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Seeing is not always believing: crop loss and climate change perceptions among farm advisors

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Abstract

As climate change is expected to significantly affect agricultural systems globally, agricultural farm advisors have been increasingly recognized as an important resource in helping farmers address these challenges. While there have been many studies exploring the climate change belief and risk perceptions as well as behaviors of both farmers and agricultural farm advisors, there are very few studies that have explored how these perceptions relate to actual climate impacts in agriculture. Here we couple survey data from United States Department of Agriculture farm service employees ($n = 6,514$) with historical crop loss data across the United States to explore the relationship of actual climate-related crop losses on farm to farm advisor perceptions of climate change and future farmer needs. Using structural equation modelling we find that among farm advisors that work directly with farms on disaster and crop loss issues, there is a significant positive relationship between crop loss and perceived weather variability changes, while across all farm advisors crop loss is associated with reduced likelihood to believe in anthropogenic climate change. Further, we find that weather variability perceptions are the most consistently and highly correlated with farm advisors' perceptions about the need for farm adaptation and future farmer needs. These results suggest that seeing crop loss may not lead to climate change belief, but may drive weather variability perceptions, which in turn affect farm adaptation perceptions. This lends further evidence to the debate over terminology in climate change communication and outreach, suggesting that weather variability may be the most salient among agricultural advisors.

1. Introduction

There is a growing focus on climate change adaptation research in agriculture spanning disciplines ranging from crop modelling to human behavior. In the social sciences, most literature explores farmer perceptions of climate change and behaviors (e.g. (Prokopy *et al* 2015b, Chatrchyan *et al* 2017, Roesch-McNally *et al* 2018)), particularly through farmer surveys (Davidson 2016). More recently however, researchers have acknowledged the important role that farmer networks can play in affecting adoption of practices and influencing behaviors (Lubell *et al* 2014). Farm advisors, Extension and other professionals often interact frequently with farmers and are trusted sources of information (Arbuckle *et al* 2013), leading to increased focus on the role of farm advisors, industry professionals, and Cooperative Extension in tackling on-farm climate change adaptations. Studies also examine these individuals' perceptions of climate change risks and attitudes towards adaptation (Arbuckle *et al* 2014, Prokopy *et al* 2015a, Schattman *et al* 2018). In this study we couple farm advisor survey data with historical crop loss data to advance our understanding of perceptions of climate change, personal experience with extreme weather and adaptation behaviors and needs among US Department of Agriculture (USDA) Service Center employees.

Existing work on farmer and farm advisor perceptions largely focuses on perceptions of climate change (i.e. see (Chatrchyan *et al* 2017) for a review of recent studies) without exploring these perceptions against historical climate data or weather and climate-induced impacts (Niles and Mueller 2016). Scholars have debated the relationship between climate change beliefs among the general public and observed historical climate and weather changes. For example, in Michigan, people's personal perceptions of climate change generally matched with historical climate and weather data (Akerlof *et al* 2013), whereas others found that people's existing beliefs motivate what historical changes they believe they have observed (Myers *et al* 2013) or that risk perceptions are a stronger predictor of climate change belief than personal experience (Marlon *et al* 2018). Additionally, climate change perceptions, which are drivers of adaptation behavior and support for climate policy (Niles *et al* 2013, Roesch-McNally 2018) can be affected by personal experience with climate impacts (Spence *et al* 2011, Haden *et al* 2012) as well as socio-political factors (Hamilton and Stampone 2013). Therefore understanding how perceptions of climate change relate to experienced weather and climate-induced impacts is important to assess the influence of these varying causes on climate change belief and behaviors.

In this study we explore perceptions of climate change, weather variability, and future farmer behaviors/needs among employees at the USDA, specifically the Farm Service Agency (FSA) and the Natural Resources Conservation Service (NRCS). FSA and NRCS employees are critical farm advisors across a suite of farm programs in the United States. USDA places field staff in county offices across the country to assist in carrying out the USDA mission and Farm Bill related programs. Specific to this study, NRCS field staff assist in the Conservation Planning Process (CPP) and administer technical and financial assistance to landowners interested in implementing NRCS Conservation Practices. Conversely, FSA field staff administer disaster payments and crop insurance for crops that are uninsurable under traditional federal crop insurance programs (USDA FSA 2017). FSA staff are also involved in the CPP, but this role is more administrative and these staff are not expected to provide conservation planning advice as NRCS staff are (Weiner *et al* 2018).

