UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Análisis de preferencias hacia las acciones de adaptación y mitigación al cambio climático: perspectiva del agricultor en el noroeste de México

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Tesis por compendio de publicaciones

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ABSTRACT

Climate change is the most recurrent natural process on a global scale and one of the greatest challenges of our times; due to the close relationship between society, productive activities and economic development. One of the productive activities most vulnerable to climate change is agriculture, which is threatened in the quality and yield of crops and with it, food security worldwide. Climate variability increases uncertainty in production, affecting the behavior and decisions of farmers. In this thesis, we analyzed farmers' preferences towards the mitigation and adaptation actions to climate change in the northwestern region of Mexico. A Specific emphasis was carried out on farmers' technical efficiency, risk and environmental attitudes. The -irrigation district (076) of Valle del Carrizo in the north of the state of Sinaloa, Mexico was taken as a case study. The data was collected through a face-to-face survey, conducted with a group of 370 farmers stratified by farm size, gender and age.

Firstly, farmers' risk attitudes were analyzed using the hypothetical Multiple Price List (MPL) Method known as lotteries. This risk behavior was posteriorly related to farmer' environmental attitude using the New Ecological Paradigm (NEP). Farmers' perceptions towards climate change and their socioeconomic were also highlighted. The results showed a risk level of 0.32, according to the constant relative risk aversion coefficient (CRRA), placing farmers in the region as a risk-averse group. The heterogeneity analysis showed that farmers who received economic support and used it in structural investment at the farm level were more risk-tolerant; respect to the gender, women were more risk-tolerant than their counterparts (risk tolerant: 61% women and 39% men). Farmers "above 60 years of age" had a lower risk aversion on average, compared to farmers in the range of 41 to 60 years' old, who were more conservative, with a higher level of risk aversion.

Secondly farmers' preferences towards climate change mitigation and adaptation actions were analyzed using the Analytical Hierarchy Process (AHP) methodology. Preferences were related to their stated risk attitudes, environmental beliefs and characteristics. The results showed that farmers' environmental beliefs and perceptions of farmers such as "the use of less polluting machinery" and "investment in improving irrigation infrastructure" were the most preferred climate change mitigation and adaptation actions for farmers from the study region. The environmental opinions analyzed allowed to identify farmers' ecocentric and anthropocentric attitudes, highlighting the commitment of most farmers to the sustainable use of natural resources.

Thirdly, the technical efficiency (TE) of agricultural producers was analyzed using the Stochastic Frontier (SF) method. The results showed the average efficiency levels (57%) for three identified groups of farmers: high TE (15% of the farmers), average TE (72%) and low TE (13%). The level of efficiency was related to their risk attitudes, their preferences on climate change mitigation and adaptation actions, and their perception of climate change. The results showed a relationship between the preferred adaptation actions against climate change. Farmers who showed greater TE preferred the action "change crops", while less efficient farmers preferred to "invest in irrigation infrastructure".

As part of the findings of this research, we found that it is necessary to involve farmers in making agricultural public policy decisions, making them aware of the effects of climate change on production in accordance with the declarations of sustainable development related to the environment.

Key words: stated risk, farmers' preferences, climate change, adaptation, mitigation, technical efficiency, environmental attitudes, sustainability.

RESUMEN

El cambio climático es el proceso natural más recurrente a escala mundial y uno de los mayores desafíos de nuestro tiempo; debido a la estrecha relación entre sociedad, actividades productivas y desarrollo económico. Una de las actividades productivas más vulnerables al cambio climático es la agricultura, que se ve amenazada en la calidad y rendimiento de los cultivos y con ella, la seguridad alimentaria a nivel mundial. La variabilidad climática aumenta la incertidumbre en la producción, afectando el comportamiento y las decisiones de los agricultores. En esta tesis analizamos las preferencias de los agricultores hacia las acciones de mitigación y adaptación al cambio climático en la región noroeste de México. Se hizo especial hincapié en la eficiencia técnica, el riesgo y las actitudes medioambientales de los agricultores. Se tomó como estudio de caso el distrito de riego (076) del Valle del Carrizo en el norte del estado de Sinaloa, México. Los datos se recopilaron a través de una encuesta cara a cara, realizada con un grupo de 370 agricultores estratificados por tamaño de finca, género y edad.

En primer lugar, se analizaron las actitudes frente al riesgo de los agricultores mediante el método hipotético de lista de precios múltiples (MPL) conocido como loterías. Este comportamiento de riesgo se relacionó posteriormente con la actitud ambiental de los agricultores utilizando el Nuevo Paradigma Ecológico (NEP). También se destacaron las percepciones de los agricultores sobre el cambio climático y su situación socioeconómica. Los resultados mostraron un nivel de riesgo de 0.32, de acuerdo con el coeficiente de aversión al riesgo relativo constante (CRRA), colocando a los agricultores de la región como un grupo adverso al riesgo. El análisis de heterogeneidad mostró que los agricultores que recibieron apoyo económico y lo utilizaron en inversiones estructurales a nivel de finca eran más tolerantes al riesgo; Respecto al género, las mujeres fueron más tolerantes al riesgo que sus contrapartes (tolerantes al riesgo: 61% mujeres y 39% hombres). Los agricultores "mayores de 60 años" tenían una menor aversión al riesgo en promedio, en comparación con los agricultores en el rango de 41 a 60 años, que eran más conservadores, con un mayor nivel de aversión al riesgo. En segundo lugar, se analizaron las preferencias de los agricultores hacia las acciones de mitigación y adaptación al cambio climático utilizando la metodología del Proceso de Jerarquía Analítica (AHP). Las preferencias fueron relacionadas con sus actitudes de riesgo declaradas, creencias y actitudes ambientales. Los resultados mostraron que las creencias y percepciones ambientales de los agricultores como “el uso de maquinaria menos contaminante” y “la inversión en mejora de la infraestructura de riego” fueron las acciones de adaptación y mitigación del cambio climático de mayor preferencia para los agricultores de la región de estudio. Las opiniones ambientales analizadas permitieron identificar las actitudes ecocéntricas y antropocéntricas de los agricultores, destacando el compromiso de la mayoría de los agricultores con el uso sostenible de los recursos naturales. En tercer lugar, se analizó la eficiencia técnica (TE) de los productores agrícolas utilizando el método de Frontera Estocástica (SF). Los resultados mostraron los niveles de eficiencia promedio (57%) para tres grupos identificados de agricultores: TE alto (15% de los agricultores), TE medio (72%) y TE bajo (13%). El nivel de eficiencia se relacionó con sus actitudes de riesgo, sus preferencias en las acciones de mitigación y adaptación al cambio climático y su percepción del cambio climático. Los resultados mostraron una relación entre las acciones de adaptación preferidas frente al cambio climático. Los agricultores que mostraron mayor TE prefirieron la acción "cambiar cultivos", mientras que los agricultores menos eficientes prefirieron "invertir en infraestructura de riego".

Como parte de los hallazgos de esta investigación, encontramos que es necesario involucrar a los agricultores en la toma de decisiones de política pública agrícola, sensibilizándolos sobre los efectos del cambio climático en la producción de acuerdo con las declaraciones de desarrollo sostenible relacionadas con el medio ambiente.

Palabras clave: riesgo declarado, preferencias de los agricultores, cambio climático, adaptación, mitigación, actitudes ambientales, sostenibilidad.

Contenido

CAPÍTULO 1 INTRODUCCIÓN Y ANTECEDENTES

1.1 Introducción

Existen múltiples evidencias que indican que la agricultura siempre ha sido un pilar económico y social fundamental en todo el mundo, sin embargo, el sector agrícola es un importante emisor de gases de efecto invernadero (GEI), que afectan el cambio climático (CC) (Yue, et al., 2017) (Rivera y Di Paola, 2013). El cambio climático es uno de los mayores desafíos de nuestros tiempos. Este fenómeno (CC) se refiere a la variación a largo plazo del clima, generado por causas naturales o acciones humanas que distorsionan los parámetros climáticos, como la temperatura y la precipitación (MAPAMA, 2018). El cambio climático según la Convención Marco sobre Cambio Climático se refiere a un cambio en el clima que se atribuye directa o indirectamente a la actividad humana que altera la composición de la atmósfera global y se produce además de la variabilidad natural del clima observado durante períodos de tiempo comparables. (IPCC, 2014). La relación entre la sociedad, la agricultura y el desarrollo económico en las zonas rurales está estrechamente vinculada a las consecuencias del cambio climático (Valladolid, 2017).

Hay escenarios climáticos que enfatizan que un mayor aumento de la temperatura es predecible en tierra y en el mar, lo que tendrá consecuencias en las actividades agrícolas (Galindo, et al., 2014). Es importante destacar, que la agricultura en las regiones de África y América Latina es más vulnerable al cambio climático debido a su posición geográfica en el mundo (Cline, 2007; Bermúdez, 2000 y Ortiz, 2012). Asimismo, la relación entre el cambio climático y la agricultura es compleja, dado que esta última depende de la variación de la temperatura y los niveles de precipitación, así como de los aumentos de factores extremos, tales como; sequías, huracanes, inundaciones, incendios forestales, etc. (Vargas, 2007). El clima es el componente más importante en la práctica de actividades agrícolas y está afectando continuamente las decisiones de los agricultores, principalmente al incrementar la incertidumbre en la producción (Rivera y Di Paola, 2013).

