Farmers' environmental perceptions and preferences regarding climate change adaptation and mitigation actions – towards a sustainable agricultural system in México

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Abstract: Climate change compromises sustainable agricultural development. It has deep economic, environmental, and social impacts, particularly on vulnerable rural regions in developing countries where agriculture constitutes the backbone of the economy. This study analyzes farmers' preferences regarding the potential implementation of several mitigation and adaptation actions addressing climate change. Data were collected on 370 farmers in the "Valle del Carrizo" region of northwestern México. Using the Analytical Hierarchy Process (AHP) methodology, the farmers' preferred mitigation and adaptation actions were identified and related to their stated attitudes regarding risks using the Multiple Price List (MPL) lotteries approach. Farmers' environmental beliefs and perceptions as key means of understanding concepts of sustainability were related to their preferences. The use of less polluting machinery and investment in improving irrigation infrastructure were identified as the most preferred actions. Environmental opinions reviewed using the New Ecological Paradigm (NEP) scale allowed for the identification of the participants' ecocentric and anthropocentric attitudes, highlighting the commitment of most farmers to the sustainable use of natural resources. Agricultural policies should be developed according to farmers' preferences and behaviors. The design and implementation of measures and policy tools addressing climate change should be inclusive and developed at the micro-level considering farm and farmer typologies.

Keywords: climate change, adaptation, mitigation, sustainable agriculture, environmental factors, Analytical Hierarchy Process, New Ecological Paradigm scale.

1. Introduction

Climate change is one of the most significant challenges facing human society. The ways in which weather events are developing pose social, economic, and environmental risks and are raising more concern with the appearance of various unexpected phenomena such as floods, storms, droughts, and heat waves. Climate change refers to the variation of the earth's climate generated either by natural causes or human actions that affect the variability of climatic parameters such as temperature, rainfall, and drought [Gan et al., 2016].

Climate change compromises sustainable agricultural development, which is based on three converging levels of environmental, economic, and social impact. Climate change is not only an environmental phenomenon, but it has also deep economic and social consequences, especially for vulnerable developing countries, posing great challenges to their agricultural development and welfare [Tesfahunegn, Mekonen, & Tekle, 2016]. The effects of climate change are closely related to a decline in economic growth, complicating efforts to reduce poverty and to ensure the food security of marginalized local agricultural communities [López & Hernández, 2016].

Agriculture is of great importance to the economic development of developing countries and constitutes the backbone of their economies by providing their populations with food, raw materials, and employment opportunities [Ogen, 2007]. Socially, agriculture forms the basis for achieving food security, which basically depends on the eradication of extreme poverty and hunger [Von Braun, Swaminathan & Rosegrant, 2004]. Agriculture is essential to community livelihoods in rural and marginal areas. In this context, agricultural policies and public intervention in rural communities are necessary tools that contribute to the reduction of poverty as part of an economic and social development approach [Croppenstedt, Knowles, & Lowder, 2018].

Climatic patterns are the most significant input factor for agricultural production [Frutos et al., 2018], and their variability is closely related to output productivity. At the same time, the agricultural sector and animal farming in particular constitute an important source of greenhouse gas (GHG) emissions, which are closely related to climate change [Rivera & DiPaola, 2013]. Agriculture in regions of Africa and Latin America is most vulnerable to climate change due to its geographic positioning and because local economies and populations rely heavily on agriculture activities for subsistence purposes, especially in rural and marginal areas [Ortiz, 2012].

In the study region examined in the present work, climatic conditions are extreme and have in recent years become even more atypical with high levels of precipitation occurring over short periods and with lower temperatures than normal recorded [Lara et al., 2017]. Such patterns have affected levels of agricultural production and crop quality and jeopardized food security within the region and country. Additionally, climate change projections associated with global warming establish temperature increases of 0.5°C to 1.0°C for 2020 and of 2°C to 4°C for 2080, variations in rainfall of + 10% to -20% by 2050, and a decrease in rainfall of 5% to 30% by 2080 [Flores et al., 2012]. Such patterns will increase vulnerability to flooding and other natural disasters and lead to changes in water availability mainly affecting the agricultural and livestock sectors.

Climate change is also related to societal development. Relationships between society, agriculture and economic development in rural areas are closely linked to the consequences of climate change [Valladolid, 2017; Maia, Miyamoto, & Garcia, 2018]. Currently, the effects of climate change in different regions are heterogeneous due to specific human activities and regional economic, climatic, and social characteristics [Frutos et al., 2018]. Therefore, the implementation of strategies to adapt production in agricultural systems or mitigate effects of climate change on outputs must be implemented according to each region, farmers' characteristics and farming activities [Aguiar et al., 2018; López et al., 2016].

Climate change adaptation actions corresponds to initiatives and measures focused on reducing the vulnerability of natural and human systems to effects of actual or expected climate change [IPCC, 2014] or on reducing the likelihood of an object, person or system suffering negative impacts. Not considering the effects of climate change has negative implications for adaptation capacities, resulting in a more vulnerable situation that does not contribute to environmentally sustainable agriculture [Wheaton & Kulshreshtha, 2011]. Vulnerability is generally associated with levels of poverty within a region. Adaptation is intended to limit damage caused by current and projected climate change as much as possible [Aguiar et al., 2018]. With respect to climate change adaptation, no industry has more at stake than the agricultural sector [Lee et al., 2014]. Traditional agricultural practices can be considered adaptation tools when applying improved, drought-tolerant strategies while avoiding monoculture production [Altieri et al., 2015; Galindo et al., 2014].

Mitigation actions, according to the FAO, are measures adopted to reduce greenhouse gas emissions and/or encourage the elimination of carbon through sinks. Climate change mitigation can be achieved by limiting or preventing the generation of greenhouse gas (GHG) emissions and through activities that reduce their concentrations in the atmosphere [IPCC, 2014]. To mitigate climate change, it will be necessary to reduce demand for energy and ensure that energy consumption is based on the use of low-carbon fuels. According to the two above described concepts of adaptation and mitigation, it can be generalized that mitigation is responsible for addressing the causes of climate change while adaptation focuses on reducing the effects of climate change. Since farmers depend heavily on their crops, levels of production positively or negatively affect (their income) their sustainability, reinforcing the need to implement adaptation strategies. Adaptation strategies are key to improving the efficiency and productivity of the agricultural sector [Di Falco et al., 2011] by reducing agricultural vulnerability to climate change.

Adaptation activities can range from testing and introducing new more resistant crop varieties to building retaining walls and storm barriers to protect residents and property from flooding [O'Garra, T., & Mourato, 2016]. According to Khanal et al. (2018), adaptation actions with the greatest impacts on productivity are those related to soil and water management, which is followed by a change in the sowing calendar and in crop variety selection [Khanal et al., 2018]. Specifically, a water management adaptation involves investment in the improvement in irrigation infrastructure, which results in more security in the availability of water for irrigation, in turn reducing dependence on rain cycles, allowing for the reduction of evapotranspiration, and thereby achieving more productivity with less water consumption. Similarly, the implementation of crop and variety changes or of changes in the sowing calendar as adaptation strategies ensures a higher level of production [Khanal et al., 2019]. Climate change mitigation actions are necessary to ensure that long-term agricultural productivity and food security are not compromised, ensuring the sustainability of agricultural production [Acquah., 2011]. Through the implementation of mitigation strategies such as zero tillage methods, which allow for soil conservation as erosion decreases, it is possible to generate gains in food productivity [Di Falco et al., 2011].

According whit the last, sustainable agriculture faces two main challenges: the total exploitation of natural resources and environmental pollution [Hoang & Rao, 2010]. The development of sustainable agriculture can help address the impacts of climate change. Sustainable agriculture is based on the implementation of actions that help conserve environmental and economic resources such as water and land inputs [Bertoni et al., 2018]. Sustainable agriculture involves the production of food and other inputs through farmers' efforts and institutional participation in the use of new technologies while preserving the environment and natural resources to meet current societal needs and guarantee a better quality of life without compromising the resources of future generations [Mubiru et al., 2017].

