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U.S. Inland Pacific Northwest Wheat Farmers' Perceived Risks: Motivating Intentions to Adapt to Climate Change?

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Abstract: The Regional Approaches to Climate Change for the Pacific Northwest Agriculture (REACCH PNA) project was a USDA-National Institute of Food and Agriculture (NIFA) funded effort aimed at taking a comprehensive and interdisciplinary approach to understanding the implications of climate change on wheat and other cereal crop production in the inland Pacific Northwest (iPNW). As part of this project, two comprehensive surveys of wheat producers were conducted in 2012/13 and 2015/16, which included questions concerning production practices, risk perception, and attitudes towards climate change adaptation and mitigation. This paper explores farmers' anticipated adaptive responses to climate change across five different adaptation strategies, including, cropping system, crop rotation, tillage practices, soil conservation practices, and crop insurance. This research examines whether farmers anticipate making *little to no change* or *moderate to big* changes to their production system in response to climate change and whether perceived economic and environmental risks motivate farmers' intentions to adapt to climate change. I found that a small percentage (18–28%) of respondents intend on taking moderate to big action in response to predicted climate change, across both surveys and all five adaptation strategies. Further, high levels of perceived economic and environmental risks, associated with climate change and positive attitudes towards adaptation, are motivating intentions to adapt.

Keywords: agricultural adaptation; climate change; farmer decision making; wheat production; Northwest United States

1. Introduction

Dryland cereal production in the inland Pacific Northwest (iPNW) takes place in the semiarid portion of Central Washington and the Columbia Plateau in Northeast Oregon and Northern Idaho [1]. This region produces around 17% of the national wheat harvest [2], which is primarily produced for a bulk commodity export market with over 90% of grains sold to Asia [3]. Wheat is the predominant cropping system in the iPNW but many producers in the region also grow small grains, peas, and canola [4]. The dominant cropping system in the region has been driven, in part, by economic incentives, including commodity subsidies, farm programs, and global markets, which have incentivized intensive monoculture production in the region. The region has been productive but cultivation has also led to soil degradation and erosion due to intensive tillage and fallow practices [3].

Climate change is expected to impact dryland cereal production in the inland Pacific Northwest (iPNW) with concomitant ecological, agronomic, and economic impacts. The region is expected to experience warmer temperatures, particularly in summer months, and more frost-free days. Winters are also expected to be wetter but more of that precipitation will be in the form of rain, instead of snow, which is likely to be coupled with longer periods of drought during the summer and fall [5,6].

Increased temperatures can have a negative impact on wheat production, however, regional analyses suggest that increased carbon dioxide fertilization, due to elevated CO_2, and associated water use efficiency, will lead to stable or increased wheat yields until mid-to-late century [2,7,8]. However, by 2100 these yield increases are likely to level off and wheat yields may decline [6]. Additionally, warmer and drier summer conditions may lead to more fallow practices which could lead to decreased production and accelerated erosion rates [2,9]. Indirect climatic effects such as changes to pest, disease, and weed dynamics are also of concern [6]. While some model projections anticipate an increase in wheat yields, these models rely on temperature models and do not fully capture the effects of more frequent and extreme heat and other weather events that may impact production in less favorable ways [4] nor do they account for changes in grain quality as a result of warming.

Farmers will likely need to adapt both the social and ecological aspects of their production systems to create more resilient cropping systems for the future. Resilient social-ecological systems are responsive to shocks (e.g., drought) yet do not necessitate system-scale transformation, which may require fundamental shifts in cropping systems and management approaches; however, Folke et al. argue that when transformation is inevitable, "resilient systems contain the components needed for renewal and reorganization" [10] (p. 7). Climate risks however, are not driven by climatic factors alone but are also influenced by the actions that humans take, at multiple human institutional scales, to moderate risks and exploit potential benefits [11,12]. Therefore, climate change will require that farmers in the region respond to these risks and production uncertainties in both short- and long-term time frames [4]. Farmers' subsequent actions, or inactions, will impact future vulnerabilities. Some practices that can reduce vulnerability and climate risks in the region, referred to in this paper as climate adaptation best management practices (BMPs) [13], include cover crops/green manures, diversified rotations, precision management, and reduced tillage [4]. The use of crop insurance is also an economic risk management strategy used by farmers to mitigate the impacts of weather and market fluctuations on their operation [14].

Farmers may purposefully adapt their farm operations to more extreme and variable weather associated with climate change, yet they are also motivated by other goals and objectives [13,15–17]. Thus it is critical to examine how farmers situate their management decisions in the face of uncertainty posed by climate changes and how their perception of risks influence their adaptation intentions. Given the importance of the iPNW for agricultural production and livelihood maintenance of many rural communities across the region, it is essential that we understand what farmers might do in response to a changing climate.

Over the past decade, there has been a proliferation of research that examines agricultural stakeholders, including farmers, and their climate change beliefs and decision-making processes regarding climate change adaptation and mitigation, yet there is a dearth of published data from the Pacific Northwest [18]. This illustrates a gap in our understanding of diverse regional perspectives among farmers on risk perceptions and intentions to adopt climate adaptation BMPs despite the call for such regional analyses [13,18]. Specific to this study, I sought to answer key questions to better understand iPNW wheat farmers' adaptation intentions, which include: (1) How many farmers anticipate taking moderate to big changes in response to projected climate change? (2) What factors influence farmers' intentions to adapt their farm management practices, including cropping system, crop rotation, tillage, soil conservation, and crop insurance, in response to projected climate change? and (3) How do risk perceptions, both environmental and economic risks, influence adaptation intentions over time? In this study, I explore iPNW wheat farmers' responses to two surveys, administered in 2012/13 and 2015/16, which were part of a large-scale research effort designed to better understand climate impacts on dryland cereal production in the iPNW.

In the following section, I outline background literature and present a conceptual framework developed to illustrate how perceived environmental and economic risks interact and influence adaptive intentions among farmers and how this contributes to our understanding of behavioral models. The methods section outlines the survey data, analytical approach, and limitations. This is followed by a results section that highlights findings from five logistic regression models, estimated for both survey time periods, to assess farmer intentions to adapt their cropping system, crop rotation, tillage, soil conservation, and crop insurance practices in response to climate projections. The discussion and conclusion section integrates model results with ideas developed via the conceptual framework to improve our understanding of how perceived risks influence adaptive intentions. I conclude by outlining the need for future research and identify opportunities to expand educational and policy incentives to enable proactive adaptation among wheat producers in the iPNW and other agriculturally intensive regions.

1.1. Background Literature

Many social scientists agree that risk is not something independent of human society and culture but rather risk, and our understanding of it, is socially constructed [19,20]. Beck suggests that risk originates from human decision making and is thus a part of society [21]. Jaeger et al. define risk as "a situation or event in which something of human value (including humans themselves) has been put at stake and where the outcome is uncertain [22] (p. 17). Heyman suggests that risk is "a simplifying heuristic for projecting a degree of uncertainty about the future" [23] (p. 5). Therefore, conceptualizing risk emphasizes a choice between alternative and often uncertain futures [24]. Risk, however, cannot be sensed per se but rather it is perceived [25] as it is not something that we experience in our daily lives but is often tied to phenomenon that are temporally and spatially distant, or at least perceived to be so [26,27]. For many, climate change represents a temporally, and often times, spatially distant event rather than something that will have local impacts in the near-term.

1.2. Risk Perception

Risk perception is the perceived likelihood of negative consequences, given a specific phenomenon or as the consequence of a particular decision [28]. It is driven by culturally complex and uneven social experiences of uncertainty that vary across individuals, sectors, and nations and will reflect cultural values and group membership [29,30]. Slovic et al. [31] suggest that there are three dimensions of risk, which are risk as feelings, risk as analysis, and risk as politics and these components of risk influence how people perceive potential future risks. Van der Linden examines this further and suggests that risk perception associated with climate change is multidimensional and it is influenced by cognitive factors, experiential factors and socio-cultural factors, as well as socio-demographics [32]. Further, climate risk perceptions among individuals, including farmers, may not always reflect a scientific or expert-based understanding of scientific probabilities associated with risks (risk as analysis) [33] but rather may reflect the broader social and political landscape that an individual operates within (risk as politics) [34]. Indeed, normative factors significantly influence an individual's climate change risk perceptions [32].

Multiple factors influence how individuals perceive risks. Personal experiences with extreme weather events directly influencing risk perceptions and are, also significant predictors of climate change beliefs and support for adaptation [13,29,32,35–37]. Niles et al. [38] found that previous climate experiences influence farmers' perception of climate change risks because spatially, temporally, and socially "close" events influence risk perceptions and behavioral change. Schattman et al. [39], they found that Vermont farmers' climate risk perceptions are influenced by both personal experiences with extreme weather events and external information sources. Belief in anthropogenic climate change can influence farmers' perceptions of risks associated with climate change [40] and these beliefs are linked to partisan ideology [34] that drives climate science skepticism.

