late versus early adopters and cited as a reason for the failure to engage in conservation (Duquette et al., 2012). However, we see evidence that farmers who know they will pass their operation on to a family member are more likely to adapt, and to adapt in more adaptive vs. maladaptive ways, perhaps a reflection of lower discount rates for the future or a tendency to be more future-oriented when considering one’s legacy.

When looking at what differentiates one specific adaptation from another, most of the difference seems to come from the influence (or lack thereof) of identity. Specifically, we see that conservation identity is a

strong positive driver of adaptive strategies or those that have co-benefits to society beyond food production (e.g., cover crops and filter strips), while it is a strong negative driver of those maladaptive strategies that may have negative impacts on society at-large (e.g., increased use of fertilizer). This is again, consistent with recent work finding a strong positive effect of identity on conservation related behavior (Cullen et al. 2020; Lavoie and Wardropper 2021; Upadhaya et al. 2021). What is perhaps more interesting, is that identity is not a driver of decisions to install more tile drainage or to rent out the farm as an adaptation strategy. The decision process for these adaptations is very different, driven to some degree by experienced impacts of climate change and future concern about the weather (for tile drainage), but also by specific characteristics of the farmer and their operation (for renting out the farm). Specifically, increasing tile drainage is more likely among younger farmers with larger farms and less off-farm income who are more concerned about future weather impacts. Too much rain at the wrong time of year is one of the most experienced impact in this region (USGCRP 2017; Angel et al. 2018), and this survey data was collected in 2019 in a year when many farmers never even managed to get their crops planted due to spring rains (Congressional Research Service 2020). It is perhaps not surprising that this practice is both the most likely to be driven by weather and climate related concerns, but also to be more common among farmers with larger operations who plan to be farming for many years to come.

The decision to rent out the farm is, as mentioned previously, not driven by identity, but also not tied to specific negative experiences or concern about future weather. Instead, this is a strategy chosen by older farmers with smaller farms and no succession plan, perhaps reflecting the general trend in agriculture of consolidation as farmers retire and rent out their land leading to an overall decrease in the number of farms while the average farm size continues to increase (NASS 2020). There is a perhaps surprising effect of belief in anthropogenic climate change on the decision to rent out the farm, where those with stronger climate beliefs are more likely to rent out their farm. Only 26% of our sample believe that the climate is changing due to human activities (Taber et al. 2020), a number that is significantly lower than national averages ranging from 50 to 71% (Motta et al. 2019). As a result, it may be that there is something unique about this group that makes them more likely to rent out their land when they retire. While very few studies have tried to explain what type of farmer believes in anthropogenic climate change, there is some evidence that this belief is more common among women and those identifying as a democrat in the United States (Chatrchyan et al. 2017), as well as those with greater trust in environmental organizations (Arbuckle et al. 2015). We see some evidence in our data that beliefs in anthropogenic climate change are higher among those who are more conservation minded in their identity, who are older, and who do not have a succession plan (see Online Resource 3 for a full correlation matrix of all the variables in the analysis). We expect there may be an indirect effect we are not accounting for here where age and not having a succession plan is increasing the tendency to rent out acreage partially through beliefs about climate change.

## 5. Conclusions

As we think about engaging farmers in adaptation to promote sustainability and resilience in the agroecosystem, these results highlight a few critical points. To begin, increasing tile drainage is likely to

be an increasingly common strategy to adapt to the particular challenge of large rain events in the spring and fall when farmers need to be in the field. Beyond growing more resilient varieties of crops already grown, which 55% of our sample report doing already as an adaptation strategy, installing more drainage tile was the most popular future adaptation (Taber et al. 2020). Not only was this the strategy of greatest interest, but given it is most common with reported negative experiences and among larger farms, we might expect it to become even more popular as the negative experience of climate increases (USGCRP 2017; Angel et al. 2018) and farms continue to consolidate and grow (NASS 2020). While this strategy deals with the near-term challenge of wet fields at the wrong time of year, it also has perhaps the greatest negative implications for downstream water quality given the impact of subsurface tile drainage on nutrient export (Williams et al. 2015). While we are not suggesting we try to discourage this adaptation, as it might be critical to short-term crop production, we are suggesting that greater attention be given to offsetting the impact of this practice on water quality. For example, we may need to increase edge-of-field filtration practices (e.g., wetlands, saturated buffers), so that the potentially even larger sub-surface flows can be held back and nutrients removed before that water enters local streams and rivers. This reality is already known among those focused on mitigating the impacts of climate and current land management on water quality (Scavia et al. 2017) but could be further exacerbated by farmer adaptation decisions.