Therefore, understanding farmers’ views and perceptions regarding climate change and the actions that they consider most effective against its impacts is critical. In particular, the analysis of farmers’ preferences for different mitigation and adaptation actions can lead to the development of more sustainable agricultural systems. Such preferences are also related to farmers’ views regarding environmental issues and to their ecocentric or anthropocentric beliefs. Environmental and ecological beliefs and opinions are key factors in understanding sustainability concept when related to agricultural activities [Reyna et al., 2018].

Within this context, the objectives of this research were to identify the relative importance of several climate change adaptation and mitigation actions related to agriculture activities in a marginal region in México in order to guide policy makers through the prioritized solutions that contribute to the sustainability of agricultural systems. Furthermore, farmers’ attitudes, opinions, and beliefs towards the environment were evaluated in association with their preferences’ patterns. The relation between farmers’ preference structures with their risk attitudes and their socioeconomic characteristics was also analyzed.

2. Materials and Methods

To reach the abovementioned objectives, several methodological approaches were applied.. The Analytical Hierarchy Process (AHP) was used to identify farmers' preferences and to estimate the relative importance (i.e. priorities) of different mitigation and adaptation actions. We also used an adapted form of the New Ecological Paradigm (NEP) Scale that was validated via factorial analysis (PCA) to identify predominant latent environmental dimensions. Using the Multiple Price Lists (MPL) method or "lotteries," an alternative approach to expected utility risk elicitation, the farmers' stated risk attitudes were estimated. Finally, a heterogeneity analysis was carried out to relate framers' preferences to actions against climate change effects based on their environmental and stated risk attitudes toward their farming activities.

Figure 1 summarizes the methodological approach applied in this study. In the following section, more information on our theoretical background and empirical application is given.

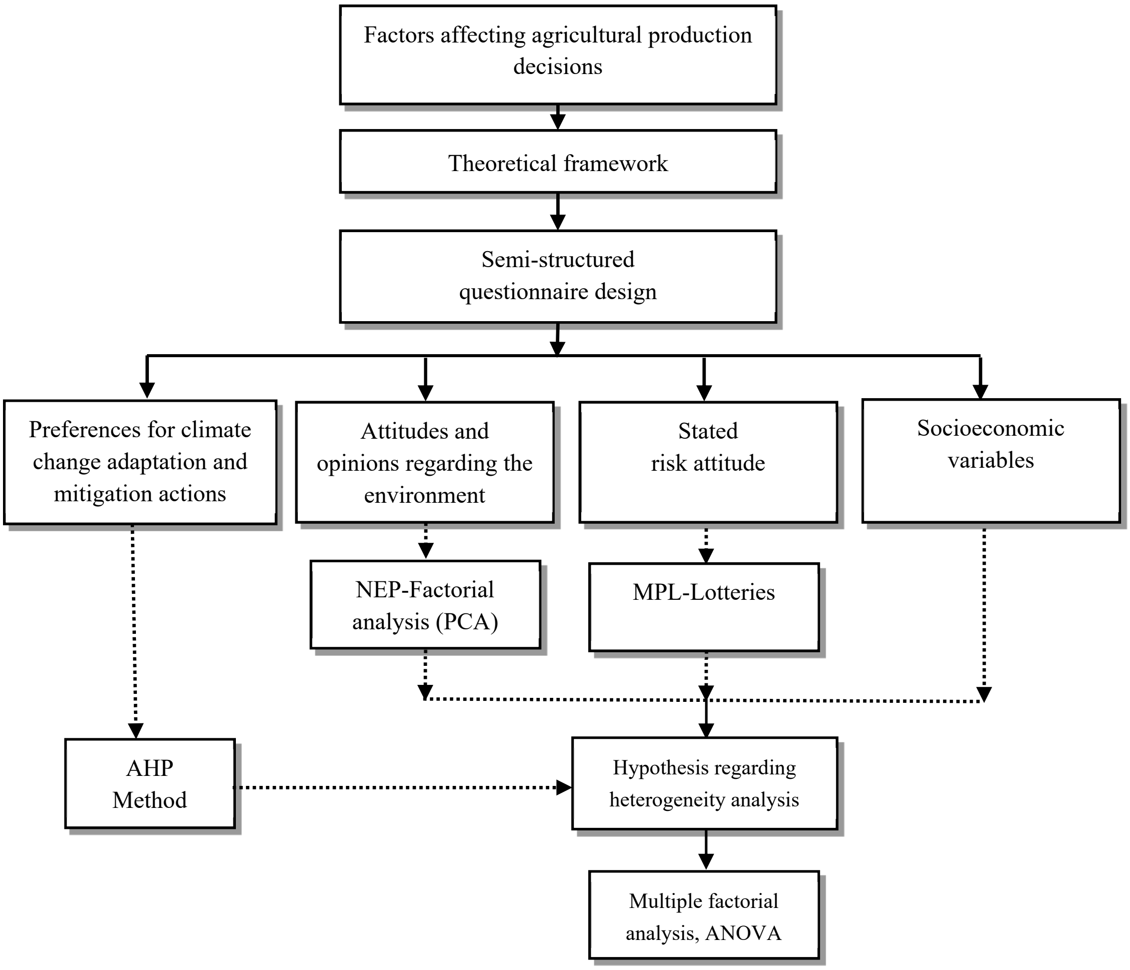

Figure 1. Methodological research approach.

2.1 The case study and sample of farmers

The data was collected through the application of a face to face survey, corresponding to a representative sample of 370 farmers from an agricultural area identified as Irrigation District 076 (DR076) in northwestern Mexico (Figure 2). The sample size was determined based on the formula of finite populations with a confidence level of 95% and an error level of 4.99% [Rojas, 2005]. Data collection was carried out in a stratified manner according to farm sizes (large and small), farmers' ages (young and old) and sex to represent both men and women within the sample using a quota sampling approach. The farmers completed semi-structured, face-to-face questionnaires from October to December 2017. The questionnaire included 108 questions and was divided into several blocks according to types of information collected. These were classified as 1) farmers' preferences for climate change adaptation and mitigation actions, 2) environmental attitudes and opinions derived from the NEP scale, 3) stated risk attitudes derived from the MPL approach, and 4) farmers' socio-economic features [Kallas, et al., 2010] and farm characteristics [Kallas et al., 2012].

Each farmer took approximately 40 minutes to answer the interview questions, and interviews were carried out with the support of students from the Autonomous Intercultural University of Sinaloa who were trained to deliver the survey. Before the interviews, the survey was reviewed and approved by the ethics committee of the Autonomous Intercultural University of Sinaloa following the ethical principles of the Declaration of Helsinki and according to confidentiality rules and a privacy policy guaranteeing the security of the personal data of each participant. In addition to the above, each participant was informed of the survey's focus and of how he/she should respond to questions and was asked to sign a consent form to participate in the study.

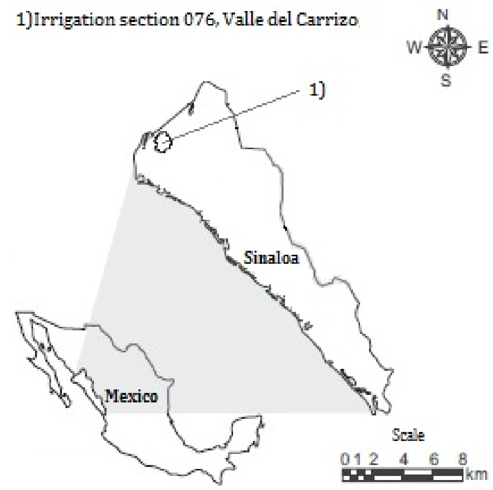

Figure 2. Location of the study area.

2.2 Description of the AHP methodology

The AHP method is a multicriteria analysis tool that was developed by Saaty at the end of the 1970s [Saaty, 2001]. It allows for the improvement in decision-making processes, in turn generating added value in terms of knowledge [Moreno et al., 1998]. It is important to highlight that decision making should be understood as a methodical process by which a person or group of people choose(s) between two or more alternatives with different quantitative or qualitative attributes to achieve an individual or common good that complies with previously conceived expectations [Moody, 1992]. The AHP technique has been widely used in agricultural research mainly in analyzing farmers to establish priorities in decision making, resolve agrarian and environmental problems and analyze marketing issues related to consumers' preferences [Kallas & Gil, 2012; Ndamani & Watanabe, 2017; Aslam et al., 2018].