The long-term implications of climate change may be difficult for farmers to address, given that they already deal with seasonal, and day-to-day changes in the weather that demand their attention and response. In this vein, Stuart et al. [41] found that most farmers in Michigan did not perceive climate change as a risk or were unsure about it. Morton et al.'s [33] study of Corn Belt producers, found that 85% of respondents reported that there was too much uncertainty about the impacts of climate change to justify changing their current practices. In Niles et al. [38], researchers concluded that California farmers were more concerned about uncertainty with climate regulations than actual climate change impacts. Further, Coles and Scott found that rather than taking purposeful actions in response to climate change, "farmers and ranchers continue to rely on past experiences and short-range forecasts, hedging each year instead of taking significant risks" [42] (p. 307). However, Takahashi et al. [12] found that the majority of farmers in New York are already taking adaptive responses in light of experienced climate changes but that most felt that their actions were limited due to broader concerns about economic risks and the unpredictability of changing market conditions. This implies that there is regional as well as temporal variation in risk perception among U.S. farmers. However, others have found that actual behavioral changes associated with adaptation are driven more by perceived climate change risks than experiences with specific climate events [43].

Climatic factors are certainly not the only risks that farmers face. Farmers must confront and assess for a suite of production risks, which include uncertainty about markets, policy, and site-specific weather variability. Many may perceive that climate change is a distant threat, whereas seasonal economic risks must be prioritized and mitigated in the short-term [43,44]. Further, "farmers may not have framed climate change as a problem they need to respond to, particularly in relation to other economic (e.g., declining commodity prices) and environmental (e.g., water quality concerns with production) concerns" and therefore feel their inaction is justified [33] (p. 224). Commodity prices are a major concern for farmers who produce for commodity markets and these economic concerns are tied to broader political social, economic, and environmental events that are simultaneously occurring at local, national, and global scales, which leads to a great deal of uncertainty [42]. Coles and Scott found that many farmers in Arizona are hesitant to change their practices, if they have been successful with them in the past, because "uncertainty in the viability of new strategies as well as both climate and commodity price forecasts discourages propensity to change behaviors" [42] (p. 307).

The economic impacts of climate change, however, will depend, in part, on how farmers respond to new climatic conditions, and subsequent changes in policy and market conditions, through their adoption of adaptation strategies that are designed to mitigate risks and reduce vulnerability [36]. Therefore, how farmers adapt to climate change is based, in part, on how they perceive climate risks and their subsequent willingness to change management strategies to reduce the vulnerability of their operation.

1.3. Risk Perception Influence on Adaptive Intention Model

Based on the literature described above, a conceptual framework (Figure 1) was developed to illustrate how risk perceptions may influence farmer intentions to adapt agricultural practices to projected climate change. In addition to examining risk perception influences on adaptation intentions, this model includes attitudes towards adaptation as well as socio-demographic variables which I postulate are also important predictors of adaptation intentions.

The analysis presented in this study examines the relationship between perceived environmental and economic risks, attitudes towards adaptation, and socio-demographic characteristics' influence on iPNW wheat farmers' intentions to adapt. It is critical to note, that one would expect, based on behavioral models [45,46], that behavioral intentions drive actual behavior changes over time. These behaviors, in the context of agricultural adaptation, can either attenuate or exacerbate risks at multiple spatial and temporal scales; ideally, actual behavioral changes and their impacts would be evaluated to assess whether they generally build resilience at the farm or landscape scale [15]. However, for this analysis, I was unable to include an analysis of actual behaviors over time.

Attitudes towards adaptation have been found to be important in predicting farmer's intentions to adapt to climate change [15] and in influencing their risk perceptions due to climate change [32]. Indeed, attitude can be defined as the "affect for or against a psychological object" [47] (p. 261). With this in mind, researchers have included attitudes, or affect, as part of a conceptualization of experiential processes that link "risk as feelings" [31] to overall climate risk perceptions [32]. Further, attitudes have been found to be multidimensional and generally predictive of farmers' behavioral intentions [48–50].

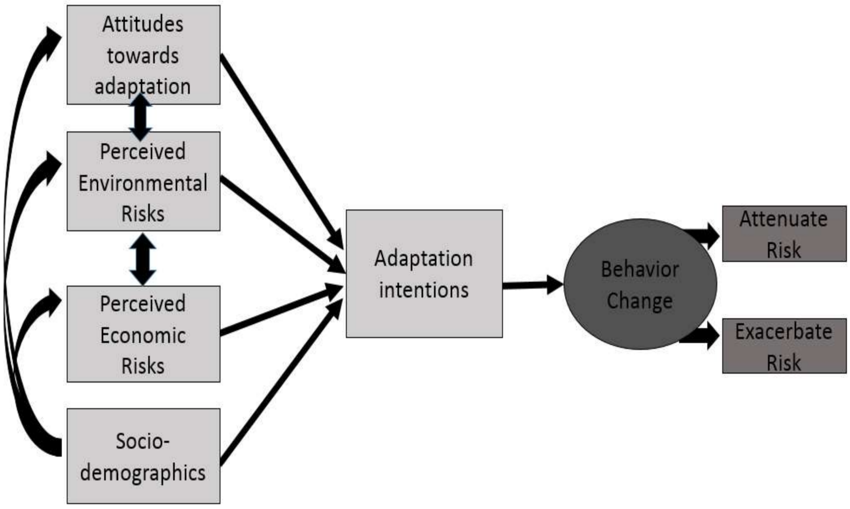

Figure 1. The Risk Perception Influence on Adaptive Intentions Model postulates the relationship between attitudes towards adaptation, perceived environmental and economic risks associated with climate change, farm/farmer background and their influence on adaptation intentions and subsequent behavior change (not examined in this study).

Farmers' risk perceptions, specifically economic and ecological risks [39] have been found to be important in behavioral models [28], particularly studies examining conservation practice adoption [51,52] and in predicting adaptation and mitigation behavioral intentions [40]. Risk perceptions are an important predictor of adaptive intentions given that researchers have found strong relationships between positive attitudes towards adaptation and higher levels of perceived climate risks [15,53,54]. Therefore, a higher perception of climate risks will influence an individual's decision to adopt adaptation strategies [28,39]. These analyses have not been conducted in the iPNW, therefore questions remain as to the strength of these associations.

There are often a number of socio-demographic characteristics that have been included as control variables to assess individual farmer characteristics that might influence intentions to change behavior. These variables, including education, age, and income have been included in a number of studies on conservation practice adoption among farmers in the U.S. [48,55] as well as in models explicitly looking at farmer responses to climate change [11,15,18,33]. When it comes to predicting climate change risk perceptions, Van der Linden suggests that studies have found little to no correlations between these variables and risk perceptions [32]. However, in the realm of conservation practice adoption, which is linked to climate adaptation best management practice adoption, Liu et al. [56] found, in their meta-analysis, that many studies have found that farmers' age, experience, education level, and gender have varying impacts on conservation practice adoption. They did report that many studies they examined found that farmers with more income and higher gross sales tended to be more likely to adopt conservation practices and one might presume that a similar relationship might hold for climate adaptation best management practices as well. However, political ideology and partisan affiliation have been found to be more salient socio-demographic characteristics that help explain risk perception [32] and climate change beliefs [34,57] as well as conservation practice adoption more generally [56].

2. Materials and Methods

2.1. Survey Data

This study reports on findings from two surveys collected as part of the Regional Approaches to Climate Change in the Pacific Northwest (REACCH PNW) project that was funded by the USDA NIFA program (Award 32011-68002-30191). The project mission was to explore climate change adaptation and mitigation strategies for the region to enhance the resilience of cereal cropping in the iPNW. Both surveys were approved by the University of Idaho Institutional Review Board (Protocol # 10-139). The survey asked a broad suite of questions regarding farm management, climate change beliefs, attitudes towards adaptation and mitigation as well as many socio-demographic questions. The survey was designed iteratively by the REACCH PNW team, engaging interdisciplinary perspectives across agronomy, soil science, entomology, economics, sociology, etc. The first survey, referred to in this paper as AP1 (Agricultural Producer Survey 1), was administered by the Social Science Research Unit (SSRU) at the University of Idaho and was conducted by mail in December 2012 and January 2013, following the Dillman et al. method [58]. This study was conducted in collaboration with the National Agricultural Statistics Services (NASS) [59] (see Table 1). The survey was administered using the National Agricultural Statistics Survey (NASS) sample frame, which consisted of 1988 unique farm operations that had 50 or more acres of wheat under production at any time in the four years prior to taking the survey and mirrored the geographic extent of the REACCH project (Figure 2).

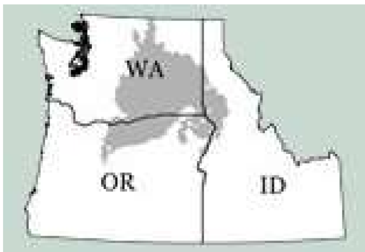

Figure 2. Regional Approaches to Climate Change in the Pacific Northwest (REACCH PNW) project area illustrating the major wheat producing region of the inland Pacific Northwest (iPNW).