Por otro lado, las percepciones son un elemento clave de los sistemas sociales que influyen en las actitudes y respuestas al cambio climático, impactando en la toma de decisiones y la gobernanza a corto y largo plazo. (Soubry, et al., 2020). Por lo tanto, las percepciones de los agricultores sobre el cambio climático desempeñan un papel cada vez más importante en la producción agrícola y en las decisiones de los agricultores a nivel de finca (Bonatti, 2011; Makuvaro, et al., 2018 y Zhai, et al., 2018).

Es importante señalar que se han implementado diversas acciones de mitigación y adaptación al cambio climático en los últimos veinte años (Ortiz, 2012). Las acciones de adaptación incluyen cambios en el cultivo y / o cultivos alternativos y mayores inversiones en infraestructura de riego (Galindo, et al., 2014). Además, varios estudios sugieren que las prácticas agrícolas tradicionales representan una herramienta para la adaptación, mediante el uso de variedades tolerantes a la sequía, policultivos, deshierbe oportuno, recolección de plantas silvestres, entre otras técnicas. Estas medidas buscan fortalecer la agricultura moderna a través de prácticas sostenibles para ajustar las experiencias agrícolas, que a su vez permitirán la conservación de la agricultura tradicional. (Altieri y Nicholls, 2008) (Galindo, et al., 2014)

Existe evidencia de que los recursos hídricos son vulnerables al cambio climático y que las consecuencias para la sociedad y los ecosistemas dependen de las medidas de adaptación. (Adger, 2007). El estrés hídrico y una demanda exacerbada de agua para el riego son, en resumen, los impactos más probables a escala mundial, en el sector agrícola.

Por otro lado, el Panel Intergubernamental sobre Cambio Climático (IPCC) define la mitigación como la "intervención antropogénica para reducir las fuentes o mejorar los sumideros de gases de efecto invernadero".

Mitigar el cambio climático no es solo una tarea para los agentes de la cadena productiva o los agricultores. Es una tarea conjunta que debe comenzar con las instituciones públicas y su participación en ella. Las políticas agrarias que promueven una agricultura sostenible y menos intensiva conducirían a mitigar el cambio climático (Rivera y Di Paola, 2013)

La fertilización representa un aspecto destacado en la mitigación del cambio climático, en términos de sus repercusiones negativas que afectan la productividad de los cultivos. Sin embargo, todavía hay dudas sobre los posibles beneficios, dado que las múltiples interacciones y los factores de estrés no se incorporan a los modelos actuales. (Ocampo, 2011)

Un aspecto importante para destacar es el concepto de "vulnerabilidad de los cultivos", ya que, al ser diferentes en cada región, las tecnologías aplicadas también cambian; dependiendo de la inestabilidad climática natural debido a alteraciones en los regímenes de lluvia y viento y la incidencia de eventos extremos (Ocampo, 2011). La alta vulnerabilidad de la región latinoamericana tiene una baja capacidad de adaptación a los desastres naturales consecuencia del cambio climático (Honty, 2007), debido a la escasa disposición de recursos económicos, materiales, científicos y tecnológicos para compensar los costos asociados con la adaptación. Cabe señalar que la baja capacidad de reacción política paga muy poco las implicaciones del cambio climático (Honty, 2007). Esta vulnerabilidad se entiende como la probabilidad de que una comunidad sufra daños materiales y humanos ante desastres naturales según la CEPAL y el BID, dependiendo de la fragilidad de su infraestructura, vivienda, actividades productivas, nivel de organización, sistemas de alerta, progreso político e institucional, es por eso por lo que la agricultura es un sector clave, donde la variabilidad del clima se traduce en el impacto en la alimentación, el estilo de vida, los ingresos y la seguridad alimentaria. Existen múltiples factores que afectan la vulnerabilidad en las zonas rurales, sin embargo, el clima no parece ser el principal (Alfaro, 2017).

En el caso de México, dado su espacio geográfico, sus escenarios climáticos y su orografía, ocurren eventos hidrometeorológicos extremos con graves consecuencias, donde el territorio más afectado suele ser la zona costera, las zonas de inundación y las laderas de las montañas.

Además de lo anterior, se espera que la sequía meteorológica crezca en ciertas regiones; se han presentado cambios en el 50% del entorno forestal (Zamora, 2015). Además, se prevé que la agricultura de secano se reducirá severamente.

Un punto que se considera relevante es que el gobierno mexicano acepta la existencia del cambio climático en la geografía nacional; por lo que considera necesario aplicar acciones que le permitan adaptarse en sus diferentes regiones. (Zamora, 2015)

En México, las Áreas Naturales Protegidas (ANP) han ganado notoriedad porque la adaptación al cambio climático de sus ecosistemas y poblaciones contribuye a la mitigación de los efectos adversos del mismo (Zamora, 2015)

1.2 Objetivos principales

Tomando como base lo anterior, para llevar a cabo el análisis de la agricultura, fue tomado como caso de estudio, la región agrícola que comprende el distrito de riego 076 del Valle del Carrizo, el cual, se encuentra ubicado en el norte del estado de Sinaloa, México, y que, desde la perspectiva del agricultor, sus preferencias de adaptación y mitigación a través del análisis del riesgo declarado y su nivel de eficiencia técnica, se proponen los siguientes objetivos:

1. Analizar las actitudes de riesgo declaradas de los agricultores en una región agrícola del noroeste de México, utilizando el método de listas de precios múltiples (MPL), conocido como "Loterías", como un método alternativo de obtención de riesgo que pertenece al enfoque de utilidad esperada. Adicionalmente se busca analizar la heterogeneidad del nivel de riesgo declarado frente a las opiniones medioambientales y las percepciones del cambio climático de los agricultores.

2. Identificar la importancia relativa de varias acciones de adaptación y mitigación del cambio climático relacionadas con las actividades agrícolas en una región marginal de México para

brindar argumentos a los responsables de la formulación de políticas al priorizar soluciones que contribuyan a la sostenibilidad de sus sistemas agrícolas.

3. Analizar si la eficiencia técnica se ve afectada por la preferencia de los agricultores por las medidas de adaptación y mitigación al cambio climático en México, mediante el uso del método de frontera de producción estocástica paramétrica (SPF) para identificar su relación con las preferencias declaradas de los agricultores por varias medidas de adaptación y mitigación del cambio climático, utilizando el método del proceso de jerarquía analítica (AHP). Asimismo, identificar la dirección y la magnitud de la relación entre Eficiencia Técnica (ET) y las preferencias de los agricultores.

Esta tesis contribuye a la literatura existente sobre las actitudes de riesgo de los agricultores, al aportar una nueva perspectiva utilizando el método Listas de Precios Múltiples (MPL) en México. De igual manera, a nivel metodológico, este documento también contribuye a los escasos estudios que utilizan el método de Proceso de Jerarquía Analítica (AHP), para determinar las preferencias de adaptación y mitigación de los agricultores, con respecto al cambio climático. Nuestro estudio verifico la validez y la idoneidad de esta técnica para comprender las necesidades y prioridades de los agricultores. Por otro lado, en esta investigación, se utilizó el método de frontera estocástica para medir el nivel de eficiencia técnica (ET) de los agricultores de la región y su relación con las preferencias sobre acciones de adaptación y mitigación del cambio climático, el nivel de riesgo declarado y sus actitudes ambientales.

Para lograr los objetivos anteriormente planteados, se ha propuesto un enfoque metodológico basado en la realización de encuestas cara a cara, cuyo tamaño de muestra se determinó en base a la fórmula de poblaciones finitas con un nivel de confianza de 95% y un intervalo de confianza del 4.99%. La encuesta fue diseñada con una perspectiva interdisciplinaria, que incluye aspectos económicos, sociales y demográficos. Incluyó un amplio conjunto de preguntas agrupadas de acuerdo con las características socioeconómicas de los agricultores, las características de sus tierras agrícolas y los tipos de cultivos (Kallas, et al., 2010) y su preferencia con respecto a la implementación de acciones de mitigación o adaptación relacionadas con la reducción de los efectos del cambio climático utilizando la técnica AHP. Las actitudes y opiniones de los agricultores que definen su comportamiento hacia el medio ambiente también se determinaron utilizando la escala del nuevo paradigma ecológico (NEP).

1.3 Enfoque metodológico y estructura de la tesis

El enfoque metodológico planteado en esta tesis parte del análisis y aplicación de distintos métodos para identificar el nivel de riesgo declarado, las preferencias de los agricultores hacia actividades de adaptación y mitigación del cambio climático y la eficiencia técnica de un grupo de agricultores de una región agrícola del norte del estado de Sinaloa México.

El nivel de riesgo es una variable clave de las decisiones bajo incertidumbre. Cada individuo o tomador de decisiones involucrado tiene una actitud diferente hacia el riesgo; por lo tanto, el grado de aversión al riesgo debe cuantificarse para identificar diferencias y similitudes. Existen numerosos métodos que se utilizan con éxito en la gestión económica y agrícola para medir las actitudes declaradas en relación con el riesgo en base a las encuestas de las personas involucradas en actividades económicas.

En este caso de estudio, el método seleccionado, como enfoque alternativo para medir las actitudes de riesgo declaradas de los agricultores fue el Método de Listas de Precios Múltiples, propuesto por Holt y Laury (Holt y Laury, 2002), específicamente la variante desarrollada por Brick, Visser and Burns (Brick, et al., 2012). Esta decisión se tomó debido a las características de la población objetivo del estudio, que no tiene un alto nivel de educación, pero está familiarizada con el concepto de loterías. El método seleccionado también se caracteriza por la simplicidad y un tiempo relativamente corto para la recopilación de datos. Además, su aplicación no requiere un conocimiento previo de los conceptos de incertidumbre y riesgo, ni un análisis exhaustivo de varias declaraciones. El método de MPL se ha utilizado en muchos estudios para medir las actitudes de riesgo de los agricultores, entre las que se encuentran aquellas creadas por Olbrich et al., (2014) y Brick et al., (2012).