The AHP method involves 3 main stages: 1) modeling, 2) assessment, and 3) prioritization and synthesis. These stages form the methodological structure described below.

Stage 1. ***Modeling.***

The activities of this stage, which are described below, include 1) problem definition and 2) structuring a decision model in the form of a hierarchy.

1. Problem identification and definition. We found that there was a lack of information on farmers' preferences in northern Mexico regarding climate change mitigation and adaptation as a normative framework in the establishment of public policies related to agricultural production to reduce effects of climate change. Accordingly, several alternative actions were evaluated from a literature review. Actions implemented to strengthen the resilience of food security systems to climate change at multiple levels were defined as measures of adaptation, and actions aimed at reducing greenhouse gas (GHG) emissions from agriculture were defined as mitigation measures while taking into account limitations inherent to the analyzed region [Mussetta et al., 2017].

Identified adaptation and mitigation actions (criteria) representing the factors based on which the hierarchical analysis was carried out include:

Adaptation Measures

A1. *Investment in improving irrigation infrastructure*. A lack of basic irrigation infrastructure restricts agricultural adaptation to climate change. Irrigation infrastructure and to a lesser extent temperature control techniques (greenhouses) facilitate adaptation to climate change by reducing climate dependence [Castells et al., 2017].

A2. *Change in crops*. Niggol and Mendelson (2008) noted that in Latin America, farmers use crops change as a way to adapt to climate change, especially where temperature and precipitation affect the selection of crops, crop yields, and incomes [Niggol & Mendelson, 2008]. Changing cultivation methods is a good measure of adaptation, especially when it comes to reducing dependence on water resources, as is the case when less water-intensive crops are used, for instance [Moniruzzaman, 2015].

A3. *Introduce improved and resistant seeds*. Improved seeds can be used by farmers in different regions to adapt to climate change. Improved seeds, among their other characteristics, develop quickly; generate high yields; are drought, plague, and pest resistant; and are more resistant to flooding [Mohamed et al., 2018].

A4. *Sowing calendar adaptation*. As a measure of climate change adaptation, the adaptation of the sowing calendar to changes at the start of the rainy season guarantees optimal growth scenarios and lower risks of drought in significant periods of planting evolution. On the other hand, the use of rainwater has greater utility and increases crop yields [Waha et al., 2012].

Mitigation Measures

M1. *Organic agriculture*. According to Xiaohong et al. (2011), organic farming uses new varieties of efficient and sustainable ecological technology and has created new ways to mitigate agroecosystem emissions through, for example, the use of bio-digesters and those that reduce water consumption [Xiaohong et al., 2011]

M2. *Zero tillage management*. Zero tillage methods effectively mitigate climate change by enhancing and/or maintaining organic matter in the soil, which lowers greenhouse gas emissions [Mangalassery et al., 2015]

M3. *Renewable energy use*. The agricultural sector can actively mitigate climate change by using manure as an alternative to fertilizers and by converting agricultural crops and waste into energy to reduce reliance on non-renewable sources (e.g., through biomass production) [Liu et al., 2017].

M4. *Use of less polluting and energy efficient machinery*. While greenhouse gas emissions are generally attributed to the energy sector due to the use of fossil fuels via agricultural machinery such as tractors, irrigation pumps, etc., the use of less polluting agricultural machinery can help mitigate impacts of climate change [Yue et al., 2017].

2. Structuring a decision model as a hierarchy. Our hierarchical scheme (Figure 3) prioritizes main criteria (adaptation and mitigation) and sub-criteria (actions) based on what is most accepted according to farmers' preferences.

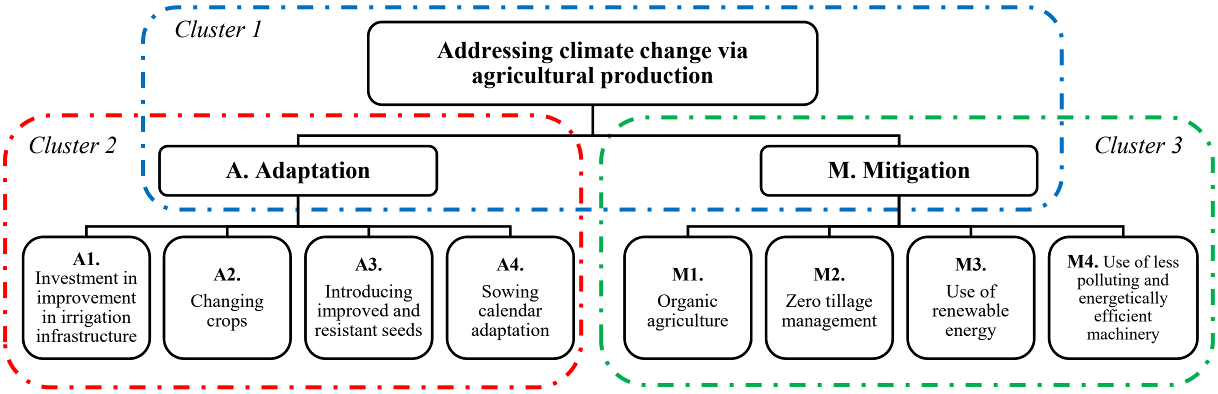

Figure 3. Decision hierarchy model and identification of clusters that form the decision hierarchy model

Stage 2. ***Assessment***.

This stage corresponds to the third phase in the empirical application of the AHP: 3) model evaluation through paired comparisons of all elements of each cluster level (Figure 3) using the verbal scale of paired comparisons proposed by Saaty (Table 1), from which the relative importance of alternative actions is then estimated.

Table 1. Verbal scale used for paired comparisons. [Saaty, 1997]

Degree of importance	Scale definition
1	Both criteria are of the same importance. The two compared elements contribute equally to the fulfillment of the parent node.
3	The preferred criterion is slightly more important than the other.
5	The preferred criterion is moderately more important than the other.
7	The preferred criterion is much more important than the other.
9	The preferred criterion is significantly more important than the other.
2, 4, 6, 8	Judgments are made to define the relative importance of compared elements.

For the upper cluster level, only one pairwise comparison is applied [n×(n-1)/2= 2×(2-1)/2 = 1] on adaptation and mitigation actions. For each of the lower level clusters according to dimension n = 4 (4 alternatives actions), 6 pairwise comparisons are used [n×(n-1)/2 = 4×(4-1)/2 = 6], where each alternative of the hierarchy is compared to the remaining alternatives within its cluster at the same hierarchical level depending on the satisfaction it provides to the respondent (farmers). Pairwise comparisons were collected using the scheme outlined below (Table 2):

Table 2. Paired comparisons included in the questionnaire

Comparison of measures (*cluster 1*)

A. Adaptation Measures									**M. Mitigation Measures**							
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

A. Comparison of adaptation actions (*cluster 2*)

A1. Investment in the improvement in irrigation infrastructure									**A2. Change in crops**							
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
A1. Investment in the improvement in irrigation infrastructure									**A3. Introduce improved and resistant seeds**							
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
A1. Investment in the improvement in irrigation infrastructure									**A4. Adaptation of the sowing calendar**							
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
A2. Change in crops									**A3. Introduce improved and resistant seeds**							
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
A2. Change in crops									**A4. Adaptation of the sowing calendar**							
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
A3. Introduce improved and resistant seeds									**A4. Adaptation of the sowing calendar**							
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

M. Comparison of mitigation actions (*cluster 3*)

M1. Organic agriculture									**M2. Zero tillage management**							
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
M1. Organic agriculture									**M3. Use of renewable energy**							
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
M1. Organic agriculture									**M4. Use of less polluting and energetically efficient machinery**							
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
M2. Zero tillage management									**M3. Use of renewable energy**							
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
M2. Zero tillage management									**M4. Use of less polluting and energetically efficient machinery**							
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
M3. Use of renewable energy									**M4. Use of less polluting and energetically efficient machinery**							
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

Stage 3. *Prioritization and synthesis*.

