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U.S. Agricultural Producer Perceptions of Climate Change

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This study examines U.S. crop producers' perceptions of climate change, its effects on crop agriculture, and likely ways farmers would adapt to weather extremes. Based on a survey of crop producers in four states, we find that a significant proportion of farmers do not perceive that climate change has been scientifically proven and do not believe that it will adversely affect average crop yields and yield variability. Farmers are likely to diversify crops, buy crop insurance, modify lease arrangements, and exit farming in response to extreme weather caused by climate change.

Key Words: agriculture, beliefs, climate change, farmer perceptions, human values

JEL Classifications: Q10, Q19, Q54

The debate surrounding climate change is one of the most fundamental political debates of our era. The catastrophic scenarios predicted as a result of climate change pose serious political choices for our generation. Scientists have been drawn into this discussion as experts to provide assessments of the evidence of climate change, to estimate human contributions to climate change, and to predict the possible impacts of climate change and responses to it. This was highlighted when the Intergovernmental Panel on Climate Change (IPCC) was named co-recipient of the 2007 Nobel Peace Prize.

In the United States, a few institutions survey public opinion on climate change. A recent annual Gallup Environment Survey in March 2012 indicated that 52% of Americans believe that climate change is occurring (Gallup, 2012). Also in early 2012, the Yale Project on Climate Change Communication (YPCCC) and the National Survey of American Public Opinion on Climate Change (NSAPOCC) independently showed that approximately two-thirds of Americans believe in the existence of climate change (Borick and Rabe, 2012; Leiserowitz et al., 2012).

Even with over half of the American public cognizant of climate change, public policy directed at mitigating climate change has not been commensurate. For instance, although the American Clean Energy and Security Act of 2009 (also called the Waxman-Markey Bill) that addresses emissions of CO_2 and other greenhouse gases passed in the U.S. House of Representatives, the U.S. Senate failed to pass

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similar climate change legislation. At the same time, climate change mitigation and adaptation efforts are generally low-priority issues among public-sector (local and state) organizations in the United States (Brody et al., 2010).

This disproportionate response to climate change is not unique to the United States. Similar surveys in Ethiopia, Mozambique, and Uganda (Patt and Schroter, 2008; Deressa et al., 2009; Roncoli et al., 2011) detail the importance of several other factors, apart from knowledge, that influence willingness to respond to climate change such as differential culture, demographics, access to resources, and perception of severity of impact. These empirical studies reinforce the position of some social scientists that knowledge of climate change *per se* is not a significant predictor of people's reactions and behaviors (Norgaard, 2009; Reynolds et al., 2010; Kahan et al., 2011; Pongiglione, 2012). In fact, Kahan et al. (2011) refer to "cultural cognition" as the unconscious tendency of people to fit evidence of risk to positions that predominate in groups to which they belong and that more literate individuals can think their way to conclusions that are better for them as individuals but not necessarily better for society. Thus, it may be more informative to analyze climate change perceptions in the context of social/cultural groups or stakeholders.

An important and vulnerable stakeholder in the climate change debate is the agricultural sector. Indeed, among the broad array of possible policy options (international trade, energy policies, consumption/production policies, and environmental policies) proposed to mitigate and adapt to climate change, an interesting subset of these policy options relates to production agriculture. For instance, renewable energy policy is closely tied to climate change. Arguably, renewable energy policy has created enormous shocks to the agricultural sector in the United States and the world. More directly, climate change legislation such as the Waxman-Markey Bill passed in the U.S. House of Representatives intends to address emissions of CO_2 and other greenhouse gases. However, the U.S. Senate failed to pass similar legislation and one of the many contentious issues was how proposed cap-and-trade provisions would affect various segments of the agricultural sector.

Given the clout agricultural producers have in Congress, the perceptions of this small but influential group may have a significant effect on the policy debate and on laws that are eventually enacted. There are no recurrent surveys of the agricultural sector's perceptions of climate change in the United States and empirical studies are limited in number and in scope. Weber (1997) found that approximately half of the 48 farmers surveyed in east–central Illinois did not believe in the existence of global warming. Diggs (1991) showed that after a drought experience, three-fourths of farmers surveyed in the Great Plains believed that the climate is changing. In contrast, Saleh Safi, Smith, and Liu (2012) showed that vulnerability to climate change did not affect climate change risk perception among Nevada farmers and ranchers.

This study examines U.S. crop producers' perceptions of climate change and its likely effects on crop agriculture. Based on a mail survey of over 1,300 farmers in four states, we investigate producer characteristics to identify those that affect producer beliefs about climate change, its impacts, and likely farmer responses. Our study is the first to measure climate change perceptions of U.S. agricultural producers over a broad geographical range and to identify characteristics that influence their perceptions. Our results suggest that a large proportion of producers in our survey do not believe that climate change is scientifically proven nor do they believe that climate change will adversely affect crop yields. However, a large percentage of farmers also do not have an opinion. There is some evidence that climate change perceptions vary with education, age, willingness to accept risk, the amount of farm assets, the percentage of farm assets in land, and the extent of importance of off-farm employment. Also, most farmers believe that crop diversification, crop insurance, lease/rental modifications, and exiting farming are likely producer responses to climate change.

Methods and Procedures

Data and Survey Description

Data for this study were collected from a 2009 stratified random sample of crop producers

(corn, cotton, grain sorghum, soybeans, rice, or wheat) in Mississippi, North Carolina, Texas, and Wisconsin. The survey was conducted by the U.S. Department of Agriculture's National Agricultural Statistics Service (NASS) using its extensive database and sampling procedures. Prior NASS data were used to stratify the subjects into five categories based on gross agricultural sales with each stratum representing approximately 20% of the population. The survey excluded the lowest stratum to focus on commercial farms.[1] Six thousand questionnaires were mailed on March 24, 2009 (1,200 in Mississippi, 1,500 in North Carolina, 1,650 each in Texas and Wisconsin). Postcard reminders were mailed to all 6,000 persons included in the initial survey during the week of March 30, 2009. A second mailing of questionnaires was sent to nonrespondents on April 22, 2009. Of the 6,000 questionnaires mailed, 1,380 survey questionnaires were returned with usable information (a 23% usable response rate). To assess the representativeness of respondents, we compared demographic variables from our sample with statistics obtained from the 2007 Census of Agriculture. First, the average age of our respondents is 58.7 years versus the Census average of 57.1 years (U.S. Department of Agriculture–National Agricultural Statistics Service, 2007). Comparison of respondent farm size with Census summaries by state and primary crop type indicates that our respondents' farms are somewhat larger than average but within half of the standard deviation in all four states. This difference is largely the result of elimination of the stratum representing the smallest 20% of farms in each state. Finally, the national average debt-to-asset ratio for farms was 12.9% in 2009, whereas our respondents report a slightly higher ratio of 13.8% (U.S. Department of Agriculture–Economic Research Service, 2010).