A follow-up survey, referred to as AP2 (Agricultural Producer Survey 2) in this study, was administered in December 2015/January 2016 targeting wheat producers who met similar criteria as those who took AP1 (See Table 1). The AP2 survey instrument was modified slightly from the AP1 survey; however, only questions that remained the same, across both survey years, were included in this analysis. SSRU also designed and administered AP2, following the Dillman method [58], using a convenience sample of agricultural producers, due to the lack of NASS collaboration on this survey. The study was designed to sample individual farm operations from the 33 counties of the REACCH region (Figure 2) that had 100 or more acres of wheat under production in 2015. Two sample frames were used for this survey. The first frame consisted of 209 respondents from AP1 who volunteered to be contacted for AP2. The second frame consisted of producers who were classified as Oilseed and Grain Producers, which includes wheat farmers but is more inclusive of those who grow wheat in combination with other grain and oilseed crops. The total sample frame contained 1,284 unique operations.

Table 1. Details on differences in sampling between both AP1 and AP2 surveys.

Survey	Sample Frame	Characteristics of Respondents Analyzed	Final Sample Size	Response Rate	Sampling Margin of Error	Weighting
Agricultural Producers Survey 1 (AP1)	NASS Sample Frame (1988)	Respondents who farmed more than 100 acres of wheat in four years prior to survey	760	46.2% [60]	+/− 3% (95% confidence)	No weighting applied to data [61]
Agricultural Producers Survey 2 (AP2)	Convenience sample (1284)	Respondents who farmed more than 100 acres of wheat in four years prior to survey	449	42.7% [60]	+/− 4.4% (95% confidence)	Raked weights range: 0.69 and 5; coefficient of variation: 0.29, Design effect: 1.0841 [62].

2.2. Analytical Approach

A multiple logistic regression model was used to explore farmers' behavioral intentions based on their responses to the following prompt: "A climate model for the Inland Pacific Northwest predicts that the region will experience warmer/wetter winters and hotter/drier summers by 2050. If you were faced with the changes presented above, what amount of change would you likely make to the following practices for your operation?" Respondents were then asked to indicate whether they would make no change, small changes, moderate or big changes to their operation across five different adaptation responses. These adaptive responses include changes to their current cropping systems, crop rotations, tillage systems, soil conservation practices, and crop insurance (Table 2). Response levels were combined to form a binary response variable to illustrate a clearer picture of trends between those who plan on making *no to small changes* to their operations as compared to those who plan to make *moderate to big changes*. The survey question was written in a general way so it is not clear *how* farmers would take action, thus our measure only assesses whether they intend on taking action in response to the climate scenario presented in the survey. Multiple logistic regression is an appropriate modeling technique for assessing the relationship between a binary dependent variable and multiple independent variables [63]. Data conform to the assumptions of logistic regression and fit statistics are included for all final model estimations. All statistical analyses were conducted in SAS 9.4 using proc survey model statements.

Table 2. Descriptive statistics for the response variable across all five models assessed in both AP1 (n = 760) and AP2 (n = 449). Average values and standard errors are included for each variable. Each variable was measured as a binary response (0 = No change to small changes; 1 = moderate to big changes).

Response Variable	Mean (SE) AP1	Mean (SE) AP2
Adaptive Response 1: Cropping systems	0.183(0.014)	0.233 (0.020)
Adaptive Response 2: Crop rotations	0.199 (0.015)	0.249 (0.021)
Adaptive Response 3: Tillage systems	0.234 (0.016)	0.273 (0.021)
Adaptive Response 4: Soil conservation practices	0.225 (0.015)	0.254 (0.021)
Adaptive Response 5: Crop insurance	0.280 (0.017)	0.240(0.020)

2.2.1. Independent Variables

The conceptual framework developed in Figure 1, outlines factors that influence intentions to change behavior established in the literature, specifically articulated as adaptation intentions. As part of this analysis, I postulate that attitudes towards adaptation, perceived environmental and economic risks, and socio-demographic characteristics influence farmers' intentions to change their behavior in response to climate change. I used the literature to identify variables that would be included in the five adaptive response models assessed in this paper. These independent variables were organized in conceptual categories as outlined in Figure 1 and descriptive statistics are presented in Table 3.

To assess respondent's *attitudes towards adaptation*, three variables were included in the model (Table 3). One variable (Adjust_2_Change) was included that explicitly asked whether respondents agreed that they would need to make serious changes in their farm operation to adjust to climate change. The variable Changed_Weather was included to assess whether respondents who have already changed their crop rotations due to experiences with the weather, since 2007, are more likely to anticipate making additional adaptive changes based on projected climate changes. Finally, the Changed_High_Costs variable was included to assess whether farmers who have made changes, since 2007, to their crop rotation due to high input costs (fertilizer and fuel costs), were also more likely to intend on taking adaptive action.

Table 3. A total of 11 independent variables were included in each of the five adaptive strategy models. The table provides data on each variable and associated survey question, measure, and reports the mean values (standard errors) for both AP1 (n = 760) and AP2 (n = 449).

Category	Variable	Question	Measure	Mean (SE) (AP1)	Mean (SE) (AP2)
Attitudes Towards Adaptation	Adjust_2_Change	*I will have to make serious changes to my farming operation to adjust to climate change*	*5 point scale (1 = Strongly agree; 2 = Somewhat agree; 3 = Neither; 4 = Somewhat disagree; 5 = Strongly disagree)*	3.366 (0.039)	3.222 (0.054)
	Changed_Weather	*I have changed crop rotation due to weather (since 2007)*	Binary response (0 = No; 1 = Yes)	0.356 (0.019)	0.277 (0.021)
	Changed_High_Costs	*I have changed crop rotation due to high fertilizer and fuel costs (since 2007)*	Nominal scale (0 = No; 1 = high fertilizer *or* high fuel costs; 2 = high fertilizer *and* high fuel costs)	0.353 (0.027)	0.248 (0.027)
Environmental Risk Perception	CC_Env_Risk	*If climate changes as projected, please indicate the degree of environmental risk you perceive to farm production in your growing area*	*4 point scale (1 = No risk; 2 = low risk; 3 = moderate risk; 4 = High risk)*	2.332 (0.030)	2.588 (0.042)
	Less_Rel_Precip_Risk	*How great or small of a risk to your farm operation do you perceive less reliable precipitation*	*4 point scale (1 = No risk; 2 = low risk; 3 = moderate risk; 4 = High risk)*	3.211 (0.030)	3.170 (0.036)
	Longer_Drought_Risk	*How great or small of a risk to your farm operation do you perceive long-term drought*	*4 point scale (1 = No risk; 2 = low risk; 3 = moderate risk; 4 = High risk)*	3.266 (0.033)	3.433 (0.034)
Economic Risk Perception	CC_Econ_Risk	*If climate changes as projected, please indicate the degree of economic risk you perceive to farm production in your growing area*	*4 point scale (1 = No risk; 2 = low risk; 3 = moderate risk; 4 = High risk)*	2.678 (0.034)	2.990 (0.045)
	Clim_Ch_Policies_Risk	*How great or small of a risk to your farm operation do you perceive climate change policies*	*4 point scale (1 = No risk; 2 = low risk; 3 = moderate risk; 4 = High risk)*	3.311 (0.030)	3.320 (0.039)
	Costs_Inputs_Risk	*How great or small of a risk to your farm operation do you perceive cost of inputs*	*4 point scale (1 = No risk; 2 = low risk; 3 = moderate risk; 4 = High risk)*	3.646 (0.022)	3.613 (0.029)
Socio-Demographic Characteristics	Annual_Sales	*Which category best reflects your average gross annual sales from your entire farm operation?*	Ordinal scale (1 = less than $24,999; 2 = $25,000–$49,999; 3 = $50,000–$99,999; 4 = $100,000–$249,999; 5 = $250,000–$499,999; 6 = $500,000–$999,999; 7 = >$1,000,000)	5.297 (0.048)	5.303 (0.064)
	Education	*Circle the number which best describes the highest level of education you have?*	Ordinal scale (1 = Elementary school (8th grade or less); 2 = some high school; 3 = high school graduate or GED; 4 = Vocational training beyond high school; 5 = Associate's degree; 6 = some college, no degree; 7 = Bachelor's degree; 8 = Graduate/professional degree)	6.060 (0.051)	6.164 (0.064)

Three variables were included to represent the category of *perceived environmental risks* and its influence on adaptation intentions (Table 3). This includes a variable that assessed the degree of environmental risks that respondents anticipate climate change having on farm production in their growing region (CC_Env_Risk) and two variables that assess perceived risks specifically associated with changes in precipitation. This includes a variable measuring the level of risk assessed due to less reliable precipitation (Less_Rel_Precip_Risk) and long-term drought (Longer_Drought_Risk).

Three variables were included to assess the role of *perceived economic risks* on predicting adaptation intentions (Table 3). One variable explicitly measures farmers' assessment of the economic risks that climate change will have on farm production in their region (CC_Econ_Risk). The Clim_Ch_Policies_Risk variable was included to measure perceptions of risk directly linked to climate change policies, which are assumed to represent economic and regulatory uncertainty for farmers. Finally, a variable was included (Costs_Inputs_Risk) that explores respondents' perception of risks associated with high input costs and the effect this might have on their operation.