This phase involves 4) synthesis to identify the best alternative and 5) the examination and verification of a decision that corresponds to the last two activities of the hierarchical analysis process from which priorities (i.e., the relative importance) are estimated.

4. Synthesis to identify the most preferred criteria. For this activity, the joint prioritization of all sub-criteria proposed in the model to select the one that addresses a given problem is carried out; to this point, all comparisons must be drawn between elements of each cluster for each farmer k, from which the corresponding Saaty matrices are obtained ($\hat{A}_k$), through which local weights of the identified elements are obtained $\hat{w}_{ik}$ according to the preferences of each farmer using the Row Geometric Mean Method (RGMM) [Kallas and Gil, 2012].

The estimation of priorities ($\hat{w}_{ik}$) was carried out using Super Decisions software [Super decision, 2018] designed for the implementation of the AHP methodology. An example of results of pairwise comparison called judgments ($\hat{a}_{ijk}$) for farmer k in cluster 2 referring to adaptation measures is shown in Table (3).

Table 3. Example of the calculation of weights based on paired comparisons corresponding to cluster 2, adaptation (A) attributes for individual k = 1.

Functions	A1*	A2*	A1*	A3*	A1*	A4*	A2*	A3*	A2*	A4*	A3*	A4*
Judgment ($\hat{a}_{ij}$)	9		9		9		2		2			2
	$\hat{a}_{12}$=9	$\hat{a}_{21}$=1/9	$\hat{a}_{13}$=9	$\hat{a}_{31}$=1/9	$\hat{a}_{14}$=9	$\hat{a}_{41}$=1/9	$\hat{a}_{23}$=2	$\hat{a}_{32}$=1/2	$\hat{a}_{24}$=2	$\hat{a}_{42}$=1/2	$\hat{a}_{34}$=1/2	$\hat{a}_{43}$=2

A1*. Investment in the improvement in irrigation infrastructure
A2*. Change in crops
A3*. Introducing improved and resistant seeds
A4*. Adaptation of the sowing calendar

All judgments ($\hat{a}_{ijk}$) obtained from the pairwise comparison lead to the construction of a Saaty matrix for farmer k ($\hat{A}_k$) with dimensions (n x n = 4x4) as follows:

$$\hat{A}_k = \begin{bmatrix} a_{1.1k} & a_{1.2k} & a_{1.3k} & a_{1.4k} \\ a_{2.1k} & a_{2.2k} & a_{2.3k} & a_{2.4k} \\ a_{3.1k} & a_{3.2k} & a_{3.3k} & a_{3.4k} \\ a_{4.1k} & a_{4.2k} & a_{4.3k} & a_{4.4k} \end{bmatrix}$$

For the example shown in Table 3, the Saaty matrix is:

$$\hat{A}_k = \begin{bmatrix} 1 & 9 & 9 & 9 \\ 1/9 & 1 & 2 & 2 \\ 1/9 & 1/2 & 1 & 1/2 \\ 1/9 & 1/2 & 2 & 1 \end{bmatrix}$$

Based on the Saaty matrix, the relative importance (i.e., the weights or priorities) of different actions $\hat{W}_{nk} = (\hat{w}_{1k}, \ldots \hat{w}_{ik}, \ldots \hat{w}_{nk})$ are estimated using the RGMM:

$$\hat{W}_{ik} = \sqrt[n]{\prod_{i=1}^{i=n} \hat{a}_{ijk}} \quad (1)$$

The previously estimated weights are normalized to the unit.

$$\sum_{i=1}^{i=n} \hat{w}_{ik} = 1 \quad (2)$$

5. Examination and verification of the decision. As part of the verification stage, it is important to note that for each generated matrix, the Consistency Ratio (CR) of farmers' answers was calculated according to corresponding mathematical expressions:

$$CR = CI/RI; \quad (3)$$

where CI is the Consistence Index obtained as:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (4)$$

where n= is the number of alternatives and $\lambda_{\max}$ is the maximum value of components of the eigenvector obtained as:

$$\lambda_{\max} = \sum_i \sum_j \hat{a}_{ijk} \hat{w}_{ik} \tag{5}$$

RI is the Random Index, which is obtained by multiple random extractions of the Saaty matrix of size n x n (Table 4).

Table 4. Values of the random consistency index (RI) based on the size (n) of the matrix. [Saaty, 1994]

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

A value of CR lower than 10% indicates satisfactory consistency for the pairwise comparisons [Siraj et al., 2015]. The AHP is also considered a valid technique for the analysis of group decisions [Easley et al., 2000]. Thus, to obtain an averaged aggregated of different mitigation and adaptation measures for the sample, corresponding individual weights ($\hat{W}_{ik}$) were aggregated across farmers to obtain a synthesis of weights for each set of criteria ($\hat{W}_i$). The aggregation was carried out using the Geometric Mean (GM) procedure, which is considered the most suitable method for aggregating individual priorities in a social collective decision-making context [Forman & Peniwati, 1998]:

$$w_i = \sqrt[K]{\prod_{k=1}^{k=K} w_{ik}} \qquad \forall\, i \tag{6}$$

2.3 New Ecological Paradigm (NEP) Scale

According to Hawcroft and Milfont, environmental attitudes can be observed through psychological tendencies expressing positive or negative evaluations of the natural environment and that cannot be observed directly and thus it must be inferred. Numerous tools allow one to measure environmental attitudes, among which three psychometric tools are highlighted: The Ecology Scale, The Scale of Environmental Concern and The New Ecological Paradigm. The first two scales refer to very specific environmental issues, while the NEP scale, which is the most widely used, allows one to measure general beliefs based on relationships between humans and their environments [Hawcroft and Milfont, 2010].

According to some studies, farmers' beliefs regarding environmental issues can be measured using the NEP scale. This scale analyzes relationships between subjects' beliefs about themselves and nature. The scale reflects the ways in which humans conceptualize nature and interact with it [Vozmediano & Guillen, 2005; Dunlap et al., 2000; Lezak & Thibodeau, 2016].

In this study, farmers' preferences regarding climate change adaptation and mitigation actions were analyzed in relation to their environmental beliefs measured through the NEP scale. Predominant latent environmental dimensions of farmers could then be identified. The NEP scale was presented to farmers with an array of statements using a 9-point Likert type scale (Table 5).

Individuals' views of the environment can be revealed from their perceptions and attitudes. Using the NEP scale, an exploratory factorial analysis (Principal Component Analysis, PCA) was performed to identify the dimensionality that characterizes farmers by associating the scale's items with several independent dimensions. The identified dimensions allowed us to define latent factors that are present in the participants' environmental attitudes [Gomera et al., 2013]. An exploratory factor analysis (PCA) was carried out with Varimax rotation and using the Statistical Package for the Social Sciences (SPSS, version 23.0). Before carrying out the factorial analysis, the Kaiser-Meyer-Olkin sample adaptation measure (KMOS) was applied.

Table 5. Statements of the New Ecological Paradigm Scale

Fully disagree	Strongly disagree	Moderately disagree	Slightly disagree	Neutral	Slightly agree	Moderately agree	Strongly agree	Fully agree
1	2	3	4	5	6	7	8	9

1. The global ecological crisis has been exaggerated
2. The balance of nature supports the impacts of industrialized countries
3. Humans may be able to control nature
4. Human ingenuity will ensure that the earth will not become uninhabitable
5. Humans were created to dominate nature
6. Humans have the right to modify the environment and adapt it to their needs
7. Human interference in nature will have disastrous consequences
8. Plants and animals have the same rights to exist as human beings
9. Humans have seriously damaged the environment
10. The balance of nature is delicate and easily alterable
11. If things continue as they have, we will soon experience a significant ecological catastrophe
12. We are approaching the earth's limit in terms of sustaining the global human population
13. The earth has limited resources
14. Despite our special abilities, human beings are still subject to the laws of nature
15. The land has abundant resources, and we just need to learn to exploit them
16. Sustainable development must apply a balanced approach that controls industrial growth

Theoretically, according to Gomera et al. (2013) and Vozmediano and Guillen (2005), the application of factorial analysis should reveal five dimensions 1) a component related to anthropocentrism, 2) an ecocentric component, 3) limited consciousness, 4) a component related to human confidence in nature and 5) a last component related to perceptions of infinite natural resources.