Among the various survey questions, sampled producers were asked about their: 1) perceptions of climate change and its causes; 2) perceived effect of climate change on the mean and variability of their crop yields; and 3) how producers in their region would likely respond to climate change. Information on producer characteristics such as sociodemographics, crops grown, farm size, and willingness to accept risk were also elicited.

With regard to the specific questions on climate change, producers were first asked to indicate whether they agree or disagree with the following statements: 1) "I believe climate change has been scientifically proven"; 2) "I believe normal weather cycles explain most or all recent changes in climate"; 3) "I believe human activities are causing changes in the earth's climate"; and 4) "The El Niño/La Niña cycle of weather patterns is real and affects agricultural production in the area where I farm." We refer to these as the four climate change perception questions in the remainder of the article. Farmer responses were recorded in a Likert scale where possible responses were strongly disagree, disagree, no opinion, agree, and strongly agree.

Sampled producers were then asked about how they thought climate change would affect the mean and variability of their yields for their primary crop over the next 25 years. Responses regarding average yields were recorded in a five-category scale as follows: average yields will decrease by more than 10%, average yields will decrease between 5% and 10%, average yields will not increase or decrease by more than 5%, average yields will increase between 5% and 10%, and average yields will increase by more than 10%. An identical response format was used for the question on variability of yields. Producers were also asked whether they would change the mix of crops they grow in the next 25 years because of climate change.

Lastly, producers were asked about their perceptions on how farmers in their region might respond to extreme changes in weather (i.e. more frequent droughts, floods, frosts, etc.). Using a five-category Likert scale (1 = unlikely response to 5 = likely response), producers

[1] For Mississippi, the bounds were: $0–4,999; $5,000–19,999; $20,000–114,999; $115,000–559,999; $560,000 and above. For North Carolina, the bounds were: $0–3,999; $4,000–14,999; $15,000–49,999; $50,000–169,999; $170,000 and above. For Texas, the bounds were: $0–7,999; $8,000–29,999; $30,000–94,999; $95,000–339,999; $340,000 and above. For Wisconsin, the bounds were: $0–9,999; $10,000–24,999; $25,000–49,999; $50,000–104,999; $105,000 and above.

indicated how likely the following actions were in response to more extreme weather events: diversify crops more, irrigate more, buy more crop insurance, modify lease/rental arrangements, and leave farming. The results and discussion section summarizes farmer responses on the four climate change perception questions by region and discusses the implications.

Producer Characteristics and Climate Change Perceptions: Estimation Strategy

To better understand farmer perceptions and differences in beliefs about climate change, we use a multivariate probit regression to identify producer characteristics that have a statistically significant relationship with climate change perceptions. The dependent variables in each case are grower responses to the four climate change perception questions. More formally, the regression model is specified as follows:

$$(1) \qquad Y_{ij} = x_{ij}'\beta_j + \varepsilon_{ij},$$

where Y_{ij} is producer i's response to the j^{th} climate change perception question, x_{ij}' is a one $\times$ k vector of observed producer characteristics potentially associated with beliefs about climate change, β_j is a $k \times$ one vector of unknown parameters to be estimated, ε_{ij} is the unobserved error term, $j =$ one to m where $m =$ four which is the number of climate change perception questions, $n = 1{,}380$ is the number of producers, and k is the number of regressors.

The Y_{ij} s are both discrete and ordered responses—they can be only one of five possible cases and these cases are ordered by the intensity of belief: strongly disagree, disagree, no strong opinion, agree, strongly agree. As such, an ordered probit (or logit) model specification is appropriate for empirical analysis (Greene, 2007). Potentially, equation (1) can be estimated separately for each climate change perception question, i.e., as four independent ordered probit models. However, grower beliefs regarding the four climate change statements are likely related (e.g., producers who believe that climate change has been scientifically proven would also probably tend to believe that human activities are causing climate change), implying correlation among producer responses. Ignoring this correlation and separately estimating equation (1) for each climate change perception, question j can lead to biased estimates and incorrect standard errors (Kiefer, 1982; Velandia et al., 2009).

The potential correlation across the four climate change perception questions points to the use of a multivariate estimation approach (i.e., simultaneously estimating the four equations) or, here, a multivariate ordered probit model. However, multivariate ordered probit models have been little used in economics, because they are difficult to estimate and parameter estimates are not easily interpreted, although recent advances in Bayesian analysis are promising (Hasegawa, 2010). In light of these difficulties, to use a more tractable estimation procedure, we transform the 5-point Likert scale dependent variables into binary "zero-one" variables. That is, the responses to the four climate change perceptions were first transformed such that $Y_{ij} =$ one if a producer responded with "agree" or "strongly agree" and $Y_{ij} =$ zero if a producer responded "disagree" or "strongly disagree." By excluding "no opinion" responses, some degree of bias is eliminated that may arise from lumping respondents with no opinion in either group, because these respondents can go either way.[2]

[2] We thank an anonymous referee for pointing this out in an earlier draft where we recoded the "no opinion" responses as zero. However, as another referee noted, removing "no opinion" responses raises a concern about selection issues (i.e., the resulting sample used in the regression is significantly different from the sample that responded with "no opinion"). Hence, we conducted simple comparison of means (e.g., t tests) to determine the characteristics that may be significantly different between the group with "no opinion" and those that had definite opinions about climate change. t tests show that age, amount of ownership in farm operations, membership in NFO/NFU/Grange, proportion of irrigated crop acres, and the share of assets in land, do not, in general, statistically differ between the group with no opinion and the group that had an opinion. These two groups, however, are statistically different in terms of education, Farm Bureau membership, risk aversion, and extent of off-farm employment. The statistical similarities and differences of these two groups should always be kept in mind when interpreting the results of the regression models.