Two variables were included to capture *socio-demographic characteristics*, including annual sales and education level (Table 3).

2.2.2. Model Limitations

The differences between the sampling procedure in AP1 as compared to AP2 made it inadvisable to combine models; therefore one has to be cautious in comparing the datasets because AP1 was designed as a random sample while AP2 was a convenience sample; however applying weighting to AP2 data and focusing the analysis on farmers in both surveys who farm 100 acres or more of wheat provide us with two similar sets of respondents. Care should be taken to directly compare differences in model results across survey time periods due to the differences in sampling; however, results provide a robust illustration of key variables that influence adaptive intentions among iPNW wheat producers.

While farmers indicated whether they would make no/small or moderate/big changes, we do not know *how* these changes will occur on the landscape. Results, however, suggest that there are unique covariates that influence a farmers' intention to adapt their practices associated with cropping systems (Adaptive Response 1), crop rotation (Adaptive Response 2), tillage (Adaptive Response 3), soil conservation (Adaptive Response 4) and crop insurance (Adaptive Response 5). In the following section, results from each of these Adaptive Response models, for both survey time periods, are presented. In describing the main regression results, I emphasize covariates that are statistically significant using a p-value of <0.05. Additional variables that approach significance with p-values < 0.1 are also included in the narrative to broaden the discussion of important model relationships [64]. The American Statistical Association suggests that researchers should rely-on and interpret p-values with caution [65] therefore the raw p-values (see Tables S1–S5) for each set of covariates in each model are also reported. For each model, fit statistics, including Nagelkirke's pseudo-R^2 value and Hosmer Lemeshow, are included in these Supplementary Tables. Each model is well fitting across both survey periods, indicating that the model covariates included in the analysis illustrate robust relationships with the adaptive responses explored in this study.

3. Results

The main focus of this study is to explore what is driving adaptation intentions across five adaptive strategies that iPNW farmers may implement in response to climate change (see Table 1). Of particular interest is the role of environmental and economic risks and their influence on adaptation intentions. For all survey respondents, the percentage of those indicating that environmental risks associated with climate change present a moderate to high risk to their operation increased from 41% to 53% between survey years. Additionally, the percentage that agree that economic risks due to climate change present a moderate to high risk to their operation, increased from 60% to 68% between survey years. These descriptive statistics suggest that overall, risk perception in terms of economic and environmental impacts associated with climate change have increased over the three years between surveys (Table 4).

Table 4. Descriptive statistics for the variables CC_Env_Risk and CC_Econ_Risk for both survey AP1 (*n* = 760) and AP2 (*n* = 449). The table reports the percent of respondents who responded to this question as don't know, no risk, low risk, moderate risk, and high risk and standard error (SE) estimates for each level of response. Don't know responses were removed for the final analysis.

Risk Category	AP1 Env_Risk % (SE)	AP2 Env_Risk % (SE)	AP1 Econ_Risk % (SE)	AP2 Econ_Risk % (SE)
No Risk	14% (1.29)	10% (1.46)	11% (1.15)	7% (1.189)
Low Risk	41%(1.82)	32% (2.23)	27% (1.63)	21% (1.941)
Moderate Risk	36% (1.77)	40% (2.33)	42% (1.82)	35% (2.281)
High Risk	5% (0.82)	14% (1.64)	17% (1.4)	33% (0.25)
Don't Know	4% (0.68)	4% (0.95)	3% (0.61)	5% (1.00)

3.1. Adaptive Response 1: Cropping System

The percentage of farmer respondents who report that they will have to make moderate/big changes in their cropping system in response to projected climate change range between 18% and 23% for AP1 and AP2 surveys, respectively (Table 2). Respondents from both surveys who have already made changes to their crop rotation due to the weather (Changed_Weather) are more likely to intend to make changes to their cropping system in light of climate change (Table 5). Across both surveys, the variables measuring higher perceived environmental risks (CC_Env_Risks) and higher perceived economic risks (CC_Econ_Risks) associated with climate change were positive and statistically significant across both models thus illustrating a strong positive relationship with adaptation intentions to change cropping systems.

There are some marked differences between the cropping systems model developed for AP1 and AP2. For instance, in AP1, those who disagree that they will need to make serious changes to their operation due to climate change (Adjust_2_Change) are less likely to report that they will need to make moderate to big changes to their cropping systems in response to climate change. Additionally, total Annual_Sales has a negative and significant relationship ($p < 0.05$) with farmers' intention to adapt their cropping system to climate change for AP1 respondents yet this variable is not statistically significant for AP2 respondents. AP2 respondents who had made changes to their crop rotation due to high input costs (Changed_HighCosts) were also more likely to intend on making changes to their cropping system in light of climate change. Finally, for AP2 respondents, the variable Costs_Inputs_Risk showed a negative relationship with adaptation intentions and approached significance ($p < 0.1$). This provides weak evidence that farmers who perceive greater risk due to the change in the costs of inputs are less likely to anticipate changing their cropping system in response to climate change.

Table 5. Eleven covariates presented for five Adaptive Response models (Cropping System, Crop Rotation, Tillage, Soil Conservation, and Crop Insurance). For each variable in both survey time periods (AP1 and AP2), standardized logit coefficients, standard errors (SE), and level of significance are presented.

Category	Variables	API Cropping System STD Logit Coefficients (SE)	AP2 Cropping System STD Logit Coefficients (SE)	API Crop Rotation STD Logit Coefficients (SE)	AP2 Crop Rotation STD Logit Coefficients (SE)	API Tillage STD Logit Coefficients (SE)	AP2 Tillage STD Logit Coefficients (SE)	AP1 Soil Cons. STD Logit Coefficients (SE)	AP2 Soil Cons STD Logit Coefficients (SE)	AP1 Crop Insurance STD Logit Coefficients (SE)	AP2 Crop Insurance STD Logit Coefficients (SE)
Attitudes Towards Adaptation	Adjust_2_Change	−0.297 *** (0.115)	−0.134 (0.157)	−0.144 * (0.107)	−0.076 (0.148)	−0.169 ** (0.115)	−0.098 (0.128)	−0.155 * (0.126)	−0.072 (0.128)	−0.125 * (0.106)	−0.117 (0.137)
	Changed_Weather	0.243 ***	0.235 **	0.308 ***	0.111	0.094	0.122	0.170 **	0.050	−0.029	0.069
		(0.238)	(0.297)	(0.230)	(0.285)	(0.219)	(0.291)	(0.232)	(0.279)	(0.208)	(0.274)
	Changed_High_Costs	−0.071	0.274 ***	−0.051	0.210 **	0.040	0.131 †	0.070	0.151 *	0.085	0.108
		(0.184)	(0.232)	(0.177)	(0.222)	(0.159)	(0.216)	(0.167)	(0.202)	(0.154)	(0.222)
Environmental Risk Perception	CC_Env_Risk	0.264 **	0.284 **	0.350 ***	0.396 ***	0.258 ***	0.233 **	0.469 ***	0.285 **	0.241 **	0.259**
		(0.204)	(0.218)	(0.222)	(0.221)	(0.174)	(0.192)	(0.207)	(0.202)	(0.192)	(0.198)
	Less_Rel_Precip_Risk	0.045	0.145	0.015	−0.031	−0.039	0.102	−0.042	0.035	0.004	0.066
		(0.195)	(0.223)	(0.222)	(0.223)	(0.194)	(0.228)	(0.214)	(0.223)	(0.171)	(0.221)
	Longer_Drought_Risk	−0.029	−0.087	0.008	−0.127	0.083	−0.141	0.072	0.027	0.069	−0.107
		(0.174)	(0.253)	(0.171)	(0.246)	(0.155)	(0.229)	(0.175)	(0.221)	(0.149)	(0.216)
Economic Risk Perception	CC_Econ_Risk	0.231 *	0.549 ***	0.146	0.395 ***	0.284 ***	0.460 ***	0.219 **	0.368 ***	0.330 ***	0.250*
		(0.197)	(0.234)	(0.197)	(0.217)	(0.169)	(0.204)	(0.181)	(0.212)	(0.163)	(0.212)
	Clim_Ch_Policies_Risk	0.082	0.051	0.057	0.097	0.007	0.050	0.000	0.015	0.036	−0.091
		(0.158)	(0.162)	(0.150)	(0.170)	(0.141)	(0.177)	(0.139)	(0.173)	(0.133)	(0.175)
	Costs_Inputs_Risk	0.016	−0.139 †	0.145 †	−0.229 **	−0.042	−0.008	−0.023	0.005	−0.078	−0.019
		(0.206)	(0.219)	(0.232)	(0.236)	(0.188)	(0.220)	(0.197)	(0.217)	(0.178)	(0.233)
Socio-Demographic Characteristics	Annual_Sales	−0.151 *	−0.057	−0.028	−0.125	−0.116 *	−0.330 ***	−0.095 †	−0.258 ***	−0.110 *	−0.107
		(0.089)	(0.127)	(0.085)	(0.112)	(0.079)	(0.111)	(0.082)	(0.108)	(0.077)	(0.110)
	Education	−0.017	−0.073	−0.040	0.037	−0.008	−0.153 *	−0.080	−0.192 **	−0.029	−0.059
		(0.082)	(0.105)	(0.087)	(0.102)	(0.078)	(0.102)	(0.078)	(0.101)	(0.073)	(0.099)

Note: † $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

3.2. Adaptive Response 2: Rotations

The percentage of farmer respondents who report that they will make moderate/big changes to their crop rotation in response to projected climate change range between 20% and 25% for AP1 and AP2 surveys, respectively (Table 2). Those respondents from AP1 who believe they will have to adjust their cropping system (Adjust_2_Change) to address climate change are more likely to anticipate changing their crop rotations ($p < 0.05$) (Table 5). Across both survey time periods, those who perceive higher environmental risks (CC_Env_Risk) due to climate change are more likely to intend on changing their crop rotation in response to climate change, and for AP2 respondents, higher perceived economic risks (CC_Econ_Risk) also positively influenced their intentions to adapt.