The first identified component is referred to as anthropocentrism and was measured with affirmations focused on the supremacy of humans over nature. The second component, the ecocentric dimension, was measured with statements focused on the unbalanced state humans have created in nature. The third component reflects consciousness regarding the existence of a limit on nature related to resources of the biosphere. The fourth component measures confidence in human to manage natural resources correctly. The last component reflects perceptions of infinite natural resources and thus humans' indifference to their consumption given the presence of abundant natural resources.

2.4 Stated risk attitude: The lotteries approach

The stated risk attitude level is related to human behavior, which is specific to each individual decision maker. Individuals prefer options that ensure more utility based on their risk preferences [Mejía, 2015; Brick et al., 2011; Galarza, 2009]. Several methodological approaches have been developed to measure individuals' stated risk attitudes and their relations to actions under a certain degree of uncertainty.

The Multiple Price List (MPL) or "lotteries" have recently been used in agriculture based on the theory of the expected utility u (x) and strength of risk preferences v (x) with the "True Equivalent" used to measure attitudes toward risk [Pennings & Garcia, 2001; Jianjun et al., 2015; Orduño et al. 2018]. The MPL method allows one to identify levels of risk tolerance or aversion through a set of questions posed to decision makers and in our case to farmers. The method examines 8 scenarios with different lottery pairs where one lottery option (option A or option B) is chosen [Drichoutis & Lusk, 2012; Brick et al., 2011].

The level of risk aversion is based on the number of safe answers (option A) the interviewed farmer selects. A farmer who is risk tolerant selects a risky option (option B) for the first scenario. A farmer who is risk neutral selects option A for the first 3 scenarios and selects option B for the remaining scenarios from (4-8 scenarios) while an extremely risk averse farmer selects option A for all 8 scenarios [March et al., 2014]. In the model, the safe option (option A) corresponds to a 100%

probability of succeeding, and the risky option (option B) corresponds to a 50% probability of obtaining \$100 and a 50% probability of obtaining \$0 (based on a coin toss) in all scenarios. Amounts provided by option A are progressively decreased across all 8 scenarios to the following amounts: \$00, \$75, \$60, \$ 50, \$40, \$30, \$20, and \$10. The experimental design structure of the risk elicitation question is illustrated in the questionnaire available in the supplementary file Q_1v2 (Question 35).

2.5 Hypotheses analyzed

Based on the above literature, the below hypotheses are tested:

1. H1: Farmers' estimated preferences regarding climate change adaptation and mitigation (AHP) are related to their attitudes and opinions regarding the environment (NEP scale).
2. H2: Farmers' preferences regarding climate change adaptation and mitigation (AHP) are related to their stated risk attitudes (MPL lotteries).
3. H3: Farmers' preferences regarding climate change adaptation and mitigation (AHP) are related to socioeconomic and farm characteristics.

All the above hypotheses were tested through an analysis of variance using the ANOVA method. Preferences regarding climate change adaptation and mitigation were related to the two main latent factors (ecocentric and anthropocentric) defined from the NEP via factorial analysis (PCA).

3. Results

3.1 Farmers' preferences for adaptation and mitigation actions

The estimated average weighting of adaptation and mitigation actions based on the AHP is presented in Figure 4. The results reflect farmers' prioritization of different ways to face the impacts of climate change on their activities. Weights (i.e., relative importance) were estimated at the local (i.e., for each cluster from local weights) and global levels (i.e., for the hierarchy level from global weights).

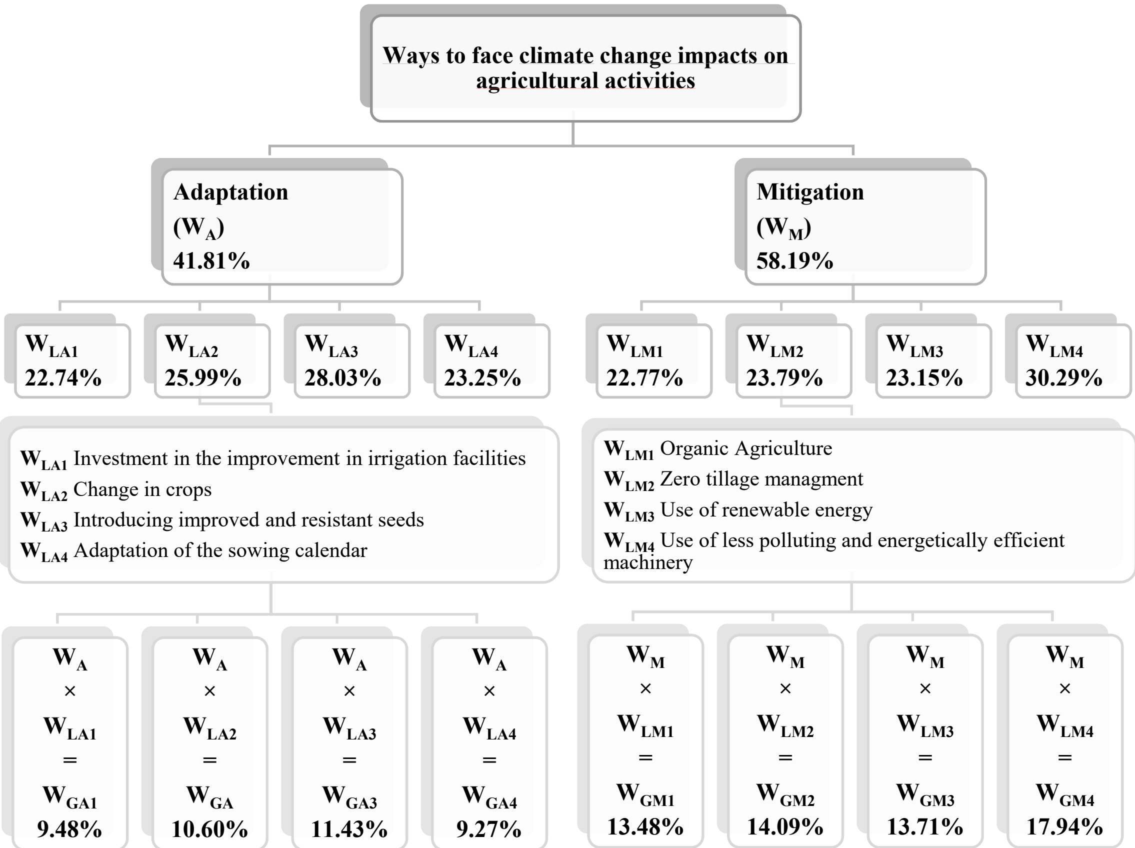

Figure 4. Average relative relevance weights determined by AHP analysis according to farmers' opinions (WA: local weight of adaptation measures group, WM: local weight of mitigation measures group, WLA: local weight of a specific (n) adaptation measure, WLM: local weight of a specific (n) mitigation measure, WGA: global weight of a specific (n) adaptation measure and WGM: global weight of a specific (n) mitigation measure).

The estimated average weights show that mitigation actions were deemed the most important options with a higher relative relevance of 58.18%. For each farmer we then estimated actions deemed the most preferred (Figure 5).

According to the farmers´ preferences, which were identified from the global weight of each individual farmer, the use of less polluting machinery was the most preferred action. The second most preferred action was investment in the improvement in irrigation infrastructure (17.57%). The changing of crops was deemed the third most preferred action, accounting for (17.30%) of the farmers´ answers. Zero tillage management was the fourth most preferred action (16.22%).

The use of renewable energy was the least preferred option and was selected by 5.95% of the farmers.