While the decision to install more tile is not governed by conservation motives, the use of edge of field practices are, and we can leverage the strong conservation identity that we find among most farmers in this region to pair their tile drained systems with practices aimed at protecting local water quality. Pairing drainage with green infrastructure projects such as wetlands or grassed ditches can be accomplished by a multitude of means from encouraging installers to highlight the benefits of the additional structures when they install tile, to including messages leveraging the high visibility of edge-of-field conservation practices as a way to signal environmental responsibility to landowners, customers and local regulators. Specific strategies may vary in their viability across communities or individual farmers. However, these data suggest that such strategies will be critical to promoting more sustainable long-term environmental outcomes.

Finally, we would be remiss if we did not point out that this population is only somewhat concerned about changing weather patterns (on average), and only somewhat likely to engage in the most popular adaptations in the future (Taber et al. 2020). As a result, there is still a clear need to frame the need for action in terms of past, current and future extreme weather in the farmer's locale, and the potential for even greater variability (Chatrchyan et al. 2017). We know these experiences and concerns can drive action, but they may not be salient enough yet among farmers to motivate the majority. While beliefs in anthropogenic climate change and the scientific consensus are weaker among this population compared to the general public (Leiserowitz et al. 2020), 76% of our sample believe the climate is changing which is on par with general public beliefs in the United States. Farmers in the eastern Corn Belt do not need to be convinced the climate is changing in order to adapt, but they do need to be made more aware of how their recent experiences with inundating rain and variability are more likely to occur in the future, and how these impacts will affect their livelihood.

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## Tables

*Table 1: Summary of the effects of modeled variables on mean adaptation inclinations as well as each individual behavior of interest where  $t=p<0.10$ ,  $*=p<0.05$ ,  $**=p<0.01$ , and  $***=p<0.001$ . ‡ pathways are included in each model to control for general adaptation inclination but not shown in model figures.*

	Other Intent‡	Cover crops	Filter strips	Fertilizer	Tile drainage	Rent out farm
Other Intent	-	0.265***	0.371***	0.379***	0.373***	0.181***
Concern	0.094*	0.034	-0.020	0.022	0.108**	0.002
Belief	0.020	0.010	-0.023	-0.007	-0.021	0.083*
Experience	0.085*	0.018	0.013	0.068	-0.076†	0.009
Cons ID	0.160***	0.274***	0.225***	-0.176***	-0.012	-0.002
Prod ID	0.048	-0.152***	-0.098**	0.161***	0.030	-0.003
Age	-0.148***	-0.103**	0.024	0.076*	-0.086*	0.254***
Educ	0.164***	0.040	-0.069*	-0.022	0.035	0.028
Succession	0.060†	0.060†	0.063*	0.007	0.013	-0.143***
Farm Size	0.258***	0.022	0.001	0.091†	0.128*	-0.143**
OF Income	0.065†	-0.026	-0.019	0.068†	-0.078*	-0.034
Ins Cyge	0.123***	0.036	0.010	-0.091**	0.049	-0.104**
Sandy Soil	-0.009	-0.025	-0.036	0.017	-0.056†	0.035
Loam Soil	-0.026	0.045	0.025	-0.101*	0.050	0.032
Clay Soil	0.002	-0.027	-0.002	-0.082†	-0.019	0.060
Sugar	-0.009	-0.160***	-0.133***	0.228***	-0.065†	0.134***
Maple	-0.061†	-0.031	-0.079*	0.197***	0.030	0.150***
Macoupin	-0.033	-0.194***	-0.118**	0.265***	-0.174***	0.074†
Upper Fox	-0.048	-0.117***	-0.188***	0.236***	-0.150***	-0.007

Table 2: Summary of the indirect and total effects of negative experiences with climate change, belief in anthropogenic climate change, and identity across the models where †=p<0.10, \*=p<0.05, \*\*=p<0.01, and \*\*\*=p<0.001. ‡ pathways are included in each model to control for general adaptation inclination but not shown in model figures.