This is, to our knowledge, the first study to combine crop loss data with advisor perspectives of climate change and extreme events to examine relationships to those behaviors respondents believe farmers will need to adopt in the future (hereafter referred to as *perceptions of future farmer needs*). Given the visual nature of crop loss as well as the many programs that USDA implements to help farmers prevent and compensate for crop loss (e.g. crop insurance, disaster payments), USDA employees are a unique focal group. We further distinguish our analysis by comparing FSA and NRCS employee responses, which may vary due to differences in agency mission.

We aim to test the following two research questions: (1) does greater crop loss correlate with increased perceptions of climate change, weather variability and perceptions of future farmer needs? (2) Do employees from NRCS and FSA have different perspectives of climate change, weather variability and perceptions of future farmer needs?

2. Methods

2.1. Survey

Survey data used to examine our research questions were based on a national survey effort to examine NRCS and FSA employees' use of climate and weather tools, attitudes towards adaptation/mitigation, and perspectives on climate change and associated risks. Surveys were modified from an existing survey that was developed as part of the USDA National Institute of Food and Agriculture funded Useful to Usable project (Prokopy *et al* 2013). The survey was administered using the Dillman Tailored Design Method (Dillman and Smyth 2014). The survey was sent to FSA employees in November/December of 2016 and to NRCS employees in February/March of 2017. While the FSA and NRCS surveys followed very similar themes, with many identical questions, surveys were tailored to the missions of each agency through extensive review from NRCS and FSA employee partners (Wiener *et al* 2018). Over 8000 NRCS employees and 10 000 FSA employees throughout the US received the online survey. Ultimately, 4621 FSA employees and 1893 NRCS employees completed the survey, resulting in response rates of 43% and 22%, respectively, using the American Association for Public Opinion Research calculator (2011). We found no systematic bias among those who responded to the survey and those who did not (see further detail on our non-response bias test in Wiener *et al* 2018).

In this survey, we focused on employees who work directly with land managers by removing employees with position titles that indicated otherwise from the distribution list. Survey respondents were also asked if they worked directly with land managers in the beginning of the survey, and we excluded those who do not (8% of FSA respondents and 14% of NRCS respondents) from the analysis in this study, leaving a final sample size of 4238 and 1634 for FSA and NRCS respondents, respectively.

2.2. Crop loss data

Crop losses by acreage and by cause of loss (COL) were obtained from both RMA and FSA for the years 2013–2016. Losses that accounted for at least five percent of total losses in a given state averaged over the four year period were included in our analysis. These COL included Drought, Excess Moisture/Precipitation/Rain, Heat, Wind/Excess Wind, Hail, Freeze, Frost, Cold Wet Weather, Cold Winter, and Flood. A four year average of those losses was calculated for each state. Losses were then normalized by the number of acres in agricultural production per state.

$$\text{Acres of crop loss}/(\text{acres in farmland} + \text{acres in rented public grazing land}) = \%\ \text{loss per state}$$

These data were compiled from the Census of Agriculture (USDA NASS 2014), and because the Census does not include permitted grazing on public lands, grazing permit data by acre was gathered from the Bureau of Land Management (Karl 2012) and the US Forest Service (Halverson 2017).

2.3. Structural equation analysis

To explore the relationship between crop damage and perceptions of climate change, weather variability and future farmer behaviors/needs we employed a multi-step process, which utilized Stata 15 (StataCorp 2017) and SPSS AMOS (Arbuckle 2014). First, a confirmatory factor analysis using principle components was conducted to develop a variable capturing FSA and NRCS 'Weather variability perceptions' (comprised of three questions) and 'Future Behaviors' (comprised of three questions) (table 1). Eigenvalues were above one and factor loadings all greatly exceeded 0.40, a generally agreed upon cut-off point (Costello and Osborne 2005), across both the NRCS and FSA datasets. These factor results enabled the development of a scale for Weather Variability Perceptions and Perceptions of Future Farmer's Needs, which both achieve Cronbach alpha for internal consistency above 0.70, suggesting good internal validity (Nunnally 1978). Both variables are utilized as latent variables in our structural equation model (SEM).