El método MPL "loterías", consiste en un formato de lista de precios múltiples, por medio del cual a cada uno de los entrevistados se les presenta un conjunto de distintos pares de loterías, dentro de los cuales debe elegir una de las opciones de lotería para cada par (Andersen, et al., 2008). (Relaciona lo niveles de aversión al riesgo con un premio o ganancia).

Dentro de la definición del modelo se generó una lista de 8 preguntas (escenarios) con un par de loterías hipotéticas denominadas opción A y opción B, similar al modelo teórico utilizado por Brick, et al., (2012). En dicho modelo al igual que en este se mantienen constantes las probabilidades de cada una de las opciones para mantener el experimento lo más simple posible. En la opción A la probabilidad de obtener la cantidad presentada se fijó a un 100% (opción segura) y dentro de la opción B (opción riesgosa) se fijó a un 50% la probabilidad de obtener la cantidad de ($100) y la con misma probabilidad de 50% no obtener nada ($0) (lanzamiento de una moneda a Cara o Cruz) en todos los escenarios; mientras que la cantidad segura presentada en la opción A, en cada una de las 8 preguntas (escenarios) se va modificando de forma decreciente de acuerdo a las siguientes cantidades ($100, $75, $60, $50, $40, $30, $20 y $10).

Otro método utilizado fue el método del Proceso de Análisis Jerárquico (AHP), el cual está clasificado como parte de las técnicas basadas en la teoría de decisión multicriterio TDMC; es un método usado para medir intangibles usando el juicio humano, permite que se realice la priorización de un grupo de alternativas de acuerdo con determinados criterios que facilitan la selección de las soluciones óptimas posibles. Lo que caracteriza a la toma de decisiones multicriterio es la existencia de diversos criterios dentro del proceso de asignación de prioridades para cada una de las distintas alternativas. Este método se utilizó para identificar las preferencias de los agricultores y estimar la importancia relativa (es decir, las prioridades) de diferentes acciones de adaptación y mitigación.

El método AHP involucra 3 etapas que forman la estructura metodológica: 1) modelado, 2) evaluación y 3) priorización y síntesis. En la etapa de modelado se realiza la definición del problema y la estructuración de un modelo de decisión en forma de jerarquía. En la etapa de evaluación se realizan las comparaciones pareadas de todos los elementos de cada nivel de grupo usando la escala verbal de comparaciones pareadas propuesta por Saaty, posteriormente, se estima la importancia relativa de las acciones alternativas. En la última etapa correspondiente a la priorización y síntesis, se realiza la identificación de los criterios más preferidos, priorizando de forma conjunta todos los subcriterios propuestos en el modelo; hasta este punto, todas las comparaciones deben trazarse entre los elementos de cada grupo para cada agricultor (matrices Saaty), a través de las cuales se obtienen los pesos locales de los elementos identificados de acuerdo con las preferencias de cada agricultor mediante el uso del Método de la media geométrica [Kallas y Gil, 2012]. En función de las ponderaciones obtenidas para cada individuo se calcula el peso global que corresponderá a cada uno de los atributos, esto, mediante el producto del peso local de cada atributo por el peso local del nodo padre, generándose un vector con los pesos globales de cada una de las alternativas definidas en el modelo. Como parte de la etapa de verificación es importante destacar que con cada matriz generada se realizó el cálculo del nivel de coherencia de las respuestas emitidas por los productores agrícolas.

También utilizamos una forma adaptada de la escala del nuevo paradigma ecológico (NEP) que se validó mediante análisis factorial (PCA) para identificar las dimensiones ambientales latentes predominantes. Adicionalmente, se realizó un análisis de heterogeneidad para relacionar las preferencias de los productores agrícolas con las acciones contra los efectos del cambio climático en función de sus actitudes ambientales y de riesgo declaradas hacia sus actividades agrícolas.

Otra de las metodologías utilizadas fue el método de frontera estocástica que nos permitió estimar el nivel de eficiencia técnica (ET) de los productores agrícolas de la región de estudio. Este enfoque fue propuesto simultáneamente por Aigner, et al., (1977) y Meeusen y Van Den Broeck (1977). Los niveles de eficiencia técnica se calcularon como una medida orientada a la producción y se definieron como la relación entre la producción observada y la frontera de producción estocástica (FPE) correspondiente, con valores en el rango de cero a uno (Guesmi, et al., 2012). Según los valores estimados de eficiencia técnica, los agricultores se agruparon en tres grupos, teniendo en cuenta la desviación estándar media y una unidad hacia arriba y hacia abajo para establecer a los agricultores con eficiencia baja, media y alta.

En el capítulo dos de esta tesis se presentarán los resultados generales de la investigación y posteriormente las conclusiones resultantes y, finalmente en el capítulo tres se presentarán las tres publicaciones que abordan las metodologías descritas.

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CAPÍTULO 2 RESULTADOS GENERALES Y CONCLUSIONES

La consideración principal de este capítulo es la aportación de la discusión de los resultados de forma breve, de tal manera, que pueda obviarse en la duplicidad de datos con respecto a lo expuesto en el capítulo tercero, en donde se esbozará ampliamente los resultados generales de la investigación, así como las conclusiones de esta.

2.1 Resultados globales

En primer lugar, uno de los resultados que reveló la información de la investigación, con respecto al nivel de las actitudes de riesgo de los agricultores, define globalmente a la población estudiada como ligeramente adversa al riesgo, al mostrar una puntuación de 0,32, según la escala de Holt y Laury. De acuerdo con la escala de Holt y Laury (2002), los resultados de MPL con respecto a las actitudes de riesgo indicadas muestran que 51.35% de los agricultores son reacios al riesgo, 7.57% son neutrales y 41.08% son tolerantes al riesgo. Estos resultados son similares a los de Trujillo, et al., (2009), Galarza (2009) y Brick, et al., (2011), quienes encontraron que los agricultores exhibían, en general, una actitud aversa al riesgo.

Con respecto al análisis de heterogeneidad del riesgo, los resultados indican que las variables relacionadas con el nivel de aversión al riesgo son: El propósito de los subsidios recibidos (valor de p = 0,002), el género del productor agrícola (valor de p = 0,046) y la edad (p-valor = 0,000). Cabe resaltar que las mujeres resultaron ser más tolerantes al riesgo que sus contrapartes (el porcentaje de hombres que toleran el riesgo = 39%, mientras que el porcentaje de mujeres que toleran el riesgo es del 61%). También, es importante tener en cuenta el nivel promedio de riesgo estimado para las mujeres que fue de -0.035, y el nivel de riesgo estimado para los hombres fue de 0.361, especialmente porque las mujeres son responsables del 60% al 80% de los alimentos del mundo y son mejores administradores del medio ambiente (Doss, et al., 2018). Además, las mujeres son más propensas a participar en actividades extensas relacionadas con la agricultura y están más comprometidas con las actividades agrícolas. Sin embargo, las decisiones relacionadas con el desarrollo del predio agrícola y la adopción de mejoras son tomadas por los hombres, excluyendo a las mujeres en el proceso de toma de decisiones de un nuevo sistema agrícola (Fisher y Carr, 2015). El uso principal de los subsidios y apoyos económicos está altamente relacionado con el nivel de riesgo de los agricultores. Los agricultores que reciben apoyo económico y lo utilizan en inversiones estructurales a nivel de finca son más tolerantes al riesgo, mientras que aquellos que no tienen subsidio tienen un perfil adverso al riesgo (Takeshima y Yamauchi, 2012). La edad también se asoció con el nivel de riesgo, los agricultores "mayores de 60 años" muestran que la experiencia adquirida a lo largo del tiempo les permite tener una menor aversión al riesgo en promedio, en comparación con los agricultores en el rango de 41 a 60 años, que son más conservadores, mostrando un mayor nivel de aversión al riesgo.

De acuerdo con el análisis de componentes principales realizado, la primera componente identificada caracteriza la percepción de los agricultores respecto a los patrones climáticos negativos, y la segunda está relacionada con el impacto en su productividad agrícola. La mayoría de los agricultores tolerantes al riesgo, se ubicaron a la derecha de la primera dimensión, mostrando una mayor percepción de los patrones climáticos relacionados con el cambio climático, en comparación con los agricultores reacios al riesgo. Los agricultores altamente tolerantes al riesgo son aquellos que son propensos a usar subsidios en inversiones estructurales a nivel de finca. Los resultados también mostraron que los agricultores con riesgo neutral no tienen percepciones bien definidas sobre el cambio climático, ni los efectos que el cambio climático podría tener en su productividad.

Los resultados sobre las preferencias de los agricultores en relación con la implementación de acciones de adaptación y mitigación identificadas de acuerdo con el método AHP utilizado, reflejan la priorización de los agricultores de diferentes formas de enfrentar los impactos del cambio climático en sus actividades. Los pesos promedio estimados muestran que las acciones de mitigación se consideraron las opciones más importantes con una relevancia relativa más alta del 58.18%; siendo el uso de maquinaria menos contaminante la acción más preferida (30.29%). La segunda acción más preferida fue la inversión en la mejora de la infraestructura de riego (17.57%). El cambio de cultivos se consideró la tercera acción más preferida, representando (17.30%) de las respuestas de los agricultores. El manejo de cero labranzas fue la cuarta acción más preferida (16.22%), de todas las acciones el uso de energía renovable fue la opción menos preferida por los agricultores (5.95%).