		Other intent‡	Cover crops	Filter strips	Fertilizer	Tile Drainage	Rent out farm
Belief	Ind.	0.011*	0.004	-0.002	0.002	0.012*	0.000
	Tot.	0.030	0.014	-0.025	-0.004	-0.009	0.083*
Experience	Ind.	0.054*	0.019	-0.011	0.012	0.061*	0.001
	Tot.	0.139***	0.037	0.002	0.081*	-0.015	0.011
Cons ID	Ind.	0.016*	0.006	-0.003	0.004	0.018*	0.000
	Tot.	0.176***	0.279***	0.222***	-0.172***	0.006	-0.001
Prod ID	Ind.	0.007†	0.003	-0.001	0.002	0.008†	0.000
	Tot.	0.055	-0.149***	-0.100**	0.163***	0.037	-0.002

## Figures

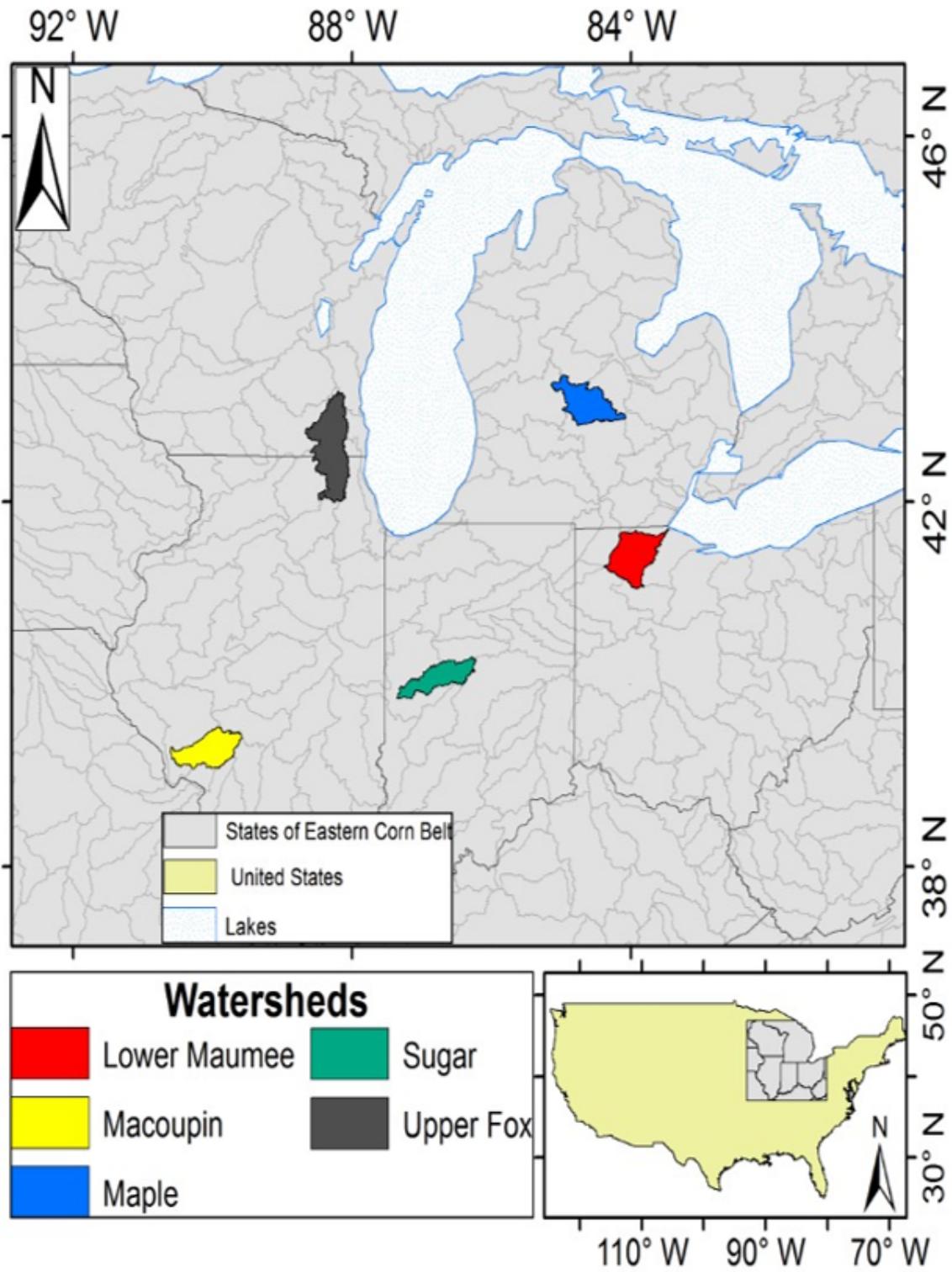
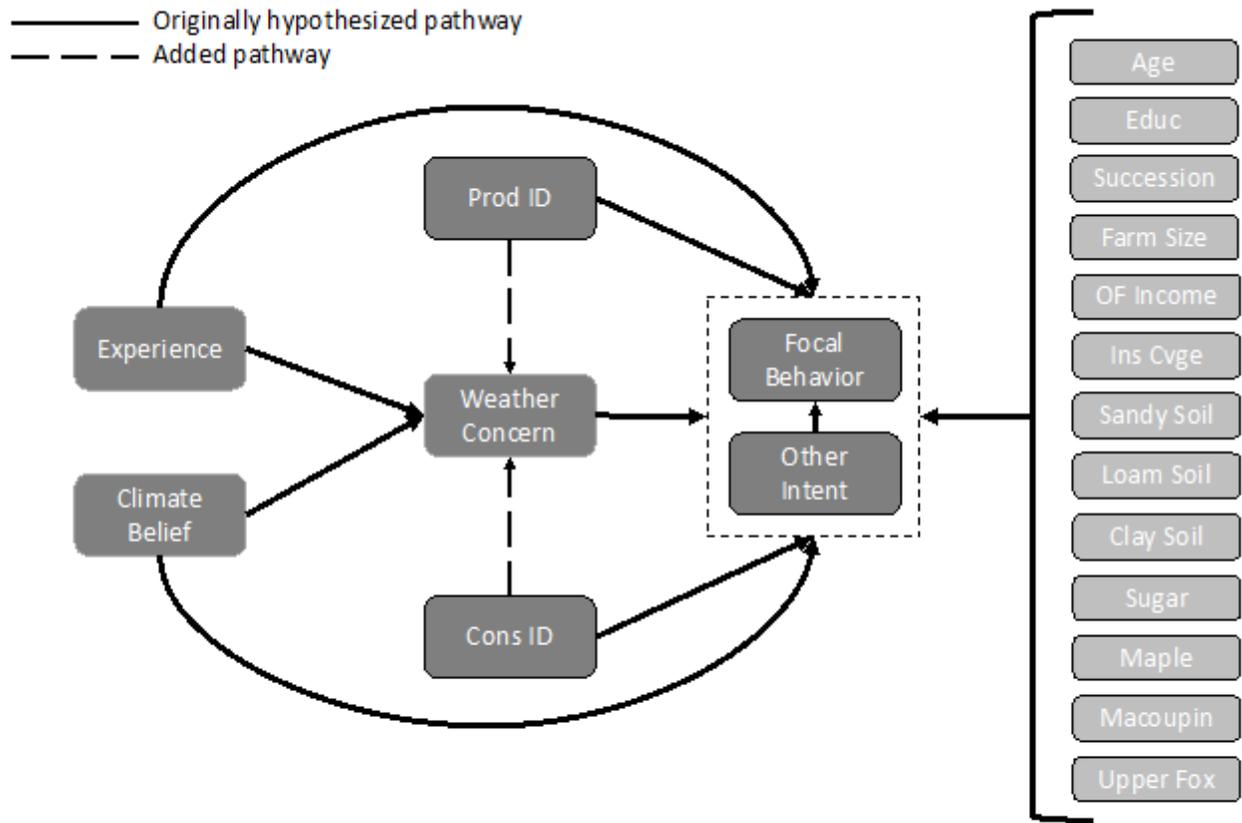