We also developed a SEM using factors including climate change perception, crop loss data, and three control variables of NRCS and FSA respondents- age, highest level of education, and number of years working at the USDA. These variables became the basis for testing two SEMs, one with each agencies' dataset. SEMs were analyzed using maximum likelihood estimation with missing values, which are shown to be more efficient, unbiased, and with near-optimal Type 1 error rates over traditional methods such as listwise deletion when data is missing (Enders and Bandalos 2001, Allison 2003). It should be noted that post-hoc analysis generated two instances in which we correlated errors, based on hypothesized relationships. This included: (1) increased need and interest (the hypothesis that respondents who feel farmers who have not had an interest in FSA programs will be more vulnerable in the future and thus have more need for FSA programs); and (2) unusual weather and extreme events (the hypothesis that respondents who feel the weather has become more variable in the last 5 years would be correlated with extreme weather events in recent years affecting producer's management in their areas). Overview model results are reported in visuals below, with full model results in supplementary materials available online at stacks.iop.org/ERL/14/044003/mmedia including the standardized indirect effects.

3. Results

3.1. Overview statistics

On average, FSA respondents were slightly older than NRCS respondents and had fewer years of formal education. However, on average NRCS and FSA employees worked for USDA for just over 17 years. NRCS employees consistently had higher rates of agreement across all questions utilized (table 2). These results were significantly different for perception of more recent variable weather (NRCS = 3.84, FSA = 3.54), extreme weather events influencing management goals of producers (NRCS = 3.53, FSA = 3.28), belief in anthropogenic climate change (NRCS = 3.70, FSA = 3.45), and agreement that farming and ranching practices should change in the long-term (NRCS = 3.91, FSA = 3.52).

3.2. SEM-FSA

The FSA SEM indicated significant relationships for all hypothesized pathways (table 3 and figure 1, supplementary figure 1, supplementary table 1–3). We find that crop loss data is positively related to weather variability perceptions ($b = 0.064$, $p = 0.000$) but negatively related to climate perception ($b = -0.080$, $p = 0.000$) and perceptions of future farmer's needs ($b = -0.033$, $p = 0.003$). However, it is worth noting that the total effects indicate that the relationship between crop loss and future farmer's needs is positive ($b = 0.028$, supplementary table 3). This suggests that higher state levels of average crop loss was directly positively related to increased weather variability perception, but associated with decreased levels of climate change perceptions and higher perceptions of future farmer's needs. We find a positive relationship of weather variability perception to climate change perceptions ($b = 0.463$, $p = 0.000$) and a positive relationship of climate change perceptions with future farmer's needs ($b = 0.026$, $p = 0.026$) and weather variability perceptions to future farmer's needs ($b = 0.797$, $p = 0.000$). Overall goodness of fit statistics suggest an excellent fit (RMSEA = 0.045, Comparative Fit Index = 0.976).

Table 1. Overview of all latent variables utilized in the structural equation model, including eigenvalues, factor loadings and Cronbach alpha coefficient of internal validity where appropriate.

Variable	Question	Eigenvalue		Factor loading		Chi^2 (p)		Alpha	
		NRCS	FSA	NRCS	FSA	NRCS	FSA	NRCS	FSA
Weather variability perception	*Please indicate your level of agreement with each of the following statements…*	2.16	2.22			1536.02 (0.000)	4420.07 (0.000)	0.808	0.824
	In the past 5 years, I have noticed more variable/unusual weather in my area			0.834	0.834				
	Changes in weather patterns are hurting the producers in my service area			0.872	0.896				
	Extreme weather events in recent years have affected the long-term management goals of producers in my service area			0.845	0.848				
Perceptions of future farmer's needs	*Please indicate your level of agreement with each of the following statements…*	2.15	2.09			1499.84 (0.000)	3576.87 (0.000)	0.801	0.783
	To cope with increasing climate variability, changing farming and ranching practices are important for the long-term success of the producers in my service area			0.816	0.774				
	I believe there is an increased need for NRCS/ FSA programs in my service area due to changing weather patterns			0.887	0.883				
	Producers in my service area that historically have not had an interest or need for NRCS/FSA programs are or will become more vulnerable moving forward			0.835	0.845				

Table 2. Mean statistics and standard deviations for all model variables broken down by NRCS versus FSA respondents.