Those farmers, who responded to AP1, who have changed their crop rotations due to weather (Changed_Weather), since 2007, are more likely to anticipate changing their rotations due to projected climate change. For AP2 respondents, those farmers who have changed their crop rotation due to high input costs (Changed_High_Costs), since 2007, were more likely to intend to change their crop rotations as a climate change adaptation strategy, yet those who perceive higher risks associated with the cost of inputs (Costs_Inputs_Risk) were less likely to intend to take action. This variable approaches significance ($p < 0.1$) for AP1 yet it is the opposite sign, suggesting some evidence that those respondents from AP1 who perceive high risks due to the costs of inputs are more likely to intend on taking action to change their crop rotation.

3.3. Adaptive Response 3: Tillage Practices

The percentage of farmer respondents who report that they will make moderate/big changes to their tillage practices in response to projected climate change range between 23% and 27% for AP1 and AP2 surveys, respectively (Table 2). The more AP1 respondents who disagree with the statement that they will have to make changes to their operation to adjust (Adjust_2_Change) to climate change, the less likely they are to anticipate making changes to their tillage practices (Table 5). Those respondents from AP1 and AP2 who perceive high levels of economic risks (CC_Econ_Risk) and higher environmental risks (CC_Env_Risk) associated with climate change are also more likely to anticipate changing their tillage practices in response to climate change

For respondents in both surveys, the variables measuring Annual_Sales was positive and significant while Education was negative and significant ($p < 0.05$) in the AP2 model only. These findings suggest generally that higher education and annual sales have a negative relationship with farmers' intentions to change their tillage practices in response to a changing climate. Additionally, among AP2 respondents, the variable Changed_High_Costs approached significance ($p < 0.1$), providing weak evidence that those respondents who have already changed their cropping systems due to high input costs are more likely to anticipate changing their tillage practices in response to climate change.

3.4. Adaptive Response 4: Soil Conservation Practices

The percentage of farmer respondents who report that they will make moderate/big changes to their soil conservation practices in response to projected climate change range between 23% and 25% for AP1 and AP2 surveys, respectively (Table 2). Those farmers who agree that they will need to make changes to adapt their operation to adjust to a changing climate (Adjust_2_Change) are more likely to intend on changing their soil conservation practices among AP1 respondents (Table 5). Additionally, for those AP1 respondents who have changed their crop rotation since 2007 due to the weather (Changed_Weather) are also more likely to intend on changing their soil conservation practices in the future. Across both surveys, CC_Env_Risk and CC_Econ_Risk were positive and statistically significant and suggest that as farmers' perception of both environmental and economic risks associated with climate change increases, the more likely they are to intend on making changes to their soil conservation practices.

For AP2 respondents, it appears that socio-demographic characteristics of Annual_Sales and Education had a negative and statistically significant relationship with farmers' intentions. Annual sales approaches significance ($p < 0.01$) in the AP1 model and also illustrates a negative relationship with intentions to adapt. Generally, those farmers from AP2 with higher education and annual sales are less likely to intend on changing their soil conservation practices in response to projected climate changes.

3.5. Adaptive Response 5: Crop Insurance

The percentage of farmer respondents who report that they will make moderate/big changes to their crop insurance practices in response to projected climate change range between 24% and 28% for AP2 and AP1 surveys, respectively. Fewer respondents in AP2 are reporting that they will change their crop insurance practices as compared to AP1 (Table 2), which is a different trend when compared to the other models examined in this study. Overall, the crop insurance model is less well-fitting than the other models (see Table S5), suggesting that there may be other covariates that were not included in these models that would better explain farmers intentions to make moderate/big changes to their crop insurance practices in response to climate change (Table 5).

For those farmers who responded to AP1 and disagree that they will need to make changes to their operation to adjust to climate change (Adjust_2_Change) are less likely to intend on changing their crop insurance practices. For both survey respondents, the more they perceived high environmental risks associated with climate change (CC_Env_Risk), the more likely they were to intend on changing their crop insurance practices. This s the same relationship found for the CC_Econ_Risk variable, suggesting that perceived environmental and economic risks are driving crop insurance adaptation intentions across AP1 and AP2 respondents. Finally, for AP1 respondents, the variable Annual_Sales was significant ($p < 0.05$) and negative, suggesting that respondents with higher annual sales were less likely to anticipate changing their crop insurance practices in light of climate change.

3.6. Model Comparison

Across all the five models, and for both survey years, only about a quarter of respondents plan on taking moderate to big changes in response to predicted climate change (ranging between 18–28%), which is a relatively small number given that the majority of all respondents intend to take no or small changes. Key covariates included in the models, however, suggest some cross-cutting themes about what is driving intentions to adapt across the practices examined in this study. In the majority of models for AP1, positive attitudes towards adaptation (Adjust_2_Change) and prior action taken in response to changes in the weather (Changed_Weather) were generally found to influence farmers' intention to take adaptive action in response to climate change in the future. These relationships for AP2 respondents were much weaker to non-existent.

One major finding is that high-perceived economic and environmental risks motivate adaptive responses in each of the models examined. This illustrates the magnitude of impact that risk perceptions, tied to economic viability and environmental impacts, motivate adaptive action. Across all models, environmental risk perceptions associated with less reliable precipitation (Less_Rel_Precip_Risk) and the variable Longer_Drought_Risk were not found to be statistically significant. The economic risk perceptions associated with Clim_Ch_Policies were not found to be significant in any models and risk perceptions associated with the cost of inputs (Cost_Inputs_Risks) were weakly associated with intentions to adapt but in the cases where it was found significant, the variable was negatively associated with intentions to adapt to projected climate change suggesting that farmers may be making a tradeoff between investing in inputs versus investing in adaptation.

Perhaps the biggest differences between models for each of the five adaptive responses examined in this study were found in the crop insurance model (Adaptive Response #5), particularly due to the poorer fit of the models for AP1 and AP2. This suggests that there may be other variables, which were not included in the models explored here, that more adequately explain farmers' intentions to change their crop insurance practices in response to climate change. These results suggest that there may be different relationships between risk management strategies, such as Adaptive Responses 1–4, which could be characterized as climate adaptation BMPs, as compared to crop insurance. Crop insurance would be considered a direct financial risk management practice which is used to buffer against damaging financial and climatic events.

The Annual_Sales variable was negative and significant in four out of five models for AP1 and 2 out of five models for AP2. Education was only found significant in two of the AP2 models. These variables were generally found to have a negative relationship with the adaptation responses explored, thus suggesting that farmers with higher education and higher farm revenue may not anticipate taking further adaptive action on their farms; however, it may be that these farmers have already taken adaptive responses on their farms and thus do not perceive the need for taking additional action.

4. Discussion

This study provides important and original findings on the role of risk perceptions and their influence on iPNW farmers' adaptation intentions among five adaption strategies examined across two survey time periods. These findings deliver much needed regional analyses of iPNW wheat producers' adaptation intentions not previously available. This study examined the Risk Perception Influence on Adaptive Intentions Model (Figure 1), which postulates that attitudes towards adaptation, perceived economic and environmental risks associated with climate change, and key socio-demographic factors influence farmers' adaptive intentions. These findings provide linkages to existing literature and illustrate important gaps in our qualitative understanding of farmers' adaptation intentions in the region.

Overall, favorable attitudes towards adaptation are positively linked with farmers' intentions to take adaptive actions in response to climate change, at least among AP1 respondents. Specifically, farmers who believe that they will have to make adjustments on their farm to mitigate climate risks are generally more willing to anticipate taking adaptive actions in the future. A positive relationship between attitudes towards adaptation and intentions to adapt has been found across other cropping systems in the U.S. [11,13,15]. Generally, positive attitudes associated with the use of new technologies and practices have been found to be broadly predictive of farmers' intentions to adopt other best management practices [52,66] and are consistently positive predictors of behavioral intentions [15,48–50]. This study provides some regional validation for these behavioral models. Further, the significance of the variables assessing whether farmers have previously made changes to their crop rotations due to weather (Changed_Weather) or high input costs (Changed_High_Costs), specifically for the crop rotation, cropping system, and soil conservation models, suggests that previous actions taken to mitigate weather and financial risks have some influence on farmers' intentions for taking future adaptive actions on their farms. This aligns with previous research that found that Midwestern farmers' current use of conservation practices, also categorized as adaptation BMPs, are a good indicator of what farmers intend on doing in the future [15]. However, other research suggests that historical behavior is not always the most important indicator of behavioral intentions or realized behavioral change [66,67].