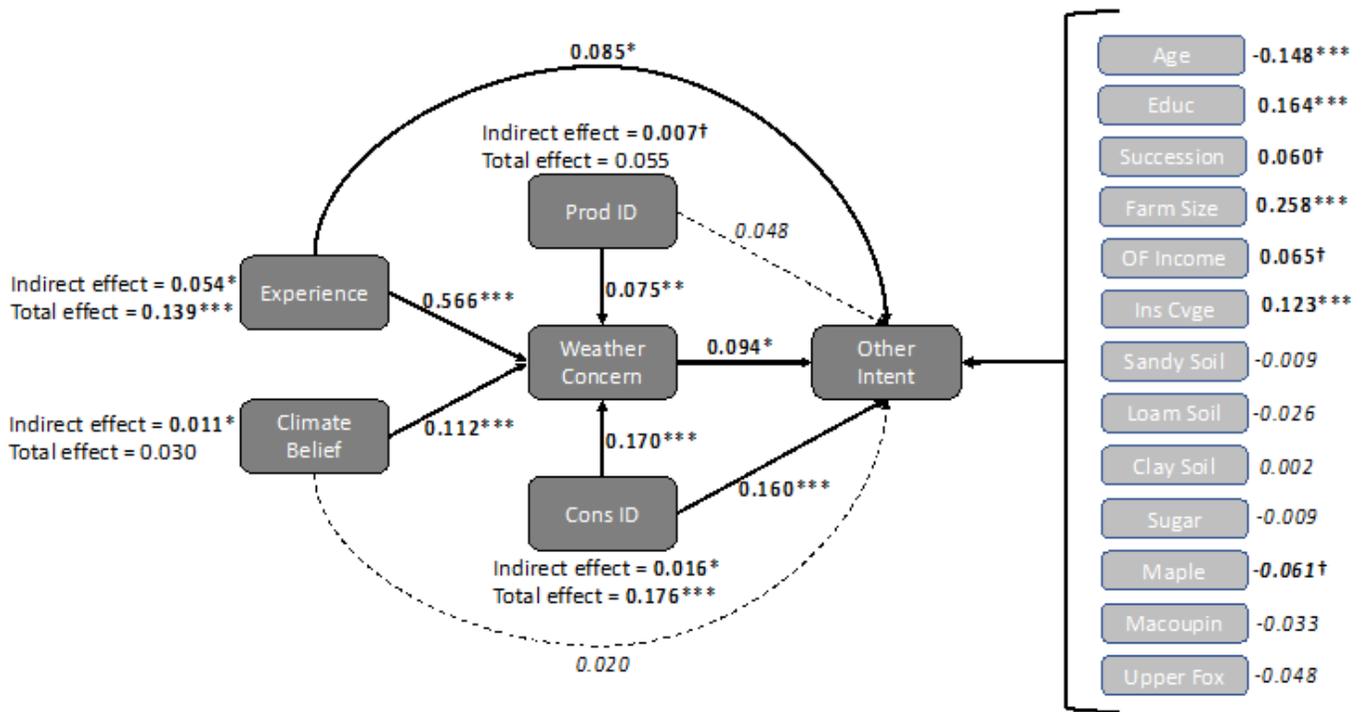
Figure 1

Eastern Corn Belt region and selected watersheds for sampling



**Figure 2**

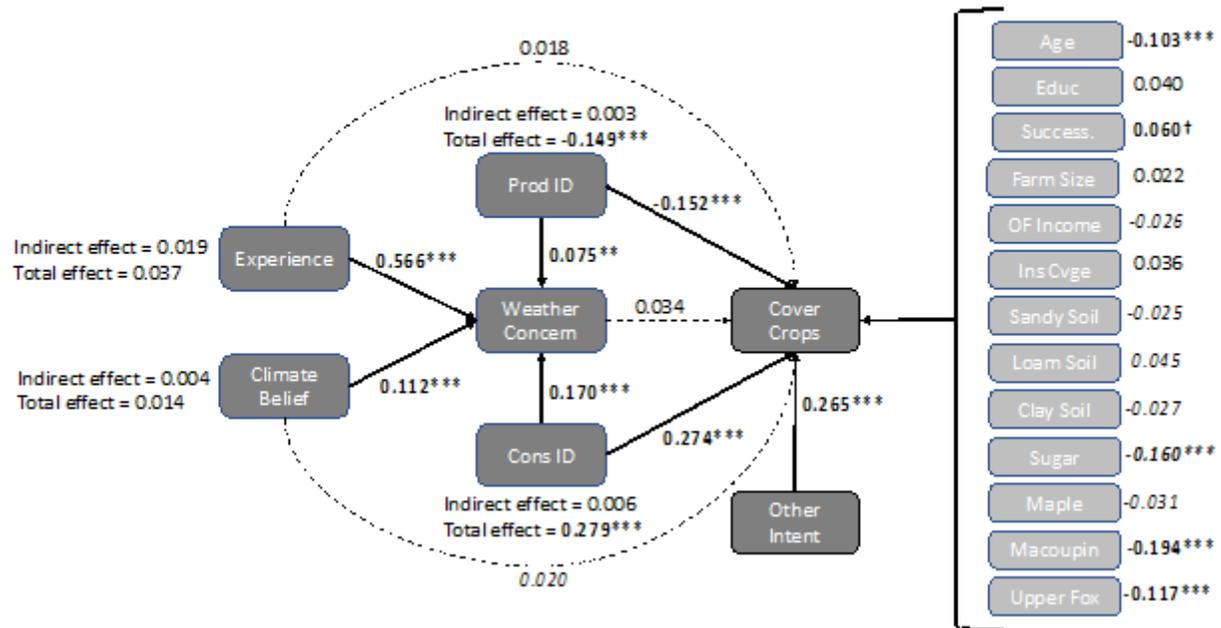
Proposed path diagram where previous negative experience with climate impacts and anthropogenic climate beliefs increase one’s concern about future weather and as a result, one’s adaptation inclination, while farmer identity influences adaptation inclinations directly and through future weather concern (controlling for a set of farm and farmer characteristics)