De acuerdo con la relación entre las actitudes ambientales definidas mediante la escala NEP y las preferencias de los agricultores para la adaptación al cambio climático y las acciones de mitigación antes identificadas, aplicando el método de componentes principales identificamos dos comportamientos relevantes principales: actitudes ambientales ecocéntricas y antropocéntricas, que conforman cuatro cuadrantes.

Los resultados indican que la mayoría de los agricultores (39%) exhibieron claramente una actitud ecocéntrica positiva (+ eco, - antro), estos agricultores creen que la naturaleza debe protegerse porque es vulnerable a las acciones de los humanos y que los humanos deben limitar su uso y realizar acciones que apoyen la naturaleza. El 27% de los agricultores exhibieron una clara actitud antropocéntrica (- echo, + antro) y un interés en proteger la naturaleza solo para un claro beneficio económico, estos agricultores consideran que los humanos están por encima de la naturaleza y que, por lo tanto, no hay límite para el uso de los recursos naturales. El resto de los agricultores exhibieron opiniones menos claras sobre el medio ambiente, un 15% mostró opiniones negativas hacia las actitudes ecocéntricas y antropocéntricas (- eco, - antro), destacando su desacuerdo con las opiniones que colocan a la naturaleza por encima de los humanos y con aquellos que colocan a los humanos por encima de la naturaleza; y el 19% mostró opiniones positivas hacia las actitudes ecocéntricas y antropocéntricas (+ eco, + antro), son agricultores que están de acuerdo con ambas actitudes a favor de la naturaleza y a favor de las prioridades de los humanos en el uso de los recursos naturales.

Estos resultados muestran que las dimensiones ecocéntricas y antropocéntricas están estrechamente relacionadas con las preferencias del agricultor.

La acción de mitigación y adaptación al cambio climático más preferida por los agricultores, correspondiente al uso de maquinaria menos contaminante y energéticamente eficiente (M4), fue seleccionada principalmente por los agricultores con una actitud positiva hacia el medio ambiente (+ eco, -anthro). Las acciones de mitigación y adaptación restantes también fueron importantes para los agricultores que exhiben más puntos de vista ecocéntricos (+ eco, -anthro). Como excepción, la acción correspondiente a introducir semillas mejoradas y resistentes (A3) fue preferida por los agricultores que no muestran una actitud clara hacia el medio ambiente (+ eco, + anthro). De igual manera los agricultores con las actitudes más ecocéntricas (+ eco, -anthro) exhibieron mayor preferencia por la acción de mitigación correspondiente al uso de energía renovable (M3).

El análisis de heterogeneidad entre las actitudes de riesgo establecidas y las preferencias de los agricultores hacia las acciones de adaptación y mitigación no muestra suficiente evidencia de que exista relación alguna. A través del análisis realizado, no se encontró una relación significativa entre las preferencias para las acciones de adaptación y mitigación y el nivel de riesgo establecido, aunque está claramente relacionado con otras variables socioeconómicas y de gestión para los agricultores.

De acuerdo con análisis de las características socioeconómicas, se observó que el 89% son hombres y solo el 11% son mujeres, el 52.16% de los agricultores encuestados se encuentran dentro del rango de edad de 41 a 60 años, el 28.38% corresponde a los agricultores mayores de 60 años y 19.46% son menores de 41 años. El número promedio de miembros de la familia se registró en 3.78. El 76% de los ingresos de los participantes se generan a partir de actividades agrícolas. El 68% de los productores reciben un subsidio para realizar su actividad agrícola; dentro de este grupo de productores que reciben subsidio, el 60% lo utilizan para cubrir los costos operativos, mientras que solo el 12.3% de los agricultores lo utilizan para invertir en equipos y tecnología agrícola. La mayoría de los agricultores (63%) no suelen utilizar ningún tipo de seguro agrícola. La mayoría de los agricultores participantes son propietarios del predio agrícola (79%), destacando en su producción el cultivo de trigo en un 29%, de alfalfa con un 24% y el cultivo de soja en un 9.73%.

Características socioeconómicas como la edad y sexo del agricultor, además de contar con un contrato de seguro agrícola, un crédito agrícola, pertenecer a una asociación agrícola o el tipo de selección de cultivos se encuentran relacionadas con las acciones de mitigación y adaptación preferidas por los productores agrícolas. En relación con lo anterior, se observó que los agricultores menores de 40 años prefieren la "inversión en la mejora de la infraestructura de riego", los agricultores de 40 a 60 años prefieren el enfoque de "cambio en el cultivo", y los agricultores mayores de 60 años prefieren la "gestión de labranza cero". Los agricultores sin seguro de cosechas prefieren el "cambio en los cultivos", mientras que aquellos con seguro prefieren "el uso de maquinaria menos contaminante y energéticamente eficiente" para reducir los impactos del cambio climático. Por otro lado, los productores con seguro sobre sus cosechas tienen menos preocupaciones con respecto a los impactos del cambio climático y, por lo tanto, muestran preferencia por otras acciones que reducen principalmente los efectos negativos sobre el medio ambiente. De igual manera se observó que los agricultores que cuentan con un crédito agrícola, seguros agrícolas y que pertenecen a una asociación agrícola prefieren "el uso de maquinaria menos contaminante y energéticamente eficiente" y entre sus cultivos seleccionaron cebollas, chiles, maíz, soja, sorgo y triticale. Mientras que los agricultores sin crédito agrícola y bajo un régimen de tenencia de la tierra en propiedad privada que cultivan patatas prefieren aumentar la inversión en la mejora de la infraestructura de riego, y los agricultores sin crédito agrícola, que no pertenecen a una asociación agrícola y cultivan sandía y cártamo principalmente se inclinan por la acción de mitigación identificada como "gestión de labranza cero".

En lo que respecta a la eficiencia técnica (ET), los resultados muestran que la estimación promedio fue de 0.57, lo que indica que los agricultores alcanzan el 57% de su producción potencial máxima, y la mayoría de ellos tienen puntajes de eficiencia promedio (72% de puntaje de TE moderadamente eficiente, 13% de puntaje bajo y 15% de puntaje de TE alto), es decir, existe una gran oportunidad para mejorar la ET en un 43%, mediante un uso más racional y menos arbitrario de los insumos que reduciría los costos de producción y contribuiría al sustento de la granja.

Se considera que la baja eficiencia puede estar asociada con un mal uso de la tecnología existente, por lo que la optimización tiene que ver con, entre otras cosas, la optimización de la infraestructura de riego, enfocada en reducir sustancialmente el consumo de agua y energía (Galindo, 2013), dado que, en general, el consumo de energía puede considerarse uno de los gastos más importantes asociados con la producción agrícola. Además, reducir el consumo de energía generaría ahorros económicos y reduciría las emisiones contaminantes en el medio ambiente, lo que daría como resultado una forma de agricultura más sostenible.

La eficiencia técnica se relacionó con las variables socioeconómicas: edad, el régimen de propiedad y el porcentaje de ingresos provenientes de la agricultura, Los jóvenes agricultores que son propietarios de sus tierras agrícolas con más del 50% de sus ingresos provenientes de actividades agrícolas son más eficientes técnicamente. Estos resultados están en línea con el hallazgo en Guesmi, et al., (2010) y Perdomo y Mendieta (2007) que destacan la variable edad e ingresos como factores determinantes de ET.

En relación con las preferencias de los agricultores, el riesgo y las actitudes ambientales y las percepciones del cambio climático, los resultados muestran que los agricultores más eficientes prefirieron la acción de adaptación “cambio de cultivos”, destacando la importancia de adoptar variedades nuevas, de baja demanda de agua y resistentes a las enfermedades para enfrentar el cambio climático. Estos agricultores exhibieron una actitud antropocéntrica hacia el medio ambiente, destacando relativamente menos sensibilidad a los problemas del cambio climático. En particular, se encontró una percepción más baja con respecto a la variación de fenómenos ambientales como las sequías y los episodios de congelación.

Los agricultores con menor eficiencia técnica prefirieron la inversión en instalaciones de riego como una acción de adaptación y exhibieron una actitud ecocéntrica. Este bajo nivel de ET podría estar relacionado con su extenso sistema de producción y con el tipo de gestión agrícola. Estos incluyen la adopción de una estrategia de baja degradación del suelo mediante la aplicación de agricultura de labranza cero, bajo uso de fitosanitarios y siguiendo una rotación natural de cultivos. Los agricultores menos eficientes están aprovechando los recursos naturales disponibles con un bajo nivel de adopción de innovaciones tecnológicas. Este resultado es similar al hallazgo de Álvarez y Del Corral (2010) quienes declararon que los agricultores que adoptan tecnología agrícola intensiva son más productivos y técnicamente más eficientes que los extensivos. En este contexto, la toma de decisiones de los agricultores ecocéntricos está impulsada no solo por sus objetivos económicos sino también por los ambientales. Tienden a preservar el medio ambiente como un aporte de sus actividades que aseguran la generación de un ingreso satisfactorio (Kallas y Gil, 2010). Los agricultores ecocéntricos podrían adoptar tecnologías agrícolas que tengan un impacto positivo en su productividad y sean amigables con el medio ambiente (Parks y Brekken, 2018), como la adopción de un sistema de riego eficiente. Desde el punto de vista de la agricultura sostenible, se requiere un equilibrio entre sus componentes económicos, sociales y ambientales. De lo contrario, cualquier otra posición a favor de solo uno de estos factores supone el detrimento del resto.