Using these newly constructed binary variables allows us to use a more straightforward multivariate probit estimation method to estimate the parameters in equation (1).[3] Pairwise correlations of the error terms for each pair of climate change perception questions are computed and their significance tested plus standard errors for the parameter estimates are computed using the heteroscedasticity-consistent standard errors of Eicker-Huber-White (Eicker, 1967; Huber, 1967; White, 1980), clustering by county (i.e., standard errors clustered at the county level to account for within-county correlations that may bias the standard errors of estimates).

Empirical Specification

The four dependent variables in our specification are the binary variables (Y_{ij}) equal to one when the producer "agrees" or "strongly agrees" (and zero when the producer "disagrees" or "strongly disagrees") with any one of the four respective climate change perception statements: 1) "I believe climate change has been scientifically proven"; 2) "I believe normal weather cycles explain most or all recent changes in climate"; 3) "I believe human activities are causing changes in the earth's climate"; and 4) "The El Niño/La Niña cycle of weather patterns is real and affects agricultural production in the area where I farm."

Independent variables were chosen based on the previous literature investigating factors that affect climate change beliefs or climate change response. Because Deressa et al. (2009) found that age, education, and wealth significantly affected willingness to respond to climate change, we include the following variables in our specification: age (*Age*, in years) and an education variable (*Attended at least some college*, equals one if attended some college and zero otherwise), and three wealth-related variables (i.e., *Farm assets exceed $1,000,000*, equals one if farm assets exceed $1 million and zero otherwise, *% operated acres owned*, and *% farm assets in land*). To proxy for political leanings or views (Etkin and Ho, 2007), we include two indicator (dummy) variables to represent membership in the Farm Bureau (*Member of Farm Bureau*, equal to one if member and zero otherwise) and membership in one or more of the following: National Farmers Union (NFU), National Farmers Organization (NFO), and The Grange (*Member of NFO, NFU, Grange*, equal to one if a member and zero otherwise).[4] Variables representing attitudes toward risk were also included, including *More willing to accept risk* (equal to

[3] In multivariate probit regression, the error terms for the m alternatives have a multivariate normal distribution with a mean vector equal to zero and a covariance matrix $\mathbf{R}$ with diagonal elements equal to one. With multivariate normality and binary dependent variables, the parameters in equation (1) can be estimated using simulated maximum likelihood. Probabilities entering the likelihood function and derivatives for maximum likelihood are computed using the Geweke-Hajivassiliou-Keane simulation procedure (Geweke, 1989; Hajivassiliou, 1991; Keane, 1994) to approximate the m-fold multivariate normal integrals:

$$\int_{-\infty_m}^{x_m} \dots \int_{-\infty}^{x_1} \varphi(\mathbf{x}_1, \dots, \mathbf{x}_m) d\mathbf{x}_1 \dots d\mathbf{x}_m.$$

Here $\varphi(\cdot)$ is the m-variate normal density of $\mathbf{x}$ with mean vector equal to zero and m x m positive definite covariance matrix $\mathbf{W}$. The log-likelihood for the model is calculated as the sum of the natural logarithms of the probabilities of the observed outcomes defined as:

$$\text{Prob}(,(y_1, \dots, y_m | \mathbf{x}_1, \dots, \mathbf{x}_m) = \text{MVN}(\mathbf{Tz}, \mathbf{TRT}'),$$

where $\mathbf{z}$ is a vector defined from $\mathbf{z}_m = \beta_m' \mathbf{x}_m$, $\mathbf{R}$ is the correlation matrix, $\mathbf{T}$ is a diagonal matrix with $t_{mm} = 2y_m - 1$, and MVN refers to the multivariate normal density (Greene, 2007).

[4] The American Farm Bureau Federation does not agree with the current scientific opinion on climate change. In a reply letter by its President Bob Stallman to the Union of Concerned Scientists, it was stated: "We are skeptical of the ability of current climate models to predict changes in weather patterns 50 to 100 years into the future with sufficient accuracy to justify major domestic policy changes that will have long lasting and severe economic impacts both here and abroad" (American Farm Bureau Federation, 2010). Over the past decade, an increasing majority of Republicans question the validity of climate science, whereas an increasing majority of Democrats accept the scientific community's consensus on climate change (Dunlap and McCright, 2008).

one if farmer answered a 4 or a 5 on a Likert scale for their self-reported degree of willingness to accept risk and zero otherwise) and *Off-farm employment important* (equal to one if farmer reported a 4 or 5 on a Likert scale asking how important off-farm employment is in managing overall household income risk and zero otherwise). Crop and state indicator (dummy) variables were included in the specification to represent unobserved crop- and state-specific effects. Table 1 reports summary statistics after "no opinion" responses have been excluded. Note that in Table 1, 945 of the original 1,556 producers provided a strongly agree/agree or strongly disagree/disagree response; the remaining 611 had "no opinion". As reflected in Table 1, some producers also did not provide information for some explanatory variables, particularly age, percentage of operated acres owned, and percentage of farm assets in land.[5]

Results and Discussion

Summary of Responses to Climate Change Questions

Responses to the four climate change perception questions are summarized in Table 2. Responses to the statement: "I believe climate change has been scientifically proven" indicate that 15–20% of producers in the four states strongly disagree with this statement. When the strongly disagree and disagree responses are summed, the total negative response is nearly 50% in Mississippi and Texas. However, in all four states, between 20% and 30% of respondents indicated that they have no opinion about the issue. In fact, the largest single response in Wisconsin (31%) was no opinion. Responses of agree and strongly agree sum to 36% for North Carolina and roughly 24% to 25% for Texas, Mississippi, and Wisconsin. These results reveal that although crop producers who doubt that climate change has been scientifically proven outnumber those that do not, there remain a significant proportion of respondents that have no opinion on the issue.