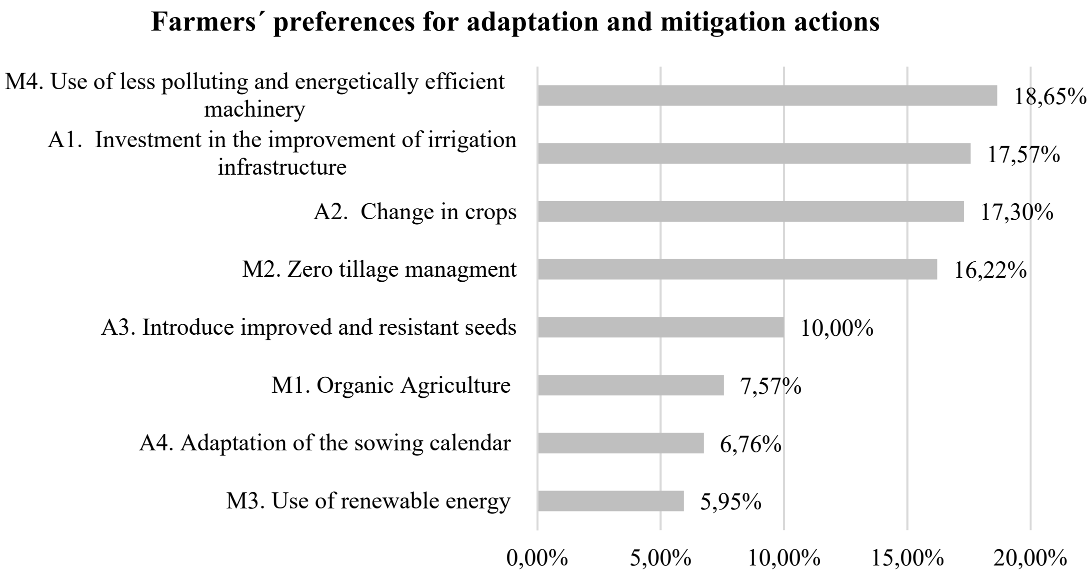

Figure 5. Farmers' preferences for climate change adaptation and mitigation actions.

3.2 H1: Relations between environmental attitudes and farmers' preferences for climate change adaptation and mitigation actions

According to the results of our first PCA applied to items of the NEP scale, with a KMOS of 0.747 indicating that the reduction in dimensionality is relevant, the variability explained by the model with 5 components is 67.11%. For this PCA, the first component included items 10, 11, 12, 13, 14 and 16 on ecocentric attitudes. The second component grouped items 2, 3, 4, 5, 6 and 8 related to an anthropocentric attitude, among which item 8 is negatively related. The last three components correspond to one or no significant item with relatively low percentages of explained variance. Furthermore, items 1 and 7 do not contribute significantly to any component. Another PCA was then carried out on the 12 items related to the anthropocentric and ecocentric dimensions. In this case, the KMOS test generated a result of 0.754 and the variability explained by the factorial analysis of the two 2 components was measured as 52.98%. This reduction in the NEP scale allowed for a better definition of components by clearly differentiating the regrouping of item 8 with attitudes related to an ecocentric attitude.

Table 6. Grouped reduced NEP scale according to each item's contribution to the new components

New ecological paradigm scale items	Factor 1 Ecocentric	Factor 2 Anthropo-Centric
11. If things continue as they have, we will soon experience a significant ecological catastrophe	**0.81**	-0.08
10. The balance of nature is delicate and easily alterable	**0.78**	0.06
14. Despite our special abilities, human beings are still subject to the laws of nature	**0.69**	0.16
12. We are approaching the earth's limit in terms of sustaining the human population	**0.63**	0.13
16. Sustainable development must apply a balanced approach that controls industrial growth	**0.63**	0.26
8. Plants and animals have the same rights to exist as human beings	**0.59**	-0.18
13. The earth has limited resources	**0.52**	0.46
3. Humans may be able to control nature	0.00	**0.80**
4. Human ingenuity will ensure that the earth will not become uninhabitable	0.06	**0.77**
5. Humans were created to dominate nature	0.04	**0.75**
6. Humans have the right to modify the environment to adapt it to their needs	0.04	**0.71**
2. The balance of nature supports the impact of industrialized countries	0.16	**0.70**
Extraction method: PCA. Rotation method: Varimax standardization with Kaiser.		
Total explained variance	52.98%	

Ecocentric and anthropocentric environmental attitudes

The farmers' distribution according to the reduced NEP scale can be observed in Figure 6. Two main relevant behaviors are identified: ecocentric and anthropocentric environmental attitudes. Accordingly, each farmer is positioned within two principal axes representing the main factors.

Four potential positions are specified in four quadrants: quadrant (+ eco, +anthro) corresponds to farmers agreeing with both attitudes in favor of nature and in favor of humans' priorities in using natural resources. This space may represent inconsistencies between farmers regarding their attitudes towards the environment.

For this same context, quadrant (-eco, -anthro) may also reflect farmers' inconsistencies regarding their stated opinions towards the environment, highlighting their disagreement with views that place nature above humans and with those that place humans above nature.

Quadrant (- echo, + anthro) refers to farmers who agreed with anthropocentric attitudes but disagreed with ecocentric views, thus representing farmers who believe that humans are above nature and that there is therefore no limit to the use of natural resources. The protection of nature in this case should only be aim at enhancing the quality of human life.

Finally, quadrant (+eco, - anthro) groups farmers who agreed with ecocentric attitudes and showed disagreement with anthropocentric behaviors. These farmers believe that nature should be protected because it is vulnerable to the actions of humans and that humans must limit its use and perform actions that support nature.

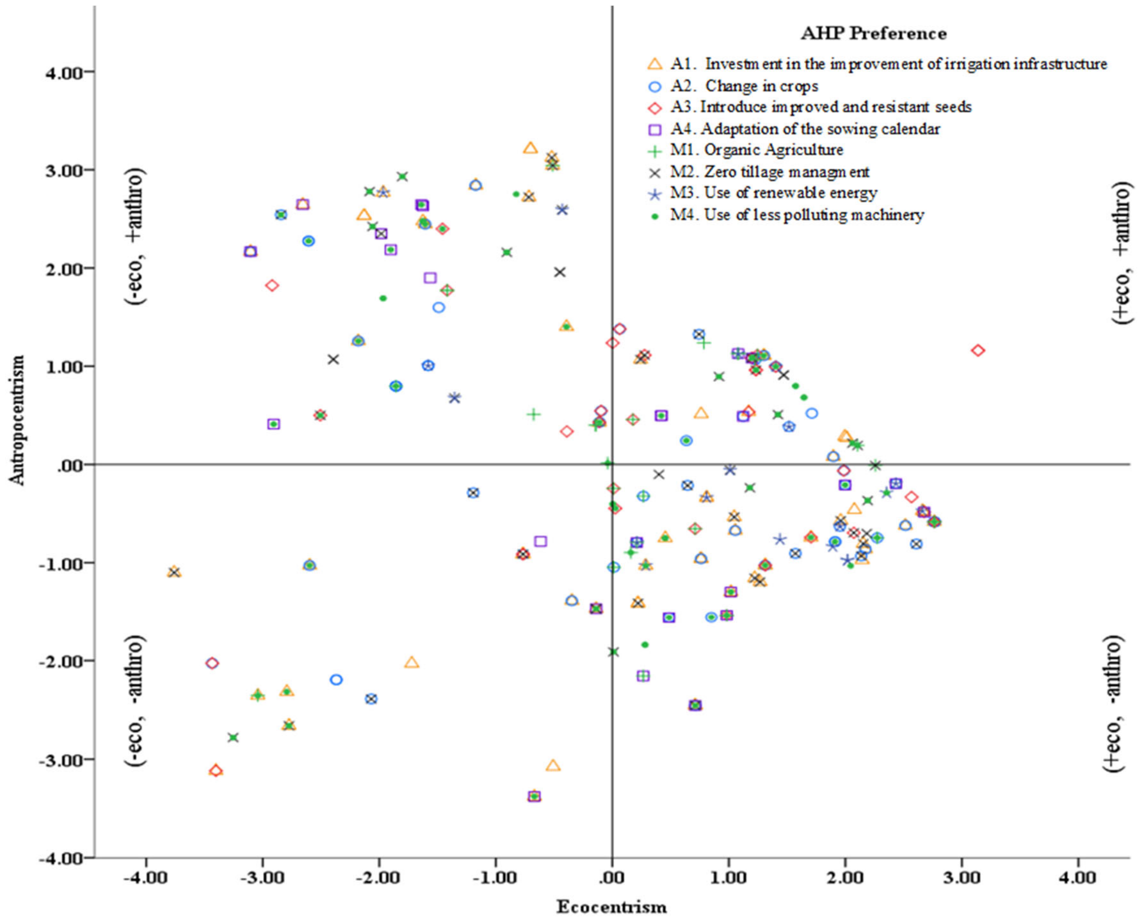

Figure 6. Farmers' distributions on the reduced NEP scale, ecocentric and anthropocentric dimensions, and relations to farmers´ preferences for climate change adaptation and mitigation actions. +eco denotes that farmers agree with ecocentric attitudes, -eco denotes that farmers disagree with ecocentric attitudes, +anthro denotes that farmers agree with anthropocentric attitudes, and -anthro denotes that farmers disagree with anthropocentric attitudes.