Variable	Question	Scale	NRCS		FSA	
			Mean	Std. Dev	Mean	Std. Dev
Weather variability perception	*Please indicate your level of agreement with each of the following statements.*	1 = Strongly disagree, 5 = Strongly agree				
	In the past 5 years, I have noticed more variable/unusual weather in my area		3.84	1.15	3.54	0.98
	Changes in weather patterns are hurting the producers in my service area		3.33	1.11	3.21	0.98
	Extreme weather events in recent years have affected the long-term management goals of producers in my service area		3.53	1.08	3.28	0.96
Perceptions of future farmer's needs	*Please indicate your level of agreement with each of the following statements.*	1 = Strongly disagree, 5 = Strongly agree				
	To cope with increasing climate variability, changing farming and ranching practices are important for the long-term success of the producers in my service area		3.91	1.12	3.52	0.92
	I believe there is an increased need for NRCS/ FSA programs in my service area due to changing weather patterns		3.38	1.13	3.31	0.98
	Producers in my service area that historically have not had an interest or need for NRCS programs are or will become more vulnerable moving forward		3.30	1.09	3.26	0.94
Climate change perception	There is increasing discussion about climate change and its potential impacts. Please select the statement that best reflects your beliefs about climate change.	Climate change (CC) is not occurring = 1; There is not sufficient evidence to know with certainty whether CC is occurring or not = 2; CC is occurring, and it is caused mostly by natural changes in the environment = 3; CC is occurring, and it is caused equally by natural changes in the environment and human activities = 4; CC is occurring, and it is caused mostly by human activities = 5	3.70	1.10	3.45	1.05
Crop loss data	4 year average of crop loss	0%–100%	9.61%	5.88%	9.61%	5.88%
Age	In what year were you born	Continuous variable (calculated year born- 2016)	47.28	11.59	49.13	26.09
Education	Please indicate your highest level of education	Some formal education, less than high-school = 1; High school graduate/ GED = 2; Some college = 3; 2 year college degree or technical degree = 4; 4 year college degree = 5; Graduate degree (MS, MD, PhD, etc) = 6	5.06	0.80	4.35	1.25
USDA	For how many years have you worked for USDA?	Continuous variable	17.48	11.33	17.24	12.12

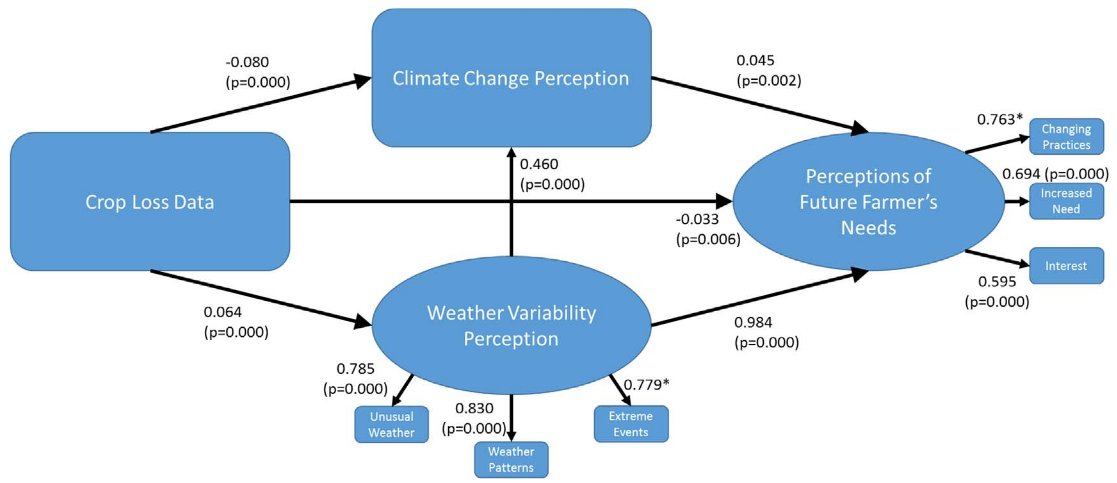

Figure 1. FSA structural equation model. Ovals indicate latent variables with squares indicating observed variables. Full SEM with covariances and control variables are included in supplementary material figure 1 and tables 1–3. Solid lines represent statistically significant relationships (which, in this model are all relationships).