Agreement with the second question, "Do you believe that human activities are causing changes in the earth's climate?," encompasses both a belief in climate change and that humans are contributing to that change. Texas producers stand out to either strongly disagree or disagree with this statement (43% of respondents) compared with 35% in Mississippi and roughly 25% in North Carolina and Wisconsin. Approximately 30% of producers in all four states express no opinion on this issue. Agreement or strong agreement with the proposition that human activities are causing climate change is strongest in North Carolina at 47% followed by Wisconsin (42%), Mississippi (36%), and Texas (26%). Overall these results indicate that nearly one-third of producers have no opinion on this issue with the remaining two-thirds weighted toward agreement or strong agreement in all states but Texas, where almost half of producers do not believe that human activity is a cause of climate change.

An interesting contrast can be drawn between the responses to these first two questions. Comparing the percentage of producers who agree or strongly agree with the statements in the two tables, there is as much or more agreement to the human cause question as to the existence question in every state. This suggests that there is a nontrivial portion of crop producers who believe humans are causing climate change but who do not consider climate change scientifically proven. In particular, of the 469 producers who strongly disagree/disagree that climate change is scientifically proven, 17% strongly agree/agree that humans are responsible for it, whereas 55% held the opposite view (strongly disagreed/disagreed) (Appendix Table 1).

Table 2 also reports the responses to the statement, "I believe normal weather cycles explain most or all recent changes in climate." Across all states, the level of agreement or strong agreement with this proposition is striking (approximately ~76% in Mississippi, 71% in Texas, 66% in Wisconsin, and 61% in North Carolina). In most instances, there is a smaller fraction of producers who say they

[5] This explains why the data set used for the multivariate probit regression has an N = 411.

Table 1. Summary Statistics for Farmer Responses to Climate Change Perception Questions[a]

Variables	No. of Observations	Mean	Standard Deviation	Minimum	Maximum
A. Transformed binary dependent variables (i.e. = 1 if agree or strongly agree with the statement below; = 0 if disagree or strongly disagree)					
I believe climate change has been scientifically proven	945	0.17	0.38	0	1
I believe normal weather cycles explain most or all recent changes in climate	945	0.39	0.49	0	1
I believe human activities are causing changes in the earth's climate	945	0.22	0.41	0	1
The El Niño/La Niña cycle of weather patterns is real and affects agricultural production in the area where I farm	945	0.40	0.49	0	1
B. Independent variables					
Attended at least some college	945	0.30	0.46	0	1
Age	461	58.81	12.06	26	88
Member of Farm Bureau	945	0.28	0.45	0	1
Member of NFO, NFU, Grange	945	0.01	0.12	0	1
More willing to accept risk	945	0.16	0.36	0	1
Farm assets exceed $1,000,000	945	0.16	0.37	0	1
Percent operated acres owned	477	0.42	0.32	0	1
At least 50 crop acres irrigated	945	0.80	0.40	0	1
Percent farm assets in land	418	45.85	23.75	0	100
Off-farm employment important	945	0.20	0.40	0	1
Corn	945	0.19	0.39	0	1
Cotton	945	0.04	0.19	0	1
Sorghum	945	0.01	0.12	0	1
Rice	945	0.01	0.11	0	1
Soybean	945	0.13	0.34	0	1
Other	945	0.54	0.50	0	1
Mississippi	945	0.22	0.41	0	1
North Carolina	945	0.20	0.40	0	1
Wisconsin	945	0.20	0.40	0	1
Texas	945	0.24	0.43	0	1

[a] Excludes "no opinion" responses.

have no opinion on this topic than was the case with the responses for Question 2.

There appears to be a set of respondents who may believe that normal weather cycles explain recent changes in climate but that climate change has not been scientifically proven, and humans are not responsible for it. In fact, 257 farmers belong to this group, of which 89% (8%) strongly agreed/agreed (strongly disagreed/disagreed) with the statement that normal weather patterns explain most or all recent changes in climate change; the remainder had no strong opinion (Appendix Table 2).

Table 2 also summarizes responses to the fourth climate change perception statement about the related issue of El Niño and La Niña weather cycles. Producers were asked to state their disagreement or agreement with the statement: "The El Niño/La Niña cycle of weather patterns is real and affects agricultural production in the area where I farm." A relatively small percentage of producers either

Table 2. Summary of Responses to Climate Change Perception Statements by State (percent respondents)

	Mississippi	North Carolina	Texas	Wisconsin
"I believe climate change has been scientifically proven" (N = 1050)[a]	(N = 166)	(N = 215)	(N = 281)	(N = 388)
Strongly disagree	20.5	14.9	22.1	17.0
Disagree	34.3	21.4	27.1	25.8
No opinion	21.1	27.4	26.3	31.4
Agree	18.7	30.2	18.9	20.4
Strongly agree	5.4	6.1	5.7	5.4
"I believe human activities are causing changes in the earth's climate" (N = 1,050)[b]	(N = 166)	(N = 215)	(N = 282)	(N = 387)
Strongly disagree	8.4	9.3	15.3	10.9
Disagree	26.5	14.9	28.4	16.3
No opinion	28.3	28.4	30.5	31.3
Agree	28.3	42.3	20.9	33.1
Strongly agree	8.4	5.1	5.0	8.5
"I believe normal weather cycles explain most or all recent changes in climate" (N = 1,060)[a]	(N = 169)	(N = 217)	(N = 287)	(N = 387)
Strongly disagree	4.1	4.6	2.8	2.1
Disagree	2.4	8.3	5.9	9.6
No opinion	17.8	26.7	19.9	21.7
Agree	59.2	45.6	50.2	52.2
Strongly agree	16.6	14.8	21.2	14.5
"The El Niño/La Niña cycle of weather patterns is real and affects agricultural production in the area where I farm" (N = 1,049)[b]	(N = 165)	(N = 214)	(N = 283)	(N = 387)
Strongly disagree	2.4	2.8	0.7	1.8
Disagree	6.7	6.1	1.1	8.5
No opinion	23.6	23.8	17.3	27.1
Agree	53.9	51.9	52.3	49.6
Strongly agree	13.3	15.4	28.6	12.9

[a] Responses significantly different across states (p value < 0.01).
[b] Responses not significantly different across states.

disagree or strongly disagree with this statement. Like with earlier questions, the percentage of producers who have no opinion on this topic is fairly large, ranging from 17% in Texas to 27% in Wisconsin. However, on balance, there is a strong tendency toward agreement with this statement. Roughly 50% of producers in all states express agreement that El Niña/La Niña cycles exist and affect agricultural production where they farm. In Texas, 29% of respondents strongly agree with this proposition compared with 15% in North Carolina and approximately 13% in Mississippi and Wisconsin.