Su percepción del cambio climático no estaba claramente definida, con una ligera tendencia hacia bajos niveles de percepción. Según estos resultados, podemos deducir que el principal problema que enfrentan los agricultores menos eficientes es la disponibilidad de agua, o específicamente la necesidad de optimizar su uso, dado el alto costo del agua en la producción de cultivos. Los sistemas de riego son un elemento clave para lograr una alta eficiencia técnica en la producción agrícola (Ortiz, 2012). La posición poco clara con respecto al cambio climático no les permite identificar que el costo derivado del consumo de agua se debe al mayor uso del agua debido a la variación en el clima (mayor evapotranspiración debido al aumento de la temperatura, menor humedad en el suelo como resultado de la sequía) Los efectos del cambio climático, identificados por los agricultores principalmente como el aumento de la temperatura y la mayor incidencia de enfermedades y plagas y problemas de malezas, fueron percibidos en mayor medida por los agricultores moderadamente eficientes.

2.2 Conclusiones

Hacer frente de manera efectiva a los impactos del cambio climático en la agricultura implica la implementación de acciones de mitigación y adaptación de acuerdo con las percepciones, actitudes y preferencias de los agricultores. Los responsables de la elaboración de las políticas relacionados con la producción agrícola deben basarse en lo anterior a fin de mejorar la efectividad de las políticas aplicadas, mediante la implementación de acciones con mayor aceptación que mejoren el bienestar social y económico de los agricultores, y de esta manera redirigir el apoyo que se brinda actualmente, al priorizar medidas que promuevan el desarrollo de actividades agrícolas más sostenibles a nivel regional y nacional.

En la región estudiada, en términos generales, los agricultores exhibieron una actitud adversa al riesgo, reconociendo la importancia de mejorar la comercialización de sus cultivos y la efectividad de los tratamientos contra enfermedades y plagas. Características como el sexo y la edad de los agricultores se relacionaron con su nivel de riesgo declarado. Los agricultores mayores de 60 años resultaron ser más tolerantes al riesgo que los agricultores más jóvenes. Es importante destacar es que las mujeres agricultoras de la región resultaron ser más tolerantes al riesgo que los hombres y más propensas a invertir a nivel de predio agrícola el dinero recibido en forma de apoyo público o subsidio. Sin embargo, están marginadas como tomadoras de decisiones a nivel de políticas y, por lo tanto, están aún menos involucradas en el diseño y la implementación de políticas públicas en el sector agrícola, principalmente debido a limitaciones culturales.

Los agricultores tolerantes al riesgo demostraron ser muy conscientes de los efectos del cambio climático en la producción y demostraron estar de acuerdo con las declaraciones de desarrollo sostenible relacionadas con el medio ambiente, lo que puede generar una mayor resiliencia en la región. Lo anterior refuerza la importancia de que sean involucrados en el proceso de generación de políticas públicas agrícolas. Además, las políticas públicas deben dirigirse de manera efectiva a los agricultores con actitudes adversas al riesgo para construir relaciones seguras con ellos, lo que puede mejorar sus percepciones y capacidades de adaptación en relación con el cambio climático.

Las percepciones del cambio climático de los agricultores se destacaron por los efectos adversos sobre la producción, a través de la percepción de una mayor incidencia de plagas y enfermedades en sus cultivos, aumentos en el desarrollo de malezas, aumentos y variaciones de la temperatura y cambios en la temporalidad de los períodos de lluvia.

A través del Proceso de Jerarquía Analítica, se descubrió que los agricultores priorizan acciones que implícitamente brindan beneficios económicos a corto plazo. El uso de maquinaria eficiente y menos contaminante se identificó como una de las mejores alternativas no solo por sus impactos positivos en el medio ambiente sino también por sus beneficios económicos en términos de reducción de costos de energía a nivel de granja. Los agricultores con actitudes ecocéntricas exhibieron una mayor disposición a adoptar medidas contra el cambio climático, mientras que aquellos con puntos de vista antropocéntricos exhibieron principalmente preferencias más fuertes por actividades relacionadas con mejoras en su productividad.

Los resultados muestran que las preferencias de los agricultores por las acciones de mitigación y adaptación están estrechamente relacionadas con los tipos de cultivos. La inversión en mejorar la infraestructura de riego como una actividad de adaptación fue ampliamente aceptada por los agricultores con problemas de disponibilidad de agua que cultivan batatas. Esta acción de adaptación ayuda a los agricultores a optimizar su uso del agua y abordar los problemas de disponibilidad de agua en la región al aumentar su productividad y limitar el desperdicio de agua. Adoptar un cambio en los cultivos como una acción de adaptación también fue preferido por los agricultores que cultivan sorgo, y la preferencia por el enfoque de mitigación de labranza cero está relacionada con los cultivos de sandía y cártamo.

El diseño de políticas públicas agrícolas debe considerar las preferencias de los agricultores hacia las acciones de mitigación y adaptación al diseñar e implementar medidas que aseguren una agricultura sostenible. Las herramientas políticas y las intervenciones deben ser inclusivas y desarrolladas a nivel micro en función de las tipologías agrícolas, y se debe fomentar la diversidad de cultivos.

Las áreas rurales que son vulnerables a los impactos del cambio climático, donde la agricultura desempeña un papel económico relevante, muestran la importancia de implementar estrategias de adaptación y mitigación específicas para mejorar el nivel de eficiencia técnica a nivel de granja. La adopción de estas acciones no implica una mayor tecnificación del campo, sino un mejor uso de los recursos e insumos disponibles actualmente mediante la introducción de sistemas alternativos de gestión agrícola, como el uso de la agricultura orgánica y la labranza cero, la adaptación del calendario de siembra y el cambio de cultivos.

Los efectos del cambio climático en los sistemas agrícolas dependen del tipo de sistema de producción agrícola implementado. Por lo tanto, es necesario adaptar estos sistemas de acuerdo con los requisitos cambiantes del entorno natural causados por la variación climática, para aumentar la capacidad de producción mediante el uso óptimo de los recursos disponibles, lo que resulta en un mayor nivel de eficiencia técnica. Los resultados sugieren la necesidad de aprovechar los recursos disponibles para enfrentar los efectos adversos del cambio climático. Adoptar el uso de semillas mejoradas y cambiar los cultivos se encuentran entre las acciones más importantes según las preferencias de los agricultores. Los formuladores de políticas agrícolas deben generar incentivos para que los agricultores de la región adopten este tipo de acciones de adaptación y difundir información técnica sobre las mejores prácticas para alentarlos a poner en práctica estas acciones.

En relación con los agricultores con menos eficiencia técnica, cuya actitud ambiental era más ecocéntrica, su eficiencia ecológica también debería explicarse mediante un uso más sostenible de los recursos hídricos, ya que este es uno de los principales factores que afecta negativamente el rendimiento agrícola.

En el sector agrícola, las políticas económicas que se implementan deben estar dirigidas a aumentar los ingresos y mejorar los medios de vida de los hogares rurales para mejorar sus capacidades y activos productivos mediante el uso sostenible de los recursos. Nuestros resultados muestran que las autoridades competentes deben incluir varias acciones que podrían representar una hoja de ruta en la región estudiada. Primero, es necesario realizar una investigación sobre los impactos del cambio climático en la agricultura en la región desde una perspectiva multidisciplinaria, para identificar el impacto de la implementación de acciones de adaptación y mitigación en los patrones de productividad agrícola. En segundo lugar, esta investigación destaca la importancia de identificar variedades de cultivos que se adapten mejor a las nuevas condiciones climáticas de la región. La adopción de esta medida debe ir acompañada de campañas de difusión para compartir experiencias de otros agricultores y ofrecer información sobre los beneficios económicos, sociales y ambientales de la adopción de estas prácticas. Tercero, las asociaciones agrícolas deberían generar esquemas de capacitación sobre prácticas agrícolas de adaptación y mitigación para mejorar el uso racional y la conservación de los recursos naturales, a fin de reducir la aversión al riesgo y aumentar la probabilidad de implementar las nuevas prácticas. Finalmente, se deben establecer programas de incentivos económicos que puedan ayudar a los agricultores a introducir nuevas prácticas de gestión sostenible a nivel de granja que aumenten su productividad y respeten el medio ambiente, específicamente acciones de mitigación.

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CAPÍTULO 3 LAS PUBLICACIONES

3.1. Primera publicación: Analysis of Farmers' Stated Risk Using Lotteries and Their Perceptions of Climate Change in the Northwest of Mexico.

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Analysis of Farmers' Stated Risk Using Lotteries and Their Perceptions of Climate Change in the Northwest of Mexico

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Abstract: Risk attitudes are relevant factors affecting production, management and investment decisions at the farm level. They are key factors related to farmers' attitudes towards the environment and climate change. Several methodological approaches, which were considered to be preferable for measuring the level of risk of an economic agent, ranging from highly risk-tolerant to highly risk-averse attitudes, are available. The Multiple Price List (MPL) method is one of the stated approaches that is gaining relevance. In this study, we apply the MPL and relate the risk outcomes to farmers' socio-economic characteristics and their perceptions of the environment and climate change. Data were collected using a face-to-face survey, carried out with a group of 370 farmers of an irrigation district, located in the northwest of Mexico. The results showed a risk level of about 0.32, according to the Constant Relative Risk Aversion (CRRA) coefficient, locating farmers of the region in a risk-averse group. The heterogeneity analysis showed that the socioeconomic factors and the perceptions of climate change are related to the farmers´ stated risk level. Farmers who are young women, with a tendency to use public support for structural investment, were shown to be risk-tolerant. Farmers considered floods, hail, diseases, pests, and weed growth incidences to be the most frequent weather patterns in the region.