Table 3. Structural equation model results for FSA Data (Structural and Latent Results). Coefficients are standardized for comparison. Goodness of fit statistics (displayed below the table) suggest an overall excellent fit. Full model results including covariances are included in supplementary materials table 1. Note that only coefficients are standardized.

	Relationship	Standardized coefficient	Standard error	Critical ratio	$p=$
Structural	Crop loss–> Climate change perception	−0.080	0.264	−5.433	0.000
	Crop loss–> Weather variability	0.064	0.218	3.709	0.000
	Crop loss–> Future farmer's needs	−0.033	0.143	−2.730	0.006
	Climate change perception–> Future farmer's needs	0.045	0.009	3.137	0.002
	Weather variability–> Future farmer's needs	0.984	0.021	43.388	0.000
	Weather variability –> Climate change perception	0.460	0.024	26.973	0.000
Latent	Weather variability–> Unusual weather	0.785	0.023	45.931	0.000
	Weather variability–> Weather patterns	0.830	0.021	52.142	0.000
	Weather variability–> Extreme events	0.779[a]	—	—	—
	Future farmer's needs–> Changing practices	0.763[a]	—	—	—
	Future farmer's needs–> Increased need	0.694	0.022	43.794	0.000
	Future farmer's needs–> Interest	0.595	0.022	36.917	0.000

Goodness of fit statistics: RMSEA $= 0.045$, CFI $= 0.976$, chi^2 $= 360.90$ $p = 0.000$,

[a] Constrained.

Table 4. Structural equation model Results for NRCS Data (Structural and Latent Results). Coefficients are standardized for comparison. Goodness of fit statistics (displayed below the table) suggest an overall excellent fit. Full model results including covariances are included in supplementary materials table 4. Note that only coefficients are standardized.

Type	Relationship	Standardized coefficient	Standard error	Critical ratio	$p=$
Structural	Crop loss–> Climate change perception	−0.120	0.348	−5.460	0.000
	Crop loss–> Weather variability	0.004	0.322	0.129	0.897
	Crop loss–> Future farmer's needs	−0.019	0.242	−1.040	0.298
	Climate change perception–> Future farmer's needs	0.025	0.021	0.984	0.325
	Weather variability–> Future farmer's needs	0.991	0.450	24.961	0.000
	Weather variability –> Climate change perception	0.567	0.039	20.232	0.000
Latent	Weather variability–> Unusual weather	0.777	0.039	28.481	0.000
	Weather variability–> Weather patterns	0.798	0.038	29.641	0.000
	Weather variability–> Extreme events	0.734[a]	—	—	—
	Future farmer's needs–> Changing practices	0.809[a]	—	—	—
	Future farmer's needs–> Increased need	0.740	0.029	31.120	0.000
	Future farmer's needs–> Interest	0.596	0.030	23.809	0.000

Goodness of fit statistics: RMSEA $= 0.047$, CFI $= 0.977$, chi^2 $= 179.70$ $p = 0.000$,

[a] Constrained.