The farmers' distribution on the abovementioned four quadrants shows that the majority (39%) exhibited a clearly positive ecocentric attitude (+ eco, - anthro), highlighting positive views of the environment in the studied region. However, 27% of the farmers exhibited a clear anthropocentric attitude (- echo, + anthro) and an interest in protecting nature only if for a clear economic benefit. The remaining farmers exhibited less clearly defined opinions regarding the environment where 15% exhibited negative views toward ecocentric and anthropocentric attitudes (- eco, - anthro) while 19% exhibited positive views toward ecocentric and anthropocentric attitudes (+ eco, + anthro).

The two abovementioned factors are related to farmers' preferences towards mitigation and adaptation actions obtained from the AHP. The results (Figure 7) show that the ecocentric and anthropocentric dimensions are closely related to the farmer's preferences. The mitigation and adaptation actions presented in Figure 7 are ordered according to their relative importance as discussed in Figure 6. An interpretation of the results shown in Figure 7 must be carried out horizontally by comparing the relative importance (%) of each action across the four quadrants.

The most preferred climate change adaptation and mitigation action (the *use of less polluting and energetically efficient machinery*, M4) was principally selected by farmers who exhibited a positive view of the environment (+eco, -anthro). The remaining mitigation and adaptation actions were also more important for farmers exhibiting more ecocentric views of the environment (+eco, -anthro). As an exception, one action (*to introduce improved and resistant seeds*, A3) was preferred more by farmers that do not exhibit a clear attitude toward the environment (+eco, +anthro).

The results listed vertically in Figure 7 show that farmers with the most ecocentric attitudes (+ eco, -anthro) exhibited the strongest preferences for *the use of renewable energy* (M3).

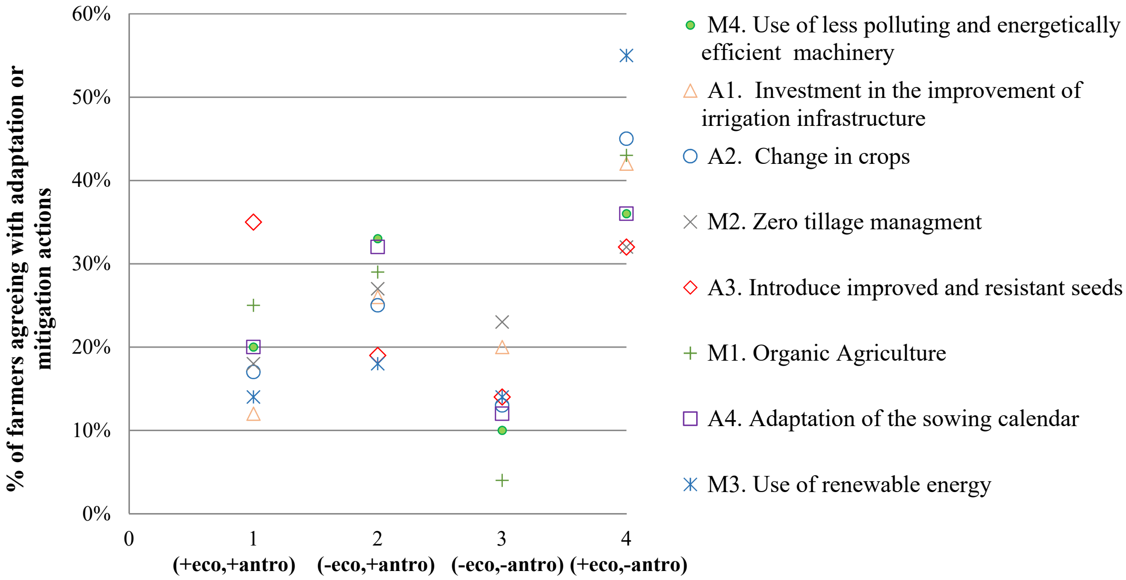

Figure 7. Farmers' distribution by preferences according to a combination of their positive or negative views of ecocentric and anthropocentric attitudes (4 quadrants).

3.3 H2: Stated risk attitudes and farmers' preferences for climate change adaptation and mitigation actions

The MPL results regarding stated risk attitudes show that 51.35% of the farmers are risk averse, 7.57% are neutral, and 41.08% are risk tolerant. The heterogeneity analysis shows that the stated risk attitudes and farmers´ preferences for adaptation and mitigation actions are not clearly related. Through the analysis conducted, no significant relationship was found between preferences for adaptation and mitigation actions and the stated risk level, though it is clearly related to other socioeconomic and management variables for farmers.

3.4 H3: Farmers' preferences for climate change adaptation and mitigation actions and their socioeconomic characteristics

Regarding the socioeconomic characteristics of the sample, most of the farmers surveyed were between 41 and 60 years of age (52%), followed by farmers over 60 years of age (28.38%) and those under 41 years of age. Only 11% of the agricultural producers were women, and the average number of family members was recorded as 3.78.

Our analysis of socioeconomic characteristics also shows that 76% of the participants' incomes are generated from agricultural activities. Approximately, 68% of the producers had received a subsidy mainly used (60%) to cover operating costs while 12.3% of farmers had applied it to invest in agricultural equipment and technology. Most of the farmers (63%) do not usually use any type of agricultural insurance. Most of the participants owned their agricultural land (79%), and the main products grown included wheat (29%), alfalfa (24%) and soybeans (9.73%).

Socioeconomic characteristics measured related to preferred mitigation and adaptation actions included the following: adopting contracted agricultural insurance, having credit for a farming land tenure regime, belonging to an agricultural association, selection of crops, and farmer's age and sex.

The results for these variables show that farmers without crop insurance prefer the "change in crops" measure, while those with insurance prefer "the use of less polluting and energetically efficient machinery" to reduce the impacts of climate change. On the other hand, framers with crop insurance have less concerns regarding the impacts of climate change and thus exhibit a preference towards other actions that principally reduce negative effects on the environment.

Farmers with credit for farming activities and agricultural insurance and belonging to an agricultural association prefer "the use of less polluting and energetically efficient machinery" and grow onions, chili peppers, corn, soybeans, sorghum, and triticale. Furthermore, farmers without credit for farming activity and with private property under a land tenure regime who grow sweet potatoes prefer to increase investment in the improvement in irrigation infrastructure.

Mitigation action "zero tillage management" was preferred by farmers without credit for farming activity, who do not belong to an agricultural association and principally grow watermelon and cartamo.

Finally, farmers under 40 years of age prefer "investment in the improvement in irrigation infrastructure," farmers 40 to 60 years of age prefer the "change in crop" approach, and farmers over 60 years of age prefer "zero tillage management."

4. Discussion

4.1 Farmers' preferences for adaptation and mitigation actions

Overall, the above results show that farmers in the study region prefer to implement mitigation actions to address climate change. These results are in agreement with those obtained by Bragado (2016), who found that mitigation actions are prioritized within the agricultural sector in addressing climate change effects.

The most preferred action among the studied farmers involves the "use of less polluting machinery," which indicates that public policy decisions should focus on promoting the use of less polluting and highly efficient agricultural machinery. This outcome was also proposed by Xu and Lin, who recommend that local governments encourage the use of energy efficient, less polluting agricultural machinery to support environmentally friendly production [Xu & Lin, 2017].