Responses to a set of questions asking producers to assess the likely impacts of climate change on crop production in their region are summarized in Table 3. Some of the results in this table are to be expected given previous tables indicating that many producers do not believe that climate change is occurring. The results in Table 3 indicate that roughly 70% of producers in all four states do not believe that climate change will affect (increase or decrease) their primary crop yield by more than 5%. For producers who do expect a yield change of more than 5%, the distribution is fairly symmetric in Mississippi in terms of

Table 3. Perceptions about the Likely Effect of Climate Change by State (in percent)[a]

Question/Response	State			
	Mississippi	North Carolina	Texas	Wisconsin
A. In the next 25 years, would you expect climate change (not other factors like seed technology) to cause average yields for your primary crop to: (N = 1,041)[b]	(N = 164)	(N = 217)	(N = 280)	(N = 380)
Average yields will *decrease by more than 10%* as a result of climate change	1.8	6.0	10.4	3.4
Average yields will *decrease from 5% to 10%* as a result of climate change	11.6	12.4	13.6	7.6
Average yields will *not increase or decrease more than 5%* as a result of climate change	72.6	72.3	68.9	71.1
Average yields will *increase from 5% to 10%* as a result of climate change	11.0	6.9	5.7	16.6
Average yields will *increase by more than 10%* as a result of climate change	3.0	2.3	1.4	1.3
B. In the next 25 years, would you expect climate change (not other factors like seed technology) to cause variability of yields for your primary crop to: (N = 1,031)	(N = 162)	(N = 216)	(N = 275)	(N = 378)
Variability of yields will *decrease by more than 10%* as a result of climate change	1.2	6.5	8.7	1.9
Variability of yields will *decrease from 5% to 10%* as a result of climate change	9.8	13.4	11.3	9.3
Variability of yields will *not increase or decrease more than 5%* as a result of climate change	72.8	68.5	70.9	70.1
Variability of yields will *increase from 5% to 10%* as a result of climate change	14.2	9.3	6.9	17.5
Variability of yields will *increase by more than 10%* as a result of climate change	1.9	2.3	2.2	1.3
C. In the next 25 years, do you expect producers in your area to make a significant change in the mix of crops they grow due to climate change? (N = 1,033)	(N = 163)	(N = 214)	(N = 277)	(N = 379)
Yes	59.8	50.5	59.5	34.8
No	40.2	49.5	40.5	65.2

[a] Responses to each question significantly different across states (p value < 0.015).

[b] When responses to Question A are broken down according to primary crop, majority of farmers still do not anticipate any yield change of more than 5% from climate change. The proportion of farmers who responded that average yields will not change by more than 5% resulting from climate change, by primary crop, are as follows: corn (73%), cotton (78%), grain sorghum (66%), soybeans (67%), wheat (62%), others (78%).

whether average yields will increase or decrease, whereas more producers in North Carolina and Texas expect yield decreases than yield increases, but a larger proportion of Wisconsin producers expect their average yields to increase. It should be noted, however, that only a small percentage of producers expects climate change to either increase or decrease their expected yields by more than 10% in the next 25 years.

Of the surveyed producers who strongly agreed/agreed that climate change is scientifically proven, 32% (14%) expected average yields to decrease (increase), whereas over half

did not expect any change in yields of over 5% as a result of climate change. On the other hand, among those who strongly disagreed/disagreed, four-fifths did not expect any yield changes of over 5% resulting from climate change and 7% (12%) expected yields to decrease (increase) (Appendix Table 3).

A similar pattern is observed among producers who strongly agreed/agreed to a human-caused climate change where 26% (15%) expected average yields to decrease (increase), whereas 59% did not expect any change in yields of over 5% as a result of climate change. Meanwhile, among those who strongly disagreed/disagreed, four-fifths did not expect any yield changes of over 5% resulting from climate change; the remaining producers were approximately equally divided into those who expect yields to increase and decrease (Appendix Table 4).

Responses for the question focusing on crop yield variability are similar to those regarding average yields. Again, roughly 70% of respondents in all four states do not expect climate change to increase or decrease yield variability by more than 5%. Of producers who do expect variability changes in excess of 5%, a larger proportion of Mississippi and Wisconsin producers expect increased yield variability than expect decreased yield variability, but a larger proportion of North Carolina and Texas producers expect decreased rather than increased yield variability.

Responses to the question focusing on expected effects of climate change on crop mix decisions show three states—Mississippi, North Carolina, and Texas—where the majority of producers indicate that they believe there will be a significant change in the mix of crops as a result of climate change. The lowest response to this question is in Wisconsin, where 34% of producers believe that significant crop mix adjustments will be observed. The most striking result is that, in contrast to our previous results, nearly 60% of producers in Mississippi and Texas, states where scientific proof of climate change is typically not agreed to, believe there will be some change in crop mix resulting from climate change.

Of the respondents who believe that climate change has not been scientifically proven, and humans are not responsible for it, 91% expected no change in the mix of crops grown in their area as a result of climate change; the rest expected some change in the crop mix (Appendix Table 5).

Table 4 focuses on potential responses of producers to extreme weather events. Approximately 30% of respondents have no opinion regarding crop diversification as a response to extreme weather caused by climate change, whereas 44% to 51% think that greater crop diversification is likely or very likely and a much smaller proportion view increased crop diversification as unlikely or extremely unlikely. Approximately 20–25% of producers express no opinion on the use of irrigation. Water availability likely dominates the pattern of responses among producers who have opinions on this issue. Specifically, more than 50% of Mississippi producers believe that increased irrigation is likely or very likely, whereas less than 25% of producers in the other three states considered this a likely response.