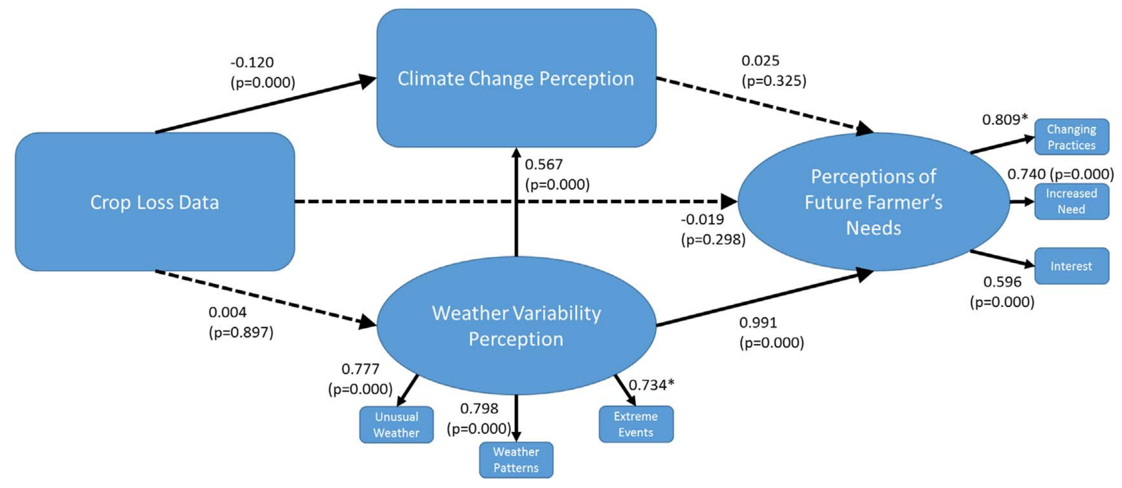

Figure 2. NRCS structural equation model. Ovals indicate latent variables with squares indicating observed variables. Full SEM with covariances and control variables are included in supplementary material figure 2 and table 4–6. Solid lines represent statistically significant relationships.

3.3. SEM-NRCS

We find fewer significant relationships in the NRCS SEM (table 4 and figure 2). Unlike the FSA respondents, we find no significant relationship between average crop loss data and weather variability perception ($b = 0.004$, $p = 0.897$) or future behaviors ($b = -0.019$, $p = 0.298$). Similar to the FSA SEM, we find that crop loss is negatively associated with climate change perceptions ($b = -0.120$, $p = 0.000$). We also find that weather variability perception is positively related to climate change perceptions ($b = 0.571$, $p = 0.000$). Similar to the FSA model, weather variability perception is positively related to perceptions of future farmer's needs ($b = 0.991$, $p = 0.000$), but unlike the FSA model, there is no significant relationship of climate change perspectives on perceptions of future farmer's needs ($b = 0.025$, $p = 0.325$). Overall goodness of fit statistics suggest an excellent fit (RMSEA = 0.047, Comparative Fit Index = 0.977).

4. Discussion

Our multiple findings detailed below have notable implications for both researchers and agency professionals. First, we consistently found that higher rates of crop loss are associated with less climate change belief among both agencies. We propose that crop loss data serves as a proxy for direct experience with climate change, specifically for individuals who work within USDA agencies associated with natural resource conservation, indemnity payments, and crop disaster designations. There are conflicting findings in the literature pertaining to the effect of direct experience on climate change perceptions. Recent research shows that individuals who experience the direct effects of climate-related extreme weather events such as flooding report higher levels of concern about climate change (Spence *et al* 2011). Other studies suggest that climate perceptions are resistant to change, even after pervasive and extreme climate-events such as drought (Carlton *et al* 2016). While our findings support the latter body of literature, climate perceptions are likely influenced by factors beyond individuals' direct experience with climate change (Akerlof *et al* 2013). Additionally, evidence suggests that the type of climate impact influences attribution of negative weather-related events to either global climate change or localized impacts associated with management practices (Whitmarsh 2008). Simply, there is strong likelihood that direct experience is one factor among many that affect climate perceptions.

Second, crop loss had a positive effect on perceptions of weather variability, though this relationship was only significant in the FSA model. This variation is potentially due to the differences in programmatic responsibilities between the two agencies. FSA's administration of many crop insurance and disaster payments necessitates acquaintance with the magnitude and causes of loss, while NRCS employees may not have professional contact with farmers during periods of crop loss, so their memory of past weather events are likely distorted in ways similar to those documented among farmers (Hansen *et al* 2004). Both interpretations align with the construct of psychological distance, meaning that occurrences that are removed from an individual's personal experience become cognitively abstract, while occurrences that happen to an individual becomes cognitively concrete (Trope and Liberman 2010) and more proximate, particularly extreme weather events (Marx *et al* 2007).