Keywords: risk attitude; farmers; multiple price list; lotteries and climate change

1. Introduction and Objectives

Climate change is one of the greatest challenges of our times. This phenomenon refers to the long-term variation of the climate generated by natural causes or human actions that distort climatic parameters, such as temperature and precipitation [1]. The way in which weather patterns occur represents a risk, especially for agricultural production due to floods, storms, droughts and hail [2]. Climate is the most significant component in the practice of agricultural activities and is continuously affecting farmers' decisions, mainly by increasing the uncertainty of the production [3].

Farmers' perceptions of climate change are increasingly playing an important role in agricultural output and farmers' decisions at the farm level [4–6]. The perceptions are a set of understandings and sensitivities, integrating an objective and subjective vision about the environment, that allows for the conceptualization of beliefs, values and norms and determines if attitudes are positive or negative [7]. These perceptions are multidimensional and are mainly related to farmers' risk attitudes, opinions and their socio-economic characteristics [8,9]. They may have a direct impact on the development of public policy programs regarding the agricultural production sector, as well as on farmers' actions related to energy consumption (type and quantity of energy used in machinery and equipment) [10–12].

In fact, several determinants can be related to the farmer's risk attitude, which in turn may affect his/her decision at the farm level. The socioeconomic characteristics of farmers (such as age, sex, percentage of income from agriculture, agricultural experience, etc.) are relevant determinants [13]. The farm descriptors (land tenure regime, agricultural subsidies, size, crop diversity and type, rainfed or irrigation land, harvest type, etc.) may also be associated with the determination of risk attitudes [14,15]. Farmers' perceptions of weather patterns are also significant factors affecting their farming management, crop rotation and investment decisions [16]. Their opinions and attitudes concerning the environment may also directly or indirectly impact their decisions, with a certain level of uncertainty [17].

In this context, the main objective of this paper is to analyze the farmers' stated risk attitudes in an agricultural region in Mexico, using the Multiple Price Lists (MPL) method, known as "Lotteries", as an alternative method that belongs to the expected utility risk elicitation approach. We also seek to analyze the heterogeneity of the risk attitude level with farmers' opinions concerning the environment and perceptions of climate change. The heterogeneity analysis will also be conducted by analyzing the risk attitudes in relation to the abovementioned farms and farmers' characteristics, perception, attitudes and opinions. Farmers´ attitudes and sensibility concerning the environment will be also included. Finally, we will identify attitude patterns, which allow for the differentiation of groups of producers whose characteristics aid in understanding the decisions that they make regarding their activities in order to inform policy makers on farmers' preferences.

This paper contributes to the existing literature on farmers' risk attitudes by contributing new insight, using the MPL method in Mexico. Reviewing the existing literature, there seems to be very scarce or no information regarding the measurement of the risk aversion level of farmers' stated risk in Mexico using the MPL. This paper contributes to the verification of the effectiveness and reliability of this technical risk analysis, with a specific empirical application, and can be easily understood by farmers, without the need for specific prior knowledge of the interviewees. It also offers the opportunity to compare our results with other agricultural systems with similar or different management practices and crops.

2. Background

The specific study site is identified as irrigation district DR076, which is located in the Carrizo Valley in the state of Sinaloa in Northwestern Mexico, and is eight meters above sea level (Figure 1). The extension of the irrigation district DR076 is approximately 70,172 ha and has 24,017 inhabitants, distributed in 27 localities, with a Gross Domestic Production (GDP) of $143,052 ($ = Mexican Pesos (MXN); $100 (MXN) = 4.89 USD) [18]. Its main economic activity is based on agricultural and animal production, with land characteristics that are very appropriate for crop farming. The irrigation district DR076 is considered one of the most important regions for crop production, which are mainly cereals, such as wheat, with 76% of the total Agricultural Area Used (UAA), and corn, with 8% [19]. The main irrigation system is by gravity, where water resources are obtained from the "Rio Fuerte" river and the water dam, called "Josefa Ortiz de Dominguez," with a water volume capacity of one billion and 227 million m^3.

In the northwestern region of Mexico, the increase of the temperature and the decrease of the annual precipitation is a generalized trend [20]. In the particular case of the Irrigation District DR076, the atypical climatic conditions have been very extreme in recent years (in particular, in 2013), where the lack of rain, low temperature and strong droughts have been more frequent, causing considerable output losses [21]. In 2011, frost weather led to a total loss of the corn yield [22]. In fact, the effect of climate change is closely related to a reduction in economic growth, making it harder to reduce poverty and ensure the food security of local and marginal agricultural communities. [23].

Figure 1. Location of the study area: Irrigation District DR076, Sinaloa Mexico [24].

The risk attitude is an aspect related to the behavior of the human being, especially that affecting their economic decisions. According to the neoclassical economic theory, in general terms, individuals are risk-averse, exhibit a low risk tolerance and tend toward profit maximization [25,26]. Risk attitude is individual-specific behavior that affects personal and professional decisions, in particular, investment options, such as the amount and periodicity in any economic activity.

To analyze risk attitudes, several methodological approaches are available that are developed and implemented with a great emphasis on those aspects associated with economic activities, such as agriculture. The stated risk elicitation is one of the most widely used approaches, in which individuals are asked in a survey about their risk behavior. This approach can rely on the multi-affirmation method, which often includes the self-assessment of risk attitude. It can also rely on methods that are based on empirical data analysis and on the expected utility theory. The Expected Utility Theory was initially introduced by Daniel Bernoulli in 1738. According to this theory, the analysis of decisions under uncertainty, individuals choose the option that provides the highest expected utility, corresponding to the sum of the products of probability and utility over all possible outcomes. John von Neumann and Oskar Morgenstern contributed to the original conception of the theory in 1944 by explaining the decision under uncertainty that minimizes the risk of an election, and this was followed in this research [27,28]. This conception is based on several conditions that are related to rational equability, in which agents rationally assess the odds of the different scenarios to be evaluated. In this context, the decisions taken under risk are analyzed among different alternatives, assuming that the decisions have an order of preference and are defined based on a probability distribution for a certain number of affirmations or sentences [29].

However, the risk attitude cannot be only measured directly based on the expected utility, $U(X)$, because it also depends on the strength of the preference ("not to risk"), represented by $V(X)$ [30–32], where X corresponds to the income (a specific amount), in order to obtain a more accurate measure of the risk attitude, which is known as a "True Equivalent" measure [33]. True Equivalent is a certain amount of money, and a person is indifferent to whether there is a secure payment or uncertain payments of a certain investment [34]. This measure was applied in this study.

3. Theoretical Framework of the Stated Risk Analysis

As previously noted, risk is a key variable of decisions under uncertainty. Each involved individual or decision-maker has a different attitude towards risk; hence, the degree of risk aversion needs to be quantified in order to identify differences and similarities. There are numerous methods that are used successfully in economics and agricultural management to measure stated attitudes concerning risk based on surveys of the individuals involved in economic activities. These methods could be divided into: (i) Methods based on an attitudinal scale, with multiple affirmations or statements, (ii) methods based on the theory of expected utility, and (iii) methods that involve a combination of the previous ones.

The attitudinal scale methods are constructed based on the score assigned to multiple statements using a certain scale of values [35]. Using these methods, the risk attitude is considered a latent construct (a dependent variable) that is not directly observable, but can be estimated through other explanatory variables that are related to the statements proposed by different researchers, depending on the topic of study.

The empirical methods based on the economic theory of expected utility [36,37] estimate an indicator of risk aversion as a function of probabilities in a non-parametric framework, since it is not a function of the utility that is supposed to govern the behavior of individuals. The following is a brief description of the main applications measuring the stated risk level in agriculture, based on surveys and interviews:

- Bardhan's attitudinal scale of five points on dairy farmers in India, which identifies the most relevant sources of risk according to farmers' perceptions and attitudes [38], based on 31 statements related to the social and psychological attributes of each farmer [39].
- Risk attitude measuring instrument RAMI of Fausti and Gillespie, applied to cattle producers in the United States [40]. The instrument was made up of five questions, and the last three were defined according to the certainty equivalence framework associated with the expected utility model.
- Scale of the measurement of risk attitudes, based on three factors of Allub's scale concerning the hypothesis that risk aversion and income diversification are the factors that influenced the farmers' decisions in a case study in Argentina [41]. It considered that risk aversion is determined by three factors: The socio-economic status of the farmer, the degree of involvement or participation in the rural development program, and the farmer's perception of the agro ecological conditions of the farm.
- Method of measuring the risk attitude with three components of Bard [16]. This scale was implemented on grain producers in the United States. The method consists of three components: The risk attitude scale, a self-assessment question and a model based on the expected utility.
- The Multiple Price List "Lotteries" (MPL), of Olbrich, Quaas, and Baumgärtner, based on the Theory of Expected Utility (EUT), was implemented to analyze the risk attitude of livestock producers in Namibia's pastures using the MPL format [42], proposed by Binswanger [43] and studied by Holt and Laury [28].