Approximately 42–56% of producers in all states believe that buying crop insurance is a likely or very likely response to extreme weather caused by climate change. Only approximately 14–26% believe that crop insurance as a response to extreme weather is unlikely or extremely unlikely, whereas the remaining producers do not have an opinion. Between 30% and 35% of producers offer no opinion on modifications to lease and rental arrangements. Of the remaining producers, there is a strong tendency to believe that these contractual arrangements are likely or very likely to be revised. Approximately 21–26% of producers indicate no opinion on whether more extreme weather would lead producers in their area to leave farming, whereas 38–56% considered this response likely or very likely.

Of those producers who strongly agreed/agreed that climate change is scientifically proven, roughly half indicated that farmers are likely/very likely to diversify crops more (51%), buy more crop insurance (55%), modify lease/rental arrangements (51%), exit farming (50%) in response to extreme weather in their location and approximately one-third (32%) responded that farmers are likely/very likely to irrigate more (Appendix Table 6).

Table 4. Perceptions About the Likely Response of Farmers to More Extreme Weather Resulting from Climate Change by State (percent of respondents)

Response to Extreme Weather/Perception of Likelihood	State			
	Mississippi	North Carolina	Texas	Wisconsin
A. Diversify crops[a] (N = 984)	(N = 153)	(N = 193)	(N = 263)	(N = 375)
Extremely unlikely	5.9	9.8	10.7	11.2
Unlikely	9.8	14.0	8.0	13.9
No opinion	28.8	30.6	34.2	30.9
Likely	39.2	31.6	25.9	29.3
Very likely	16.3	14.0	21.3	14.7
B. Use more irrigation[a] (N = 961)	(N = 153)	(N = 191)	(N = 252)	(N = 365)
Extremely unlikely	20.3	30.4	43.2	42.5
Unlikely	6.5	18.3	15.9	20.3
No opinion	19.0	26.7	23.0	20.6
Likely	29.4	18.9	12.3	11.8
Very likely	24.8	5.8	5.6	4.9
C. Buy more crop insurance[a] (N = 995)	(N = 155)	(N = 199)	(N = 266)	(N = 375)
Extremely unlikely	7.1	6.0	12.0	10.4
Unlikely	7.1	10.1	14.7	11.5
No opinion	31.0	27.6	30.8	30.1
Likely	32.9	35.7	23.7	31.2
Very likely	21.9	20.6	18.9	16.8
D. Modify lease/rental arrangements[b] (N = 976)	(N = 154)	(N = 194)	(N = 259)	(N = 369)
Extremely unlikely	7.1	11.3	12.7	14.4
Unlikely	11.0	10.3	8.1	9.2
No opinion	32.5	32.0	32.8	34.2
Likely	37.0	34.0	32.4	30.9
Very likely	12.3	12.4	13.9	11.4
E. Leave farming[a] (N = 1,004)	(N = 161)	(N = 199)	(N = 268)	(N = 376)
Extremely unlikely	14.9	10.6	11.6	20.7
Unlikely	11.2	11.1	13.1	14.9
No opinion	25.5	21.6	24.6	25.5
Likely	19.9	25.1	24.6	23.1
Very likely	28.6	31.7	26.1	15.7

[a] Responses significantly different across states (p value < 0.05).
[b] Responses not significantly different across states.

Producer Characteristics and Climate Change Perceptions: Estimation Results

Table 5 presents estimation results for the multivariate probit regression analysis of producer responses to the questions summarized in Table 2. The final estimation used 411 observations with a likelihood ratio χ^2 statistic of 133.64 with 74 degrees of freedom, supporting the significance of the regression. Table 5 reports the estimated correlation coefficients and marginal effects. Marginal effects are calculated for the unconditional expected value for each observation and averaged over all observations.[6] All correlation coefficients (across

[6] We calculated average marginal effects as a result of the following reasons: 1) no individual may actually have mean values on all the independent variables; 2) no individual has a fractional value like 0.36 on a categorical variable like *Farm Bureau Membership*, among other variables; and 3) effects are only calculated at one set of values, the means. With average marginal effects, a marginal effect is computed for each case, and then all the computed effects are averaged.

Table 5. Multivariate Probit Regression Results (N = 411)

	Climate Change Has Been Scientifically Proven		Human Activities Are Causing Climate Change		Normal Weather Explains Recent Climate Changes		El Niño/La Niña Affects Local Production	
Variable	Estimate	dy/dx[c]	Estimate	dy/dx[c]	Estimate	dy/dx[c]	Estimate	dy/dx[c]
Attended at least some college	0.056	0.019	–0.004	–0.001	0.127	0.033	0.378**	0.084**
Age (years)	0.007	0.002	0.013**	0.005**	–0.009	–0.002	–0.010	–0.002
Member of Farm Bureau	0.205	0.071	0.005	–0.002	–0.052	–0.013	0.046	0.010
Member of NFO, NFU, Grange	–0.070	–0.024	–0.142	–0.051	–0.074	–0.019	–0.053	–0.012
More willing to accept risk[a]	0.125	0.043	0.274**	0.099**	0.316*	0.081**	0.133	0.029
Farm assets exceed $1,000,000	–0.367**	–0.127**	–0.197	–0.071	0.307*	0.079**	–0.152	–0.034
Percent operated acres owned	–0.033	–0.011	0.023	0.008	0.391	0.100	0.129	0.028
At least 50 crop acres irrigated	–0.073	–0.025	0.167	0.060	0.272	0.070	0.336	0.074
Percent farm assets in land	–0.005*	–0.002*	–0.001	–0.000	–0.001	–0.000	0.002	0.000
Off-farm employment important[a]	0.216	0.075	0.263*	0.095*	0.123	0.032	0.187	0.041
Primary crop[b]								
Corn	–0.070	–0.024	–0.123	–0.045	–0.020	–0.005	–0.078	–0.017
Cotton	–0.385	–0.134	–0.618**	–0.223**	0.358	0.092	–0.163	–0.036
Sorghum	0.230	0.080	0.518	0.187	–0.508	–0.130		
Rice	–0.083	–0.029	0.196	0.071			–0.488	–0.108
Soybean	–0.017	–0.006	–0.080	–0.029	–0.182	–0.047	–0.607	–0.134
Other	–0.491	–0.171	–0.563	–0.203	–0.284	–0.073	–0.620	–0.137
State[b]								
Mississippi	–0.186	–0.065	0.402	0.145	0.129	0.033	–0.415	–0.091
North Carolina	0.505	0.176	0.655**	0.236**	–0.608	–0.156	–0.429	–0.095
Wisconsin	0.376	0.131	0.534*	0.193*	–0.519	–0.133	–0.554	–0.122
Constant	–0.710		–1.260***		1.222**		1.628***	

[a] Reported 4 or 5 on Likert scale.