Because weather variability is more observable (Marx *et al* 2007), experienced at a personal level (Whitmarsh 2008), and less politicized than climate change (Dunlap *et al* 2016), it stands that perceptions of weather variability has a relatively strong influence on FSA and NRCS employees' perceptions of the need for on-farm adaptation among their clientele and was also influenced by crop loss. Indeed, we consistently found that perceptions of weather variability are better correlated than climate perceptions with respondents' perceptions of future farmer needs, which is supported by previous research on perceptions of weather variability and intentions of agricultural advisers to respond to such events (Arbuckle *et al* 2014, Mase *et al* 2015). Though weather variability and climate change are scientifically related, past research shows that the former is often a more palatable term among agricultural stakeholders than the latter (Arbuckle *et al* 2014), though evidence varies regionally (Chatrchyan *et al* 2017). Importantly, our findings' suggest that a lack of climate change belief does not necessarily diminish FSA and NRCS employees' intentions to provide climate and weather resources to support adaptation in their service delivery. Instead, our data indicate that framing the topic in the context of weather variability may be best suited for extension outreach both that is appealing to Extension and agency professionals, but also to farmers themselves, as other research has found that the language of weather variability, as opposed to climate change, resonates with many farmers (Arbuckle *et al* 2014). Additionally, including both perceptions of climate change and weather variability in our models explains more about respondents' intentions to support on-farm adaptation among their farmer clientele than would be possible with either variable alone (Arbuckle *et al* 2014).

Finally, the direct negative relationship between crop loss and perceptions of future farmer's needs among FSA respondents is unexpected, since we anticipated that higher rates of crop loss would positively relate to perceptions of future farmer's needs. However, as previously noted, the total effects for this relationship are positive. These results suggest that both direct and indirect effects are at play, especially since we did find that the relationship of crop loss to weather variability and then future farmer's needs was significant. One potential explanation is that FSA service provision includes assisting farmers with some federal crop insurance and disaster payment programs. Since future behaviors is in part about the need for farmers to change practices and for increased need for FSA programs, FSA employees may believe these programs already effectively assist farmers in dealing with climate-induced impacts and will continue to do so in the future. Previous work also found that crop insurance may simply be seen as a cost of doing business in most large-scale agricultural contexts, therefore reducing the sensitivity of producers to weather variability (Bryant *et al* 2000) and acting as a disincentive for purposeful adaptation (Roesch-McNally 2018).

We note several limitations of the existing study for consideration. First, state-level crop loss data minimizes the differential biophysical and socio-economic conditions of various crops (e.g. wheat, corn, almonds, pecans), and also assumes state-wide, homogenous impact of top COL, whereas many COL may be more localized (e.g. hail, flooding). Therefore, the state-level unit of analysis affects the way crop loss is experienced by the respondent. However, our analysis attempts to optimize using a common spatial unit. In instances of localized crop loss those effects may not be widely seen or experienced by USDA employees throughout that state, particularly in larger states. Second, most COL are included in our analysis; however failure in irrigation supply is not included in FSA programs, thus we may underestimate crop losses for those irrigated crops, which are especially prevalent in the American Southwest. Third, we utilize a four year average of the years leading up to the survey, which may not adequately capture an extreme event within that timeframe, or fully capture longer term shifts in climate impacts. Since extreme events can relate to climate perceptions and behaviors (Demski *et al* 2017, Rudman *et al* 2013), event-related crop losses may be underestimated in our analysis when averaged across four years. Future analyzes may link crop loss data with historical climate data to more accurately understand extreme events in this context. Finally, we acknowledge that there has been variability in the ways in which climate change belief has been measured and modelled in the recent literature and the implications this may have for the outcomes and results. We measure this belief on a five point scale, which provide greater variability than a binary outcome.

5. Conclusion

Agricultural advisors are increasingly recognized as important sources of climate change information for farmers; as such, their own perceptions of climate change may be critical for effective farm advising. Here we demonstrate the complex relationship of crop loss and personal experience with climate and weather events to perceptions of weather variability and climate change. Importantly, weather variability perceptions, not climate change belief, have the strongest correlation to predicting advisors perceptions of future farmer needs. Our work suggests that increasing crop losses may continue to influence weather variability perceptions and positively reinforce advisor perceptions of farmer needs. We suggest that additional climate perceptions research can benefit from the coupling of climate and other biophysical data to elicit similar analyzes in the future.

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