Climate change risks are unique because they are not "situated" in our daily environment and thus their potential risks are not necessarily directly experienced [27]; however, more and more extreme weather events are being associated with climate change [68,69] and direct personal experiences with climate risks can be a predictor of climate change risk perceptions [35,39,40,53]. While this work did not draw direct connections between experiences with extreme events and adaptive intentions, my findings do suggest that climate risk perceptions, associated with both economic and environmental risks, are strong predictors of adaptation intentions. As risk perceptions increase, the more likely an individual farmer is to predict that they will need to take action to respond to climate change. Mase et al. [11] found that perceived risks from weather and climate threats was one of the most important factors in influencing Corn Belt farmers' adaptation behaviors (e.g., in-field and edge of field conservation practices, purchasing additional crop insurance, and adding new technologies). Arbuckle et al. [40] found that that Corn Belt farmers with higher levels of risk perception indicated greater willingness to take adaptive action on their farms. Schattman et al. [39] found that Vermont farmers are prioritizing adaptation activities, over mitigation activities, and that perceptions of climate risks had shaped farmer motivations for engaging in adaptation activities.

Farmer socio-demographics did not prove to be very explanatory in the models assessed. However, results do suggest that higher farm sales and in some cases, education, can limit farmers' willingness to adapt their management practices to mitigate risks associated with future climate impacts. Higher levels of education have not necessarily been found to positively influence risk perceptions [32], although they have been found to positively influence whether U.S. Corn Belt farmers intend on adapting their farm operations to climate change [15]. It is likely that including socio-demographic variables that reflect a farmers' political ideology (also more broadly representative of normative influences) would be much more likely to prove significant in their acceptance of climate change and willingness to take adaptive actions [34,57]; however, these variables were unavailable for this analysis.

The iPNW wheat farmers are planning on taking adaptive actions in response to climate change projections for their region. However, the number of farmers who intend on taking moderate to big changes only represents about a quarter of all respondents (ranging from 18–28%), which indicates that the majority of farmers are not planning on taking action in response to climate change with regard to their cropping system, crop rotation, tillage, soil conservation, and crop insurance practices. Farmers who do not intend on taking actions in response to climate change may presume that the risks associated with taking action outweigh the risks of inaction. If the expected effect of a given action is assessed to be small or potentially negative, farmers risk aversion may reinforce inaction because any decision to adopt a new innovation or make changes to farm management presents a risk to a farmer. This is particularly true given that there will always be some immeasurable uncertainty associated with a given decision and its potential impacts [66]. In Morton et al. [33] they find that uncertainty with climate change impacts actually prevents farmers from taking action in response to climate change; thus illustrating the complexity of farmers' assessment of risks associated with taking action and their level of uncertainty given potential impacts of climate change. It is important to note that levels of uncertainty are also influenced by farmers access to information, often highly partisan in nature [70,71] and can be heavily reliant on advisors who may or may not have the most accurate climate change information [33,40] and may also be part of the group-think associated with partisan identity of rural, typically more conservative, farmers [34].

An important finding from this study suggests that farmers' intentions to make changes to crop insurance practices may differ from those intentions to adopt in-field adaptation BMPs. It may be that crop insurance is simply viewed as a cost of doing business in agriculture [13] and thus there is less variability in what farmers intend on doing because they anticipate continuing to use crop insurance to mitigate weather and economic risks. Farmers already utilize crop insurance practices to manage weather related risks, with around 85% of wheat being covered by crop insurance in [72]. Bryant et al. argue that crop insurance is an important risk management tool for farmers and yet it can "reduce the sensitivity of producers to unfavorable years and thereby reduce their propensity to adjust crop choice in response to growing season conditions" [73] (p. 196). It has also been argued that farmers are internalizing climate risks, illustrated by their demand for crop insurance and have thus internalized the burden of climate protection, rather than looking to society to reduce climate risks. This may be limiting government accountability when it comes to organizing a coherent strategy for responding to and mitigating risks associated with climate change [74]. These studies, coupled with the findings presented here, suggest a need for further research that examines the influence of crop insurance and actual crop loss claims on farmers' intentions to take adaptive actions to reduce climate risks in their operations. Crop insurance is often included with other farm-level adaptation strategies such as I have done here yet it may be inappropriate to do this. The role of crop insurance influencing adaptive behaviors is critically important yet it is difficult to separate the noise from the signal given that the majority of commodity producers in the U.S. are insuring their crops to manage interannual variability in the weather and fluctuations in the markets.

Future Research Directions

More regional qualitative research is needed, which explores the adaptive actions farmers are prioritizing and what they project they will need to do more of in response to climate change. This qualitative research would help us to better understand how farmers perceive, and define, economic and environmental risks and whether experiences with extreme weather, relationships with trusted advisors, or reliance on external information sources influences their perceptions of risk and to what extent. These data would enable researchers and agricultural advisors to assess where interventions might be needed to elevate farmers understanding of climate risks and potentially amplify their assessment of risk [29] at least to the extent that cognitive factors associated with knowledge of climate change actually influence an individual's risk assessment [32]. Finally, structural factors that constrain and enable action on the agricultural landscape [17,71,75] are critical factors in understanding behavioral intentions. Indeed, there are broader industrialization processes which are guiding commodity production systems in the U.S. that have constrained the choices that farmers are able to make which would allow for shifting management practices towards greater resilience [17,76]. Future survey work must do a better job of assessing multi-scalar influences on farmer's decision-making processes, bringing both micro- and macro-level analyses to bear. Additionally, inclusion of questions pertaining to party affiliation and partisan ideology would be useful to include in future survey instruments examining farmers' responses to climate changes given the extremely partisan beliefs associated with climate change in the U.S. [70].

5. Conclusions

Risks are accelerating due to climate change [68] and adaptation will be required of farmers in the iPNW region [4]; however, policy intervention may also be required if substantive actions are to be incentivized in order to reduce climate risks [3,17] and build capacity to conduct more climate change resilience planning [4]. It is possible that crop insurance can be harnessed in such a way to better incentivize purposeful and direct actions taken to respond to climate change. Tying crop insurance with conservation compliance efforts that incentivize climate friendly BMPs [3], such as no-till farming, reductions in crop residue removal, addition of manure/biosolids and the use of green manures and cover crops, may be a productive avenue for further exploration.

The challenges of climate change are great and the potential risks to agriculture are significant, yet farmers are already indicating some willingness to engage in adaptation strategies that are aimed at reducing climate risks, and accomplishing other management goals, in their operations. In particular, farmers who perceive greater risks associated with future predictions are more likely to anticipate taking adaptive action; therefore, improved outreach and extension efforts are needed to link existing best management practices, such as the Natural Resources Conservation Service's Soil Health Initiative [77] the USDA Climate Hubs (https://www.climatehubs.oce.usda.gov/), to increase farmer's access to information that concretizes climate risks at a regional and sectoral specific scale to drive greater willingness to take action in response to climate change. This will require greater partnerships among researchers, agricultural professionals, and farmers in conducting applied research and developing decision support tools and outreach programs that better illustrate the environmental and economic costs and benefits of climate change adaptation and mitigation activities [6].