Due to water scarcity, which it is becoming more frequent in the studied region, water management agencies have been forced to frequently restrict volumes and periods of water use for irrigation, subjecting crops to water stress [Ojeda et al., 2012] and causing farmers to prefer investment in improving irrigation infrastructure. Investment in irrigation infrastructure increases water use efficiency [Nelson, 2009] and may lead to a high degree of water loss. It is worth mentioning that in the presence of poor irrigation infrastructure, more than 55% of water used is wasted [Sifuentes et al., 2015].

Crop change (polyculture) methods exhibit more stability with less loss of productivity during drought seasons because they allow crops to reach acceptable levels of productivity even under unusual climatic conditions and environmental stress. Crop change can ensure a certain level of productivity in the midst of climate change. The approach can also address future social and economic needs as Altieri and Nicholls indicate [Altieri & Nicholls, 2009], corroborating our finding that farmers favor such actions third in terms of their preferences.

Alternative zero tillage management was identified as the fourth most preferred mitigation strategy among farmers in the study region. Lau, Jarvis and Ramírez (2011) and Nichols and Altieri (2013) have also advocated for zero tillage as a feasible mitigation action [Lau et al., 2011; Altieri & Nicholls, 2013].

All the above actions are closely related to economic benefits at the farm level. The adoption of less polluting and efficient machinery reduces fuel oil consumption and thus reduces production costs. Investment in irrigation infrastructure increases the productivity and quality of crops, optimizes the use of water, and decreases water waste [Nelson, 2009 and Khanal et al., 2019]. Crop changes increase productivity and decreases costs due to a lesser use of fertilizers and agrochemicals, which positively affects farm productivity [Moniruzzaman, 2015 and Khanal et al., 2018]. The adoption of zero tillage management reduces production costs, as it lowers tilling labor costs and may reduce the use of chemicals and phytosanitary methods. Zero tillage methods are usually related to organic agriculture, which may also increase the price of products [Kallas et al., 2010]. The use of renewable energy was preferred least by the farmers corroborating studies showing the need for strong investment to encourage the use of renewable energy facilities that may mitigate climate change [Kung & McCarl, 2018]. In general terms, farmers prefer options that minimize the impacts of climate change while at the same time providing them a perceived benefit in the short run at the farm level.

4.2 H1: Relations between environmental attitudes and farmers' preferences for climate change adaptation and mitigation actions

Regarding farmers' environmental attitudes, which are described by Gomera et al. (2013) and Reyna et al. (2018) as ecocentric and anthropocentric environmental attitudes, and regarding farmers' preferences to mitigate or adapt to climate change, the most preferred action, "the use of less polluting and energetically efficient machinery," was selected by farmers with positive attitudes toward the environment.

As Hajjar and Kozak (2015) argue, ecocentrics might be interested in using more environmentally sustainable technologies, while farmers without clear views on the environment prefer "introducing improved and resistant seeds." For this adaptation measure, farmers may seek to enhance their economic benefits through the implementation of a simple mitigation or adaptation action without considering positive or negative effects on the environment. Ecocentric farmers believing that nature should be protected showed the strongest preference for the use of renewable energy and mitigation actions to face climate change. This group clearly exhibited the strongest concerns regarding the environment and a clear tendency toward using more environmentally friendly technology [Hajjar and Kozak, 2015].

4.3 H2: Stated risk attitudes and farmers' preferences for climate change adaptation and mitigation actions

Our risk level results show that most of the studied farmers were risk averse. This is at first unexpected, as most of the studied farmers do not use agricultural insurance. However, our findings are in line with those of Jianjun et al. (2015), who used MPL and found an unclear relation between risk attitudes and preferences for climate change adaptation and mitigation [Jianjun et al., 2015].

According to Palm (1998), most risk-averse individuals tend to take preventive and protective actions against potential damages [Lopez & De Paz, 2007]. Farmers in our study region were found to be mostly risk averse, which would imply that they have a strong willingness to carry out actions in favor of reducing the effects of climate change through adaptation or mitigation actions.

The non-significant relationship found between preferences for adaptation and mitigation actions and the stated risk level could be explained by the fact that all actions were identified by farmers as protective measures against potentially negative impacts of climate change. Preferences for adaptation and mitigation measures among farmers in the study region are also related to other variables concerning farmers' and farm characteristics and farmers' decisions made in relation to their activities [Orduño et al., 2018].

4.4 H3: Farmers' preferences for climate change adaptation and mitigation actions and their socioeconomic characteristics

Our results show that farmers without crop insurance preferred the "change in crops" adaptation strategy, while those with insurance preferred "the use of less polluting and energetically efficient machinery." This result may be attributed to the fact that a change in crops increases productivity and thus insures farmers' incomes against impacts of climate change. This preference affords farmers confidence in terms of having enough income to support their planting commitments [Altieri & Nicholls, 2009].

Our findings show that farmers who do not need credit for their agricultural activities and who grow potatoes prefer "investment in improving irrigation infrastructure," which may be related to the fact that potato crops are very sensitive to a lack of water [FAO, 2008]. These preference patterns show that farmers are more concerned with using water solution technologies to reduce the impacts of climate change in the region. This same outcome was found for farmers under 40 years of age, showing that young individuals are more sensitive to water use and waste [Rodríguez & Jiménez, 2014]. Farmers aged 40 to 60 years instead prefer the "change in crop" approach, which may be linked to an interest in ensuring economic benefits. Finally, farmers over 60 years of age prefer "zero tillage management," which could be associated with farmers' experience. The "zero tillage management" approach is also preferred by farmers who grow watermelon and cartamo and who do not have credit for their farming activities. This outcome could be related to the fact that watermelon and cartamo do not require an extensive land preparation, thus rendering zero tillage methods a viable mitigation option [Moreno et al., 2013; Valdez et al., 2012].

5. Conclusions

This study contributes to the literature by furthering available knowledge that can inform policy makers regarding support and subsidies related to agricultural production that better meet framers' needs and preferences. This may enhance the effectiveness of policy measures by stimulating preferred actions that improve farmers' social and economic welfare. It may also guide current public support to prioritize measures that promote the development of more sustainable agriculture activities at regional and national levels. At the methodological level, this paper contributes to the few studies jointly using the AHP in relation to farmers' preferences with the NEP scale and MPL risk approach, particularly in reference to México.

To effectively face the impacts of climate change on agriculture implies the implementation of mitigation and adaptation actions according to farmers' interests and preferences. In general terms, farmers tend to prefer adaptation actions or mitigation actions because the former are perceived to offer benefits sooner when adopted. Farmers with ecocentric attitudes exhibited a greater willingness to adopt measures against climate change, while those with anthropocentric views principally exhibited stronger preferences for activities related to improvements in their productivity.

Through the Analytical Hierarchy Process, farmers were found to prioritize actions that implicitly provide economic benefits over the short run. The use of efficient, less polluting machinery was identified as one of the best alternative options not only due to its positive impacts on the environment but also due to its economic benefits in terms of reducing energy costs at the farm level.

Our results show that farmers' preferences for mitigation and adaptation actions are closely related to the types of crops cultivated. Investment in improving irrigation infrastructure as an adaptation activity was widely accepted by farmers with water availability issues who grow sweet potatoes. This adaptation action helps farmers optimize their water use and address water availability issues in the region by increasing their productivity and limiting the water waste. Adopting a change in crops grown as an adaption action was also preferred by farmers who grow sorghum. Also, a preference for the zero tillage mitigation approach was found to be related to watermelon and cartamo cultures.

Agricultural public policy decisions must consider farmers' preferences towards mitigation and adaptation actions when designing and implementing measures that ensure sustainable agriculture. Policy tools and interventions must be inclusive and developed at the micro-level based on farm typologies, and crop diversity must be encouraged.

Author Contributions: M.A.O.T conceived and designed the study, conducted analyses, collected data, and wrote the manuscript; Z.K. conceived and designed the research study, reviewed and edited the manuscript and supervised all procedures; S.I.O.H conducted the analysis and helped write the manuscript.

Funding: This research received no external funding.

Acknowledgments: The National Council of Science and Technology (CONACYT) is acknowledged for supporting this research.

Conflicts of Interest: The authors declare no conflicts of interest.

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