[b] Default crop is wheat; default state is Texas.

[c] Average marginal effects, calculated for the unconditional expected value. Marginal effects for indicator variables are calculated for a change in value from 0 to 1.

*, **, *** indicates significance at the 10%, 5%, and 1% levels, respectively.

equations) are strongly significant (p values < 0.001).

Results in Table 5 show that few producer characteristics significantly influence the probability that a farmer agrees with each statement. Producers who attended at least some college tend to agree that El Niño/La Niña affects local agricultural production and producers who are more willing to accept risk are more likely to agree that normal weather patterns explain recent climate changes. However, Table 5 also shows that these same producers who tend to attribute recent climate changes to normal weather patterns also are likely to agree that climate change is caused by human activities. That this is the case points to the possibility that

Table 6. Estimated Correlation Coefficients (standard errors in parentheses) between Errors of the Estimated Probit Regressions for Each Statement (N = 411)

	Climate Change Has Been Scientifically Proven	Human Activities Are Causing Climate Change	Normal Weather Explains Recent Climate Changes
Climate change has been scientifically proven	1.000		
Human activities are causing climate change	0.854 (0.0350)	1.000	
Normal weather explains recent climate changes	−0.461 (0.0832)	−0.443 (0.0862)	1.000
El Niño/La Niña affects local production	0.420 (0.0945)	0.362 (0.0954)	0.440 (0.0947)

although farmers are inclined to agree that human activity drives climate change, they also believe that recent changes in climate are mostly driven by normal weather patterns.

Older producers with presumably more farming experience are more likely to believe that humans are responsible for climate change but less likely to agree that El Niño/La Niña affects local agricultural production. At the same time, age negatively (although statistically insignificant) affects a producer's likelihood to agree with the statement that normal weather patterns explain recent climate change. Producers with over $1 million in farm assets are likely to disagree that climate change has been scientifically proven. These same farmers also are more likely to agree that normal weather explains recent climate change. Producers whose off-farm employment is important tend to agree that climate change is human-caused.

The effect of the reported primary crop on the likelihood of agreement with any of the statements is significant for only a few cases. Relative to producers whose primary crop is wheat, farmers of cotton were less likely to agree that humans are responsible for climate change. The lack of significance for most crops suggests that the type of crop grown is generally not an important producer characteristic associated with beliefs regarding climate change. Geographical disparity in climate change perception is generally not observed in Table 5 except in the perception of a human-caused climate change in which both North Carolina and Wisconsin are more likely to agree relative to Texas.

The correlation coefficients reported in Table 6 generally follow expectations. The strongest positive correlation is for agreement between the first two statements—producers who believe that climate change has been scientifically proven are also likely to believe that humans are causing it. Similarly, the only negative correlations are between responses for the first two statements and the third statement—producers who believe that normal weather patterns explain recent climate changes are less likely to believe that climate change has been proven and that humans are causing it. Finally, agreement with the statement that El Niño/La Niña has local agricultural effects is positively correlated with agreement with all three of the other statements. Apparently, among some of the surveyed farmers, the local effects of El Niño/La Niña suggest that humans are causing climate change, whereas among other farmers, these same local effects suggest that natural weather cycles explain climate change.

Conclusions

This article contributes to the scientific literature on climate change as one of the first to examine U.S. crop producers' perceptions of climate change and its possible effects on the agricultural sector. In general, although there is a significant fraction of crop producers in these four states—Mississippi, North Carolina, Texas, and Wisconsin—who are skeptical of the climate change evidence and even less likely to believe it has been scientifically proven, the number of producers without any strong opinion

on the matter cannot be ignored (21–31%). Our data suggest that not only is there relatively little acceptance of the existence of climate change, but also little belief that climate change will have negative effects on crop yields.

Excluding farmers who have no opinion, there is some evidence that climate change perceptions vary with education, age, willingness to accept risk, the amount of farm assets, the percentage of farm assets in land, and the importance of off-farm employment; also, no geographical disparity is observed. A caveat in interpreting these results, however, is that excluding the group with no opinion, although it clearly delineates responses, raises some concern about selection issues (see footnote 2). Nonetheless, the significance of these factors underscores several themes in understanding climate change perceptions and also points to several implications.

First, climate change is a gradual process with effects that are obscured by random weather events and cyclical climate patterns so that farmers are more skeptical about whether they are observing its effects (Weber, 1997). Because farmers do not directly perceive the consequences of climate change, previous research has suggested the need to provide scientific and statistics-based information about climate change from multiple sources to influence perceptions about climate change risks (Weber, 2006). In particular, Weber (2010, p. 6) suggests that "we should find ways to evoke stronger affective reactions towards the risk of climate change in citizens, managers, or public officials, by making the expected climate effects more vivid or concrete." There seems to be interest in providing more information or outreach efforts, but the challenge is how to effectively deliver it to U.S. agricultural producers and the general public.

Second, it appears that farmers with more assets invested in farming tend to be skeptical about the science of climate change but are likely to believe that normal weather explains recent climate changes. One wonders whether this skepticism about climate science provides a screen for those with a lot more at stake if mitigation policies were implemented such as a cap-and-trade policy.

Third, we find the climate change issue and the lack of acceptance from some lay audiences to suggest scientific skepticism. It is not clear whether this skepticism is likely to remain or change in the future. We suggest that it merits further study to see if the observed attitudes reported in this study will evolve over time.