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References

1. Eigenbrode, S.D.; Capalbo, S.M.; Houston, L.L.; Johnson-Maynard, J.; Kruger, C.; Olen, B. Agriculture: Impacts, Adaptation, and Mitigation. In *Climate Change in the Northwest: Implications for Our Landscapes, Waters and Communities*; Dalton, M.M., Mote, P.W., Snover, A.K., Eds.; Island Press: Washington, DC, USA, 2013; pp. 1–230.
2. Karimi, T.; Stockle, C.O.; Higgins, S.; Nelson, R. Climate change and dryland wheat systems in the US Pacific Northwest. *Agric. Syst.* **2018**, *159*, 144–156. [CrossRef]
3. Pan, W.L.; Schillinger, W.F.; Young, F.L.; Kirby, E.M.; Yorgey, G.G.; Borelli, K.A.; Brooks, E.S.; McCracken, V.A.; Maaz, T.M.; Machado, S.; et al. Integrating Historic Agronomic and Policy Lessons with New Technologies to Drive Farmer Decisions for Farm and Climate: The Case of Inland Pacific Northwestern U.S. *Front. Environ. Sci.* **2017**, *5*, 1–22. [CrossRef]
4. Kruger, C.; Allen, E.; Abatzoglou, J.; Rajagopalan, K.; Kirby, E. Climate Considerations. In *Advances in Dryland Farming in the Inland Pacific Northwest*; Yorgey, G., Kruger, C., Eds.; Washington State University: Pullman, WA, USA, 2017; pp. 1–615.
5. Mote, P.W.; Abatzoglou, J.T.; Kunkel, K.E. Climate variability and change in the past and future. In *Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities*; Dalton, M.M., Mote, P.W., Snover, A.K., Eds.; Island Press: Washington, DC, USA, 2013; pp. 25–40.
6. Yorgey, G.G.; Hall, S.A.; Allen, E.R.; Whitefield, E.M.; Embertson, N.M.; Jones, V.P.; Saari, B.R.; Rajagopalan, K.; Roesch-McNally, G.E.; Van Horne, B.; et al. Northwest U.S. Agriculture in a Changing Climate: Collaboratively Defined Research and Extension Priorities. *Front. Environ. Sci.* **2017**, *5*, 1–20. [CrossRef]
7. Tubiello, F.N.; Soussana, J.F.; Howden, S.M. Crop and pasture response to climate change. *Proc. Natl. Acad. Sci. USA* **2007**, *104*, 19686–19690. [CrossRef] [PubMed]
8. Stöckle, C.O.; Higgins, S.; Nelson, R.; Abatzoglou, J.; Huggins, D.; Pan, W.; Karimi, T.; Antle, J.; Eigenbrode, S.D.; Brookes, E. Evaluating Opportunities for and Increased Role of Winter Crops as Adaptation to Climate Change in Dryland Cropping Systems of the US Inland Pacific Northwest. *Clim. Chang.* **2018**, *146*, 247–261. [CrossRef]
9. Kaur, H.; Huggins, D.R.; Rupp, R.A.; Abatzoglou, J.T.; Stockle, C.O.; Reganold, J.P. Agro-Ecological Class Stability Decreases in Response to Climate Change Projections for the Pacific Northwest, USA. *Front. Ecol. Evol.* **2017**, *5*, 74. [CrossRef]
10. Folke, C.; Carpenter, S.; Elmqvist, T.; Gunderson, L.; Holling, C.S.; Walker, B. Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations. *Ambio* **2002**, *31*, 437–440. [CrossRef] [PubMed]
11. Mase, A.S.; Gramig, B.M.; Prokopy, L.S. Climate change beliefs, risk perceptions, and adaptation behavior among Midwestern U.S. crop farmers. *Clim. Risk Manag.* **2017**, *15*, 8–17. [CrossRef]
12. Takahashi, B.; Burnham, M.; Terracina-Hartman, C.; Sopchak, A.R.; Selfa, T. Climate Change Perceptions of NY State Farmers: The Role of Risk Perceptions and Adaptive Capacity. *Environ. Manag.* **2016**, *58*, 946–957. [CrossRef] [PubMed]
13. Schattman, R.E.; Ernesto Mendez, V.; Merrill, S.C.; Zia, A. Mixed methods approach to understanding farmer and agricultural advisor perceptions of climate change and adaptation in Vermont, United States. *Agroecol. Sustain. Food Syst.* **2018**, *42*, 121–148. [CrossRef]

14. Bowman, M.S.; Zilberman, D. Economic Factors Affecting Diversified Farming Systems. *Ecol. Soc.* **2013**, *18*, 33. [CrossRef]
15. Roesch-McNally, G.E.; Arbuckle, J.G.; Tyndall, J.T. What Would Farmers Do? Adaptation intentions under a Corn Belt climate change scenario. *Agric. Hum. Values* **2017**, *34*, 333–346. [CrossRef]
16. Roesch-McNally, G.E.; Arbuckle, J.G.; Tyndall, J.T. Soil as social-ecological feedback: Examining the "ethic" of soil stewardship among Corn Belt farmers. *Rural Sociol.* **2017**. [CrossRef]
17. Roesch-McNally, G.E.; Arbuckle, J.G.; Tyndall, J.T. Barriers to implementing climate resilient agricultural strategies: The case of crop diversification in the U.S. Corn Belt. *Glob. Environ. Chang.* **2018**, *48*, 206–215. [CrossRef]
18. Chatrchyan, A.M.; Erlebacher, R.C.; Chaopricha, N.T.; Chan, J.; Tobin, D.; Allred, S.B. United States agricultural stakeholder views and decisions on climate change. *WIREs Clim. Chang.* **2017**. [CrossRef]
19. Slovic, P. Perception of risk: Reflections on the psychometric paradigm. In *Social Theories of Risk*; Krimsky, S., Golding, D., Eds.; Praeger: Westport, CT, USA, 1992; pp. 117–152.
20. Sjöberg, L. Strength of belief and risk. *Policy Sci.* **1979**, *11*, 39–57. [CrossRef]
21. Beck, U. *Risk Society: Towards a New Modernity*; Sage: Thousand Oaks, CA, USA, 1992; pp. 1–272.
22. Jaeger, C.C.; Webler, T.; Rosa, E.A.; Renn, O. *Risk, Uncertainty and Rational Action*; Taylor & Francis: New York, NY, USA, 2001; pp. 1–313.
23. Heyman, B. Introduction. In *Risk, Health, and Health Care*; Heyman, B., Ed.; Arnold: London, UK, 1998; pp. 1–23.
24. Rosa, E.; McCright, A.; Renn, O. *The Risk Society Revisited: Social Theory and Risk Governance*; Temple University Press: Philadelphia, PA, USA, 2014.
25. Fischoff, B.; Slovic, P.; Lichtenstein, S. The "public" vs. the "experts": Perceived vs. actual disagreement about the risks of nuclear power. In *Analysis of Actual vs. Perceived Risks*; Covello, V., Flamm, G., Rodericks, J., Tardiff, R., Eds.; Plenum: New York, NY, USA, 1983; pp. 235–249.
26. Haden, V.R.; Niles, M.T.; Lubell, M.; Perlman, J.; Jackson, L.E. Global and Local Concerns: What Attitudes and Beliefs Motivate Farmers to Mitigate and Adapt to Climate Change. *PLoS ONE* **2012**, *7*, e52882. [CrossRef] [PubMed]
27. Helgeson, J.; van der Linden, S.; Chabay, I. The role of knowledge, learning and mental models in perceptions of climate change related risks. In *Learning for Sustainability in Times of Accelerating Change*; Wals, A., Corcoran, P.B., Eds.; Wageningen Academic Publishers: Wageningen, The Netherlands, 2012; pp. 329–346.
28. O'Connor, R.E.; Bord, R.J.; Fisher, A. Risk Perceptions, General Environmental Beliefs, and Willingness to Address Climate Change. *Risk Anal.* **1999**, *19*, 461–471. [CrossRef]
29. Kasperson, R.E.; Renn, O.; Slovic, P.; Brown, H.S.; Emel, J.; Goble, R.; Kasperson, J.X.; Ratick, S. The Social Amplification of Risk: A Conceptual Framework. *Risk Anal.* **1988**, *8*, 177–187. [CrossRef]
30. Slovic, P. Perception of Risk. *Science* **1987**, *236*, 280–285. [CrossRef] [PubMed]
31. Slovic, P.; Finucane, M.L.; Peters, E.; MacGregor, D.G. Risk as Analysis and Risk as Feelings: Some Thoughts about Affect, Reason, Risk, and Rationality. *Risk Anal.* **2004**, *24*, 311–322. [CrossRef] [PubMed]
32. Van der Linden, S. The Social-psychological determinants of climate change risk perceptions: Towards a comprehensive model. *J. Environ. Psychol.* **2015**, *41*, 112–124. [CrossRef]
33. Morton, L.W.; Roesch-McNally, G.E.; Wilke, A. Upper Midwest Farmer Perceptions: Too Much Uncertainty about Impacts of Climate Change to Justify Changing Current Agricultural Practices. *J. Soil Water Conserv.* **2017**, *72*, 215–225. [CrossRef]
34. Running, K.; Burke, J.; Shipley, K. Perceptions of Environmental Change and Climate Concern among Idaho's Farmers. *Soc. Nat. Resour.* **2016**, *30*, 659–673. [CrossRef]
35. Van der Linden, S. On the relationship between personal experience, affect and risk perception: The case of climate change. *Eur. J. Soc. Psychol.* **2014**, *44*, 430–440. [CrossRef] [PubMed]
36. Menapace, L.; Colson, G.; Raffaelli, R. Climate change beliefs and perceptions of agricultural risks: An application of the exchangeability method. *Glob. Environ. Chang.* **2015**, *35*, 70–81. [CrossRef]
37. Eakin, H.; York, A.; Aggarwal, R.; Waters, S.; Welch, J.; Rubiños, C.; Smith-Heisters, S.; Bausch, C.; Anderies, J.M. Cognitive and institutional influences on farmers' adaptive capacity: Insights into barriers and opportunities for transformative change in central Arizona. *Reg. Environ. Chang.* **2016**, *16*, 801–814. [CrossRef]