In this case study, the method selected to measure the farmers' risk attitudes was the MLP proposed by Holt and Laury [28], specifically the variant developed by Brick, Visser and Burns [44]. This decision was taken because of the characteristics of the study target population, which does not have a high level of education, but is familiar with the concept of lotteries. The selected method is also characterized by simplicity and a relatively short time for data collection. In addition, its application does not require prior knowledge of the concepts of uncertainty and risk, nor extensive analysis of multiple statements. The MPL method has been used in many studies to measure the risk attitudes of farmers, among which are those made by Olbrich et al. [42] and Brick et al. [44].

4. Materials and Methods

The data collected correspond to a representative sample of a total of 370 farmers from irrigation district DR076, and 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% [45]. The data collection was carried out in a stratified way through a semi-structured face-to-face questionnaire, carried out during the period from October to December 2017, with the purpose of identifying factors affecting farmers' risk attitudes. These factors were classified into socio-economic variables that include the particular farmer characteristics, the farm descriptors and main crops, as well as the environmental opinions and attitudes of farmers and their perceptions of weather patterns changes (the translated questionnaire is available in supplementary file Q_1). On average, the application of the interview lasted 40 min with each farmer and was carried out with the support of a group of students from the Intercultural Autonomous University of Sinaloa, who were instructed prior to the application of the survey. The following methodological approach is summarized in Figure 2.

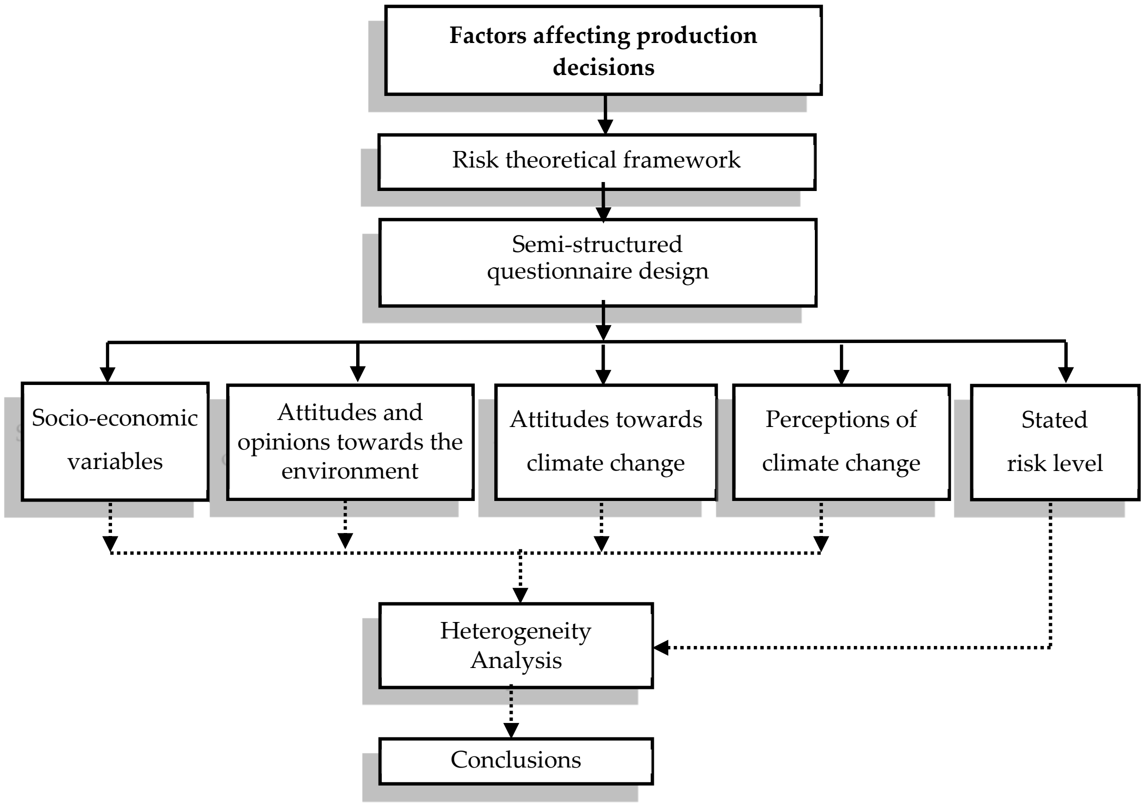

Figure 2. Methodological research approach.

The main variables, describing the 370 farmers, their perceptions, opinions and farm characteristics, are described in Tables 1 and 2.

Each farmer was presented with a questionnaire, with open-ended questions divided into several blocks according to the type of information, collected and presented in Tables 1 and 2. This questionnaire was tested before its final application on a sample of about 25 farmers. The blocks of variables were: (i) Farmers' socio-economic variables, farm characteristics (economic and management), investment and land use, following the classification presented by Kallas et al. [13], (ii) environmental attitudes and opinions, using the New Ecological Paradigm Scale NEP [46], (iii) attitudes or willingness to carry out actions to reduce climate change using an array of statements evaluated by farmers, (iv) perception of climate change constructed from literature, and (v) attitudes toward risk using the MPL method. The methods used are described below:

Table 1. The description of farmers, their perceptions and opinions. SD: Standard Deviation.

Variables	Percentage (%)		
Gender			
Male	88.92%		
Female	11.08%		
Age			
Under 40 years	19.46%		
From 41 to 60 years old	52.16%		
Above 60 years	28.38%		
Percentage of income from agriculture (%)	76.00%		
	Mean	**SD**	**Units**
Number of members of the family	3.79	1.74	members
Generations of the family dedicated to agriculture	2.28	0.83	members
Farmers' understanding about aspects related to global warming (%)			
Melting of the poles	18.38%		
Rising temperature and warming of the earth	52.97%		
Pollution	13.92%		
Emission of gases into the atmosphere	14.73%		
Farmers' opinions on the level of improvement required in his activity on a scale from0 (not required at all) to 10 (absolutely required):			
Commercialization of crops	8.28	2.69	
Fight against diseases or pests	7.25	3.14	
Choice of crops	6.24	3.45	
Quality of the soil	6.84	3.39	
Type of tillage	7.32	3.07	
Use of efficient irrigation techniques	7.06	3.48	
Farmers' perceptions on climate change on a scale from 0 (not observed at all) to 10 (highly observed):			
The temperature has increased	7.46	2.32	
The level of precipitation has changed	6.72	2.87	
The rain periods have changed their temporality	6.86	2.79	
The soil has less fertility	6.24	2.96	
The periods of drought have increased	6.56	2.79	
The harvest has decreased	6.72	2.82	
There have been more episodes of droughts	6.61	2.92	
There have been more episodes of frost	5.98	3.20	
There have been more episodes of floods	6.85	2.68	
There have been more episodes of hail	6.08	3.12	
There have been more diseases and pests	8.23	1.31	
Weeds have increased	7.92	1.88	
Farmers' level of willingness to perform the following actions on a scale from 0 (not willing) to 10 (completely willing):			
Perform only nightly irrigation	5.53	3.80	
Use low-polluting machinery	8.02	2.62	
Carry out agro ecological production	7.89	2.50	
Use renewable energy sources	7.91	2.52	
Do not burn biomass (stubble)	8.01	3.26	
Use non-nitrogenous fertilizers	7.99	2.53	
Use the zero tillage method	6.60	3.58	

Table 2. The description of the farms and main crop activities.

Variable	Mean	SD	Units
Utilized agricultural area	10.66	9.28	ha
Number of irrigations by crop season	7.56	4.61	frequency
Volume of water used in irrigation	15.46	10.97	m3/ha
Permanent employees	1.52	1.73	persons
Temporary employees	3.79	9.39	persons

Variable	Percentage	Variable	Percentage
Type of crop harvest		Have credit for farming activity [a]	
Manual	17.03%	No	54.05%
Mechanic	82.97%	Yes	45.95%
Land tenure regime		Receive some subsidy for agriculture	
Private property	32.97%	No	31.62%
Ejidal *	67.03%	Yes	68.38%
Property management regime		Purpose of the subsidies received	
Owner	79.19%	Covering operating expenses	60.50%
Owner's family without salary	5.95%	For investment in equipment	12.30%
Salaried family	0.27%	For agricultural improvement of land	12.60%
Tenant or associate	14.59%	Other agricultural expenses	14.60%
Water availability problems [c]		Agricultural insurance [d]	
No	84.05%	No	63.24%
Yes	15.95%	Yes	36.76%
Experience in water collection [b]		Origin of their agricultural training	
No	83.78%	Agrarian Experience	88.92%
Yes	16.22%	Agricultural professional-university training	6.76%
Type of irrigation		Courses, conferences, workshops, etc.	2.43%
Irrigation by gravity	95.68%	Other education sources	1.89%
Sprinkler irrigation	1.62%	Main product grown	
Mechanized Irrigation by gravity	0.81%	Wheat	28.92%
Drip irrigation/localized	1.89%	Alfalfa	24.59%
		Soy	9.73%
		Peanut	7.03%
		Corn	5.41%
		Chilli	4.32%
		Others (Onion, Sweet potato, Watermelon, Bean, Sorghum and Triticale)	20.00%

* Form of farmers' organizations in Mexico. [a] Refers to whether the farmer received a credit loan for his agricultural activity. [b] Indicates if the farmer has used some method to recollect water for crops, such as ponds or dams. [c] Refers to the problems related to the water availability in their agricultural land, such as a time-restricted access to water resources and the payment of the water quota. [d] Refers to whether farmers hired an insurance contract for their crops.