Finally, notwithstanding the influence of certain variables on the perceptions of climate change, the four perception questions cannot give any strong indication about the source of skepticism. Undoubtedly, however, if belief in climate science is embraced, measures necessary to mitigate climate change would require sacrifices that not all people are willing to make; oftentimes they require a change of habits at the individual and societal level. Future research may want to examine farmers' willingness to pay (or the payments/subsidies they are willing to accept) to implement climate change adaptation strategies, especially differentiating between those farmers who believe and those who do not believe in the existence of climate change. The current research is only an initial step in understanding farmers' perceptions about climate change and the possible strategies to implement climate mitigation/adaptation policies.

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Appendix Table 1. Breakdown of Responses to the Statements: "Climate Change has been Scientifically Proven" and "Human Activities are Causing Climate Change" (in percent) (N = 1,046)

	HUMAN ACTIVITIES ARE CAUSING CLIMATE CHANGE		
Climate Change Has Been Scientifically Proven	Strongly Disagree/Disagree (in %)	No Opinion (in %)	Strong Agree/Agree (in %)
Strongly disagree/disagree	55	28	17
No opinion	16	48	37
Strong agree/agree	12	16	72

Appendix Table 2. Breakdown of Responses to the Statement: "Normal Weather Explains Recent Climate Change" According to Previous Responses to the Statements: "Climate Change has been Scientifically Proven" and "Human Activities are Causing Climate Change" (in percent)

A. Normal weather explains recent climate change (strongly agree/agree) (N = 469)

	Human Activities Are Causing Climate Change		
Climate Change Has Been Scientifically Proven	Strongly Disagree/Disagree (in %)	No Opinion (in %)	Strong Agree/Agree (in %)
Strongly disagree/disagree	89	85	81
No opinion	76	42	52
Strong agree/agree	15	88	47

B. Normal weather explains recent climate change (strongly disagree/disagree) (N = 286)

	Human Activities Are Causing Climate Change		
Climate Change Has Been Scientifically Proven	Strongly Disagree/Disagree (in %)	No Opinion (in %)	Strong Agree/Agree (in %)
Strongly disagree/disagree	8	5	9
No opinion	7	4	4
Strong agree/agree	9	6	25

C. Normal weather explains recent climate change (no opinion) (N = 290)

	Human Activities Are Causing Climate Change		
Climate Change Has Been Scientifically Proven	Strongly Disagree/Disagree (in %)	No Opinion (in %)	Strong Agree/Agree (in %)
Strongly disagree/disagree	3	10	10
No opinion	17	54	44
Strong agree/agree	76	6	28

Appendix Table 3. Expected Change in Average Yields for Primary Crop According to Responses to the Statement: "Climate Change has been Scientifically Proven" (in percent) (N = 1,021)

	Expected Change in Average Yields for Primary Crop		
Climate Change Has Been Scientifically Proven	Decrease (in %)	No Change (increase/decrease) of Over 5% (in %)	Increase (in %)
Strongly disagree/disagree	7	81	12
No opinion	15	72	13
Strong agree/agree	32	54	13

Appendix Table 4. Expected Change in Average Yields for Primary Crop According to Responses to the Statement: "Humans are causing climate change" (in percent) (N = 1,020)

	Expected Change in Average Yields for Primary Crop		
Humans Are Causing Climate Change	Decrease (in %)	No Change (increase/decrease) of Over 5% (in %)	Increase (in %)
Strongly disagree/disagree	10	81	9
No opinion	10	77	13
Strong agree/agree	26	59	15

Appendix Table 5. Breakdown of Responses to the Question: "Do you expect producers in your area to change the mix of crops they grow due to climate change?" According to Previous Responses to the Statements: "Climate change has been scientifically proven" and "Human activities are causing climate change" (in percent)

Change in crop mix? (= YES) (N = 248)			
	Human Activities Are Causing Climate Change		
Climate Change Has Been Scientifically Proven	Strongly Disagree/Disagree (in %)	No Opinion (in %)	Strong Agree/Agree (in %)
Strongly disagree/disagree	9	13	27
No opinion	24	16	34
Strong agree/agree	48	28	46
Change in crop mix? (= NO) (N = 763)			
	Human Activities Are Causing Climate Change		
Climate Change Has Been Scientifically Proven	Strongly Disagree/Disagree (in %)	No Opinion (in %)	Strong Agree/Agree (in %)
Strongly disagree/disagree	91	87	73
No opinion	76	84	66
Strong agree/agree	52	72	54

Appendix Table 6. Measures Farmers Are Likely to Adopt after Extreme Weather According to Responses to the Statement: "Climate change has been scientifically proven" (in percent)

	Diversify More Crops (N = 973)		
Climate Change Has Been Scientifically Proven	Unlikely Response (= 1, = 2) (in %)	= 3 (in %)	Likely Response (= 4, = 5) (in %)
Strongly disagree/disagree	24	29	47
No opinion	21	37	43
Strong agree/agree	18	31	51

	Irrigate More (N = 952)		
Climate Change Has Been Scientifically Proven	Unlikely Response (= 1, = 2) (in %)	= 3 (in %)	Likely Response (= 4, = 5) (in %)
Strongly disagree/disagree	56	18	26
No opinion	52	30	18
Strong agree/agree	50	22	32

	Buy More Crop Insurance (N = 985)		
Climate Change Has Been Scientifically Proven	Unlikely Response (= 1, = 2) (in %)	= 3 (in %)	Likely Response (= 4, = 5) (in %)
Strongly disagree/disagree	24	30	45
No opinion	17	35	48
Strong agree/agree	19	25	56

	Modify Lease/Rental Arrangements (N = 967)		
Climate Change Has Been Scientifically Proven	Unlikely Response (= 1, = 2) (in %)	= 3 (in %)	Likely Response (= 4, = 5) (in %)
Strongly disagree/disagree	24	33	44
No opinion	20	38	42
Strong agree/agree	20	30	51

	Leave Farming (N = 993)		
Climate Change Has Been Scientifically Proven	Unlikely Response (= 1, = 2) (in %)	= 3 (in %)	Likely Response (= 4, = 5) (in %)
Strongly disagree/disagree	27	26	47
No opinion	34	22	44
Strong agree/agree	25	25	50