**Figure 3**

Path diagram predicting mean adaptation inclination (excluding cover crops) where †=p<0.10, \*=p<0.05, \*\*=p<0.01, and \*\*\*=p<0.001

a)



b)

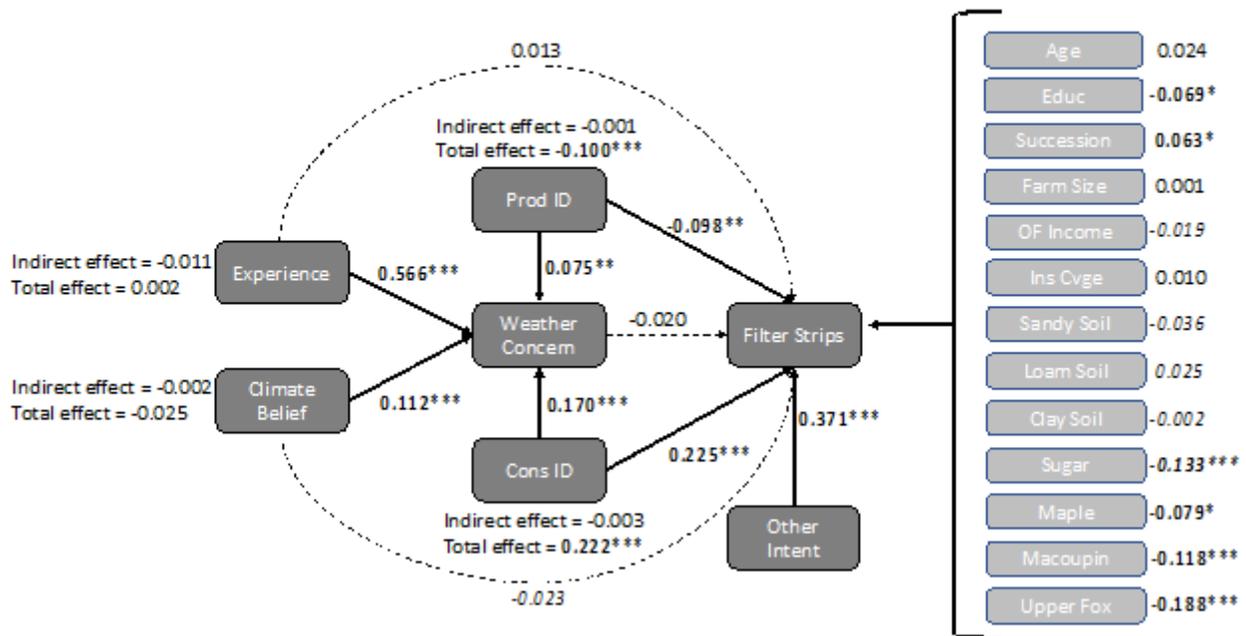
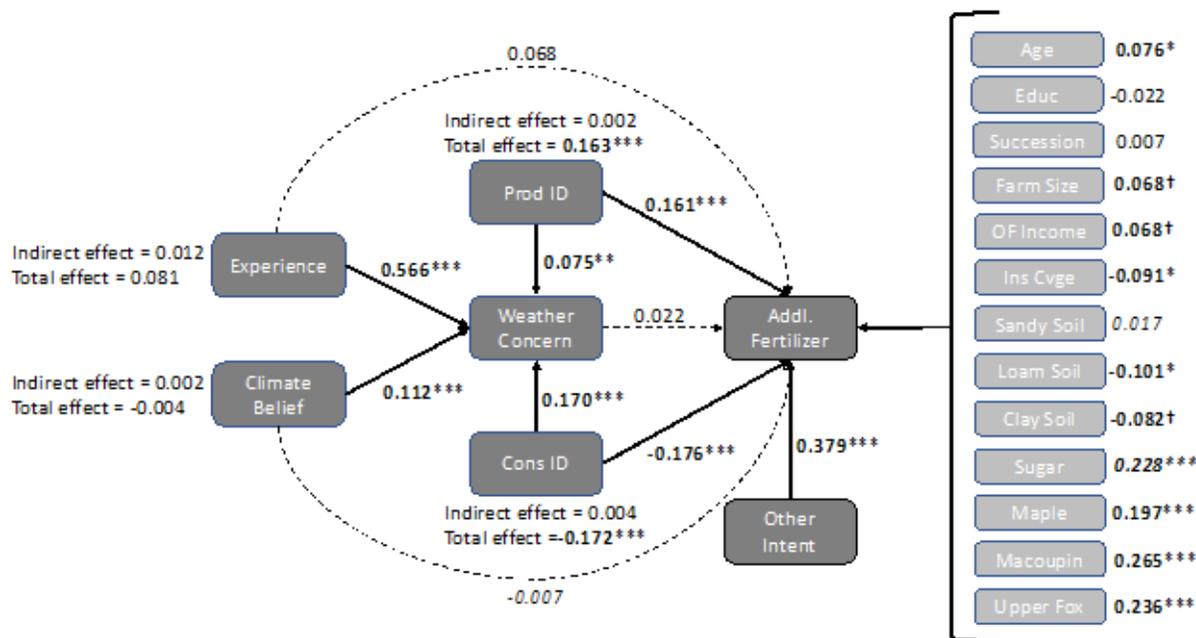