38. Niles, M.T.; Lubell, M.; Haden, V.R. Perceptions and responses to climate policy risks among California farmers. *Glob. Environ. Chang.* **2013**, *23*, 1752–1760. [CrossRef]
39. Schattman, R.; Conner, D.; Mendez, V.E. Farmer perceptions of climate change risk and associated on-farm management strategies in Vermont, northeastern United States. *Elementa* **2016**, *4*, 1–14. [CrossRef]
40. Arbuckle, J.G.; Morton, L.W.; Hobbs, J. Understanding Farmer Perspectives on Climate Change Adaptation and Mitigation: The Roles of Trust in Sources of Climate Information, Climate Change Beliefs, and Perceived Risk. *Environ. Behav.* **2015**, *47*, 205–234. [CrossRef] [PubMed]
41. Stuart, D.; Schewe, R.; McDermott, M. Responding to Climate Change Barriers to Reflexive Modernization in US Agriculture. *Org. Environ.* **2012**, *25*, 308–327. [CrossRef]
42. Coles, A.R.; Scott, C. Vulnerability and adaptation to climate change and variability in semi-arid rural southeastern Arizona, USA. *Nat. Resour. Forum* **2009**, *33*, 297–309. [CrossRef]
43. Esham, M.; Garforth, C. Agricultural adaptation to climate change: Insights from a farming community in Sri Lanka. *Mitig. Adapt. Strateg. Glob. Chang.* **2013**, *18*, 535–549. [CrossRef]
44. Holloway, L.E.; Ibery, B.W. Farmers' attitudes towards environmental change, particularly global warming, and the adjustment of crop mix and farm management. *Appl. Geogr.* **1996**, *16*, 159–171. [CrossRef]
45. Ajzen, I. The Theory of Planned Behavior. *Org. Behav. Hum. Decis. Process.* **1991**, *50*, 179–211. [CrossRef]
46. Fishbein, M.; Ajzen, I. *Predicting and Changing Behavior: The Reasoned Action Approach*; Taylor and Francis: New York, NY, USA, 2015.
47. Thurstone, L.L. The measurement of social attitudes. *J. Abnorm. Soc. Psychol.* **1931**, *26*, 249–269. [CrossRef]
48. Prokopy, L.S.; Floress, K.; Klotthor-Weinkauf, D.; Baumgart-Getz, A. Determinants of agricultural best management practice adoption: Evidence from the literature. *J. Soil Water Conserv.* **2008**, *63*, 300–311. [CrossRef]
49. Baumgart-Getz, A.; Prokopy, L.S.; Floress, K. Why Farmers Adopt Best Management Practice in the US: A meta-analysis of the adoption literature. *J. Environ. Manag.* **2012**, *96*, 17–25. [CrossRef] [PubMed]
50. Reimer, A.P.; Thompson, A.W.; Prokopy, L.S. The multi-dimensional nature of environmental attitudes among farmers in Indiana: Implications for conservation adoption. *Agric. Hum. Values* **2012**, *29*, 29–40. [CrossRef]
51. Marra, M.; Pannell, D.J.; Ghadim, A.A. The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: Where are we on the learning curve? *Agric. Syst.* **2003**, *75*, 215–234. [CrossRef]
52. Wilson, R.S.; Howard, G.; Burnett, E.A. Improving nutrient management practices in agriculture: The role of risk-based beliefs in understanding farmers' attitudes toward taking additional action. *Water Resour. Res.* **2014**, *50*, 6735–6746. [CrossRef]
53. Brody, S.D.; Zahran, A.; Grover, H. Examining the Relationship between Physical Vulnerability and Public Perceptions of Global Climate Change in the United States. *Environ. Behav.* **2008**, *40*, 72–95. [CrossRef]
54. Arbuckle, J.G.; Prokopy, L.S.; Haigh, T.; Hobbs, J.; Knoot, T.; Knutson, C.; Loy, A.; Mase, A.S.; McGuire, J.; Wright Morton, L.; et al. Climate Change Beliefs, Concerns, Attitudes towards adaptation and mitigation among farmers in the Midwestern United States. *Clim. Chang. Lett.* **2013**, *117*, 943–950. [CrossRef]
55. Knowler, D.; Bradshaw, B. Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food Policy* **2007**, *32*, 25–48. [CrossRef]
56. Liu, T.; Bruins, R.J.; Heberling, M.T. Factors Influencing Farmers' Adoption of Best Management Practices: A Review and Synthesis. *Sustainability* **2018**, *10*, 432. [CrossRef]
57. Stuart, D. Climate Change and Ideological Transformation in United States Agriculture. *Sociol. Rural* **2018**. [CrossRef]
58. Dillman, D.A.; Smyth, J.D.; Christian, L.M. *Internet, Mail, and Mixed-Mode Surveys: The Tailored Design Method*, 3rd ed.; John Wiley & Sons: New York, NY, USA, 2009; pp. 1–499.
59. National Agricultural Statistics Service (NASS). *State and County Data*; U.S. Department of Agriculture: Washington, DC, USA, 2014.
60. The American Association for Public Opinion Research (AAPOR). *Standards Definitions: Final Disposition of Case Codes and Outcome Rates for Surveys*, 4th ed.; APPOR: Lenexa, KS, USA, 2011.
61. Seamon, E.; Roesch-McNally, G.E.; McNamee, L.; Roth, I.; Wulfhorst, J.D.; Eigenbrode, S.D.; Daley Laursen, D. *Producer perceptions on climate change and agriculture: A statistical atlas*; University of Idaho Agricultural Economic Extension Series 1701; USDA National Institute for Food and Agriculture: Moscow, ID, USA, 2017.

62. McNamee, L.; Roth, I.; Wulfhurst, J.D.; Social Science Research Unit. University of Idaho, Moscow, ID, USA. Personal communication, 4 August 2016.
63. Hair, J.F., Jr.; Black, W.C.; Babin, B.J.; Anderson, R.E. *Multivariate Data Analysis*; Prentice Hall: Saddle River, NJ, USA, 2010.
64. Greenland, S.; Senn, S.J.; Rothman, K.J.; Carlin, J.B.; Poole, C.; Goodman, S.N.; Altman, D.G. Statistical tests, P values, confidence intervals and power: A guide to misinterpretations. *Eur. J. Epidemiol.* **2016**, *31*, 337–350. [CrossRef] [PubMed]
65. Wasserstein, R.L.; Lazar, N.A. The ASA's statement on p-values: Context, process, and purpose. *Am. Stat.* **2016**, *70*, 129–133. [CrossRef]
66. Greiner, R.; Patterson, L.; Miller, O. Motivations, risk perceptions and adoption of conservation practices by farmers. *Agric. Syst.* **2009**, *99*, 86–104. [CrossRef]
67. Schattman, R.E.; Roesch-McNally, G.E.; Wiener, S.; Niles, M.T.; Iovanna, R.; Carey, M.; Hollinger, D.Y. Perceptions of weather and climate risks, use of weather information, and the influence of crop loss: Results from a survey of FSA employees in the United States. *Renew. Agric. Food Syst.* **2018**. [CrossRef]
68. U.S. Global Climate Change Research Program (USGCRP). *Climate Science Special Report: Fourth National Climate Assessment, Volume I*; Wuebbles, D.J., Fahey, D.W., Hibbard, K.A., Dokken, D.J., Stewart, B.C., Maycock, T.K., Eds.; U.S. Global Change Research Program: Washington, DC, USA, 2017; pp. 1–470.
69. Coumou, D.; Rahmstorf, S. A decade of weather extremes. *Nat. Clim. Chang.* **2012**, *2*, 491–496. [CrossRef]
70. McCright, A.M.; Dunlap, R.E. Cool dudes: The denial of climate change among conservative white males in the United States. *Glob. Environ. Chang.* **2011**, *21*, 1163–1172. [CrossRef]
71. Bolin, J.L.; Hamilton, L.C. The News You Choose: News media preferences amplify views on climate change. *Environ. Politics* **2018**, 1–22. [CrossRef]
72. U.S. Department of Agriculture-Risk Management Agency (USDA-RMA). 2016. Available online: https://www.rema.usda.gov/ (accessed on 16 February 2018).
73. Bryant, C.R.; Smit, B.; Brklacich, M.; Johnston, T.R.; Smithers, J.; Chiotti, Q.; Singh, B. Adaptation in Canadian agriculture to climatic variability and change. *Clim. Chang.* **2000**, *45*, 181–201. [CrossRef]
74. Ribot, J. Cause and response: Vulnerability and climate in the Anthropocene. *J. Peasant Stud.* **2015**, *41*, 667–705. [CrossRef]
75. Stuart, D.; Gillon, S. Scaling up to address new challenges to conservation on US farmland. *Land Use Policy* **2013**, *31*, 223–236. [CrossRef]
76. Hendrickson, M.K.; James, H.S., Jr. The ethics of constrained choice: How the industrialization of agriculture impacts farming and farmer behavior. *J. Agric. Environ. Ethics* **2005**, *18*, 269–291. [CrossRef]
77. Natural Resources Conservation Service (NRCS). *Soil Health*; U.S. Department of Agriculture: Washington, DC, USA, 2015. Available online: http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/ (accessed on 16 February 2018).