Figure 4

Paths predicting a) cover crop and b) filter strip adaptation inclination, controlling for the inclination to use all other adaptations where †=p<0.10, \*=p<0.05, \*\*=p<0.01, and \*\*\*=p<0.001

a)



b)

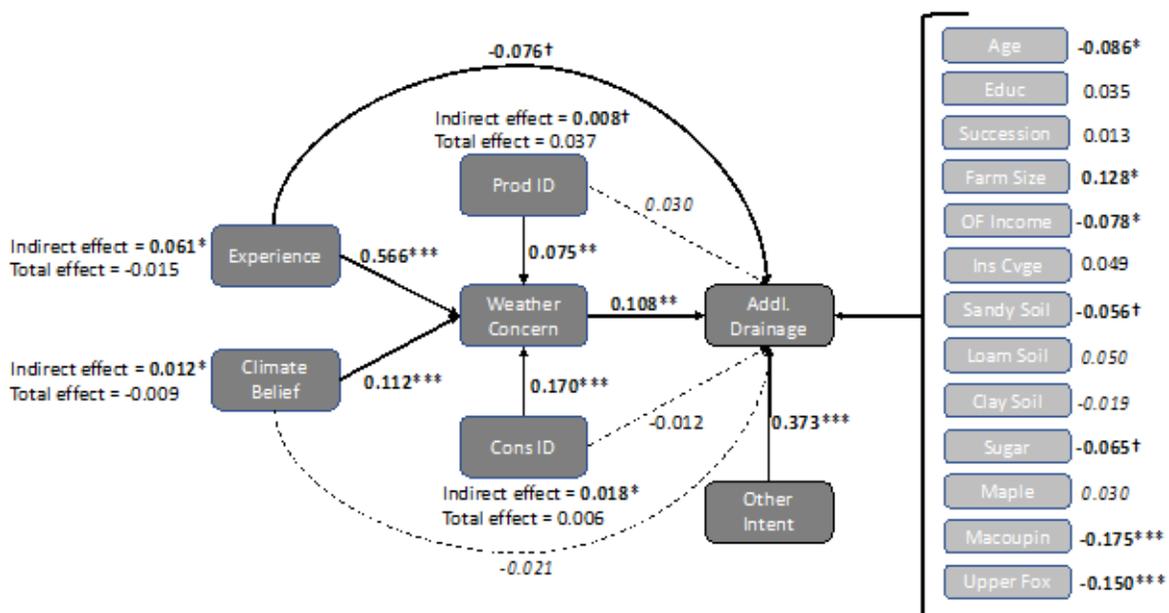
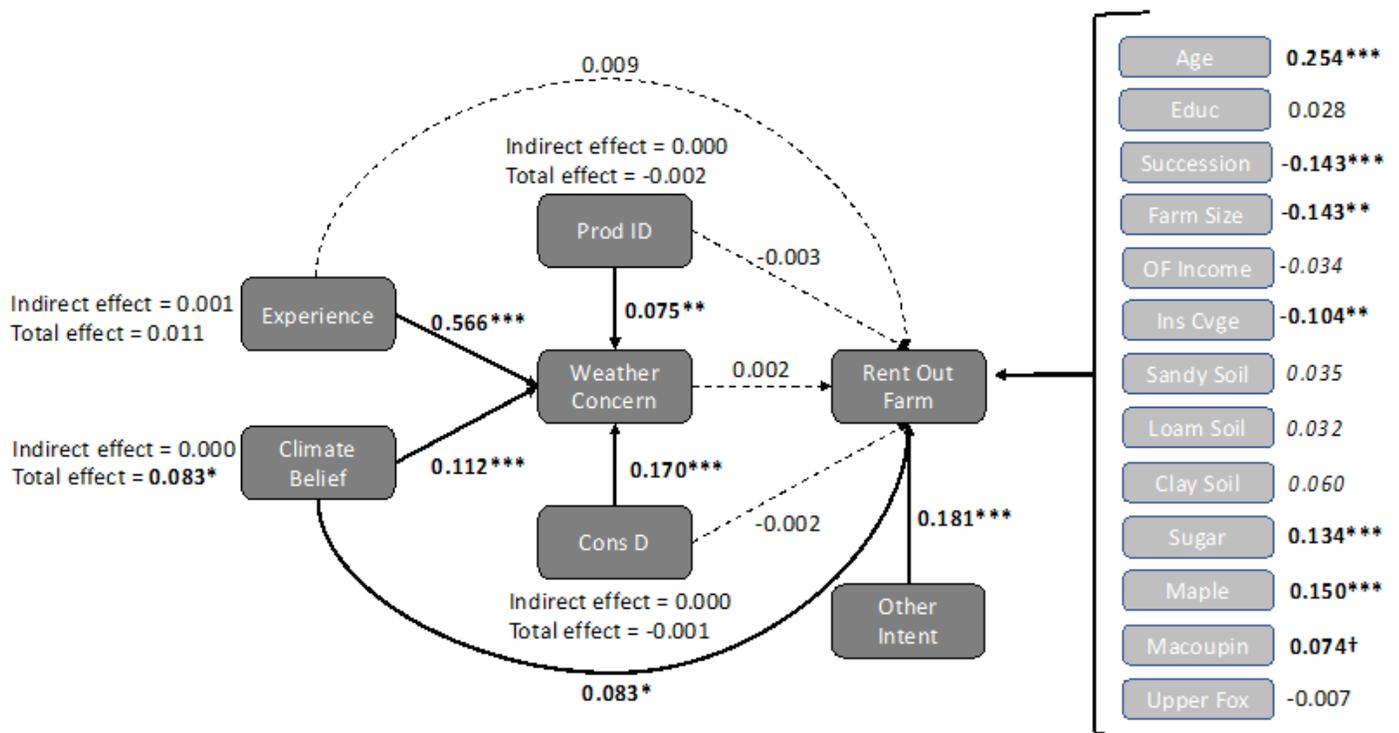


Figure 5

Paths predicting additional a) fertilizer adaptation inclination, and b) tile drainage adaptation inclination, controlling for the inclination to use all other adaptations where †=p<0.10, \*=p<0.05, \*\*=p<0.01, and \*\*\*=p<0.001



**Figure 6**

Path diagram explaining the inclination to rent out the farm as an adaptation strategy controlling for the inclination to use all other adaptations where †=p<0.10, \*=p<0.05, \*\*=p<0.01, and \*\*\*=p<0.001

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [OnlineResource1.docx](#)
- [OnlineResource2.docx](#)
- [OnlineResource3.docx](#)