4.1. Measuring Farmers' Environmental Attitudes and Opinions

The NEP scale was used to analyze farmers' environmental opinions. This scale has sixteen statements (Table 3) that express a positive or negative evaluation of the environment and relies on individual's beliefs about themselves and nature, according to a nine-point Likert type scale, where 1 means absolutely disagree, and 9 means absolutely agree [47,48]. To understand the behavior that humans have toward the environment, it is necessary to understand how they perceive it, that is, what their pro-environmental attitudes are. By performing a factorial analysis using the NEP scale, the dimensionality that characterizes farmers can be identified to determine if the items are clearly associated with an array of dimensions. The NEP scale has been used to analyze farmers' beliefs concerning environmental issues [49]. This scale reflects the way in which the human being conceptualizes nature and the way he/she behaves in relation to it [48].

Table 3. Statements of the New Ecological Paradigm Scale.

Absolutely Disagree	Strongly Disagree	Moderately Disagree	Slightly Disagree	Neutral	Slightly Agree	Moderately Agree	Strongly Agree	Absolutely Agree
1	2	3	4	5	6	7	8	9

1. A global ecological crisis is exaggerated.
2. The balance of nature supports the impact of industrialized countries.
3. Humans may be able to control nature.
4. Human ingenuity ensures that the earth is not uninhabitable.
5. Humans were created to dominate the rest of nature.
6. Humans have the right to modify the environment to adapt it to their needs.
7. The interference of the human being in nature has disastrous consequences.
8. Plants and animals have the same right to exist as human beings.
9. The human being seriously abuses the environment.
10. The balance of nature is delicate and easily alterable.
11. If things continue as they have been, we will soon experience a great ecological catastrophe.
12. We are approaching the limit number of people that the earth can hold.
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, we just have to learn how to exploit them.
16. Sustainable development needs a balanced situation that controls industrial growth.

4.2. Measuring Farmers' Perceptions of Climate Change

The perception of climate change involves the analysis, according to each farmer, of whether he/she has observed variability in certain meteorological factors or events related to the climate. To address this issue, an array of statements, collected from a literature review (Table 4) and related to climate change was evaluated, according to the farmer's own perception, on a 9-point Likert type scale (from 1 to 9), where 1 means absolutely disagree, and 9 means absolutely agree.

Table 4. Items included analyzing the farmers' perceptions of climate change.

Absolutely Disagree	Strongly Disagree	Moderately Disagree	Slightly Disagree	Neutral	Slightly Agree	Moderately Agree	Strongly Agree	Absolutely Agree
1	2	3	4	5	6	7	8	9

In the last 10 years you have noticed that the temperature has increased: [50,51]	_____
In the last 10 years you have noticed that the level of precipitation has changed: [50,52]	_____
In the last 10 years you have noticed that rain periods have changed their temporality: [53–55]	_____
In the last 10 years you have noticed that the soil has lost fertility: [3,54]	_____
In the last 10 years you have noticed that the periods of drought have increased: [50,52]	_____
In the last 10 years you have noticed that the harvest has decreased: [56]	_____
In the last 10 years you have noticed that there have been more episodes of droughts: [3,50]	_____
In the last 10 years you have noticed that there have been more episodes of frost: [50,53]	_____
In the last 10 years you have noticed that there have been more episodes of floods: [52]	_____
In the last 10 years you have noticed that there have been more episodes of Hail: [57]	_____
In the last 10 years you have noticed that there have been more diseases and pests: [58,59]	_____
In the last 10 years you have noticed vegetation changes: [60]	_____

4.3. Measuring Farmers' Risk Attitudes

4.3.1. Model Definition

Each respondent was presented with a set of different lottery pairs, and one of the lottery options must be chosen from each pair [61]. (This relates the levels of risk aversion with a prize or profit). In the definition of the model, a list of eight scenarios was generated, with a pair of hypothetical lotteries, called option A and option B, which is similar to the theoretical model used by Brick et al. [44]. In this model, as in Brick´s, the probabilities that each one of the options will keep the experiment as simple as possible remain constant. In option A, the probability of obtaining the amount presented was set at 100% (safe option), and in option B (risky option), the probability was set at 50% for obtaining the amount of ($100) and 50% for not getting anything ($0) (tossing a coin for heads or tails) in all scenarios, while the safe amount presented in option A in each of the eight scenarios is modified in a decreasing manner, according to the following amounts ($100, $75, $60, $50, $40, $30, $20 and $10).

The level of risk aversion is based on the number of safe answers (option A) that the interviewee selects. According to the experimental design structure (see question 35 in the questionnaire, available in the supplementary file Q_1), only a risk-tolerant participant would select option B in the first scenario, while an extremely risk-averse participant would be the one who, in the eight scenarios, would select option B, and a risk-neutral participant would be the one who selects option A in the first three scenarios, and in the fourth scenario, changes to option B [62].

4.3.2. Estimation of the Relative Risk Aversion Coefficient "*r*"

We defined the values of the Constant Relative Risk Aversion (CRRA), based on the function, $U(y) = y^{(1-r)}/(1-r)$, where y is the income and r the relative risk aversion coefficient for each of the six stages (Table 5). Then, the coefficient r is estimated by means of the logarithmic maximum likelihood function, conditioned to the expected utility model and the CRRA specification, defined as the difference of the expected utility ($\nabla EU = EU_A - EU_B$). In this case, the maximum likelihood equation used is:

$$\ln L^{EU}(r, z, X) = \sum_i ((\ln(\nabla EU)/z = 1) + (\ln(1 - \nabla EU)/z = 0)) \quad (1)$$

where z_i = (0,1), 1 indicates that the respondent chose the auction in scenario *i*, 0 indicates that he/she chose the safe amount, and *X* corresponds to a vector of variables of personal, agricultural and environmental characteristics and environmental risk. Once the structure of the experiment is established, according to the specification of the choice of theory of expected utility (EUT) under uncertainty, the parameters of the function of CRRA are estimated, which allow the behavior or risk preferences of participants to be modelled [44,63]. According to the theory of the expected utility (EUT, Expected Utility Theory), proposed by von Neumann-Morgenstern, different utility functions have been generated that shape the behavior of people according to their risk preferences. Among the most common is the CRRA, which allows the implicit risk in decision making to be estimated [37].

The expected utility of each lottery is calculated by means of the function:

$$EU = \sum_i (p_i \times U(X_i)) \quad (2)$$

where p_i is the probability of occurrence of the utility of the prize Xi, and U (X_i) is the utility of the prize X_i. The CRRA function is defined as a non-negative lottery prize, according to the following equation:

$$U(X) = \frac{X^{1-r}}{1-r} \quad (3)$$

where *X* corresponds to the lottery prize, *r* is the latent risk aversion coefficient, where $r = 0$ indicates risk neutrality, $r > 0$ indicates risk aversion, and $r < 0$ indicates taste or tolerance for risk [63].

Table 5. Level of risk coefficients [28].

Number of Safe Choices "A"	Range of CRRA for $U(X) = X^{(1-r)}/(1-r)$			Classification of Risk Preference
0–1	−1.71	r <	−0.95	highly risk-tolerant
2	−0.95	> r <	−0.49	very risk-tolerant
3	−0.49	> r <	−0.15	risk-tolerant
4	−0.15	> r <	0.14	risk-neutral
5	0.14	> r <	0.41	slightly risk-averse
6	0.41	> r <	0.68	risk-averse
7	0.68	> r <	0.97	very risk-averse
8	0.97	> r <	1.37	highly risk-averse

To determine CRRA values, a scenario and its immediate continuum are related, given that each scenario is independent of the rest, and the model is defined with a decreasing level of risk aversion, so it is not necessary to relate it to the subsequent scenarios, meaning that the level of risk aversion is determined by the first change of option A by option B. (Because of this, any inconsistency subsequent to B's decision can be eliminated).

For instance, the choices of an individual, who chooses option A in the first three scenarios and then changes to option B, correspond to a risk aversion coefficient in the range of −0.15 and 0.14, which would define the individual as risk-neutral, while a person who always chooses Option A (the secure lotteries), the CRRA rank that corresponds to it is 0.97–1.37, which defines the person as extremely risk-averse.

The expected values of options A and B in each of the scenarios of the experimental design can be seen in Table 6. This also includes the ranges of relative risk aversion coefficients, implicit in each possible choice, under the assumption of the constant relative risk aversion (CRRA).

Table 6. Matrix of payments in the risk aversion experiment.

Lottery	Option A		Option B				Expected Value			CRRA* Interval
Question (Scenario)	A	PA *	B1	PB1 *	B2	PB2 *	E(A)	E(B)	Difference	
1	100	1	100	0.5	0	0.5	100	50	50	−1.71, −0.95
2	75	1	100	0.5	0	0.5	75	50	25	−0.95, −0.49
3	60	1	100	0.5	0	0.5	60	50	10	−0.49, −0.15
4	50	1	100	0.5	0	0.5	50	50	0	−0.15, 0.14
5	40	1	100	0.5	0	0.5	40	50	−10	0.14, 0.41
6	30	1	100	0.5	0	0.5	30	50	−20	0.41, 0.68
7	20	1	100	0.5	0	0.5	20	50	−30	0.68, 0.97
8	10	1	100	0.5	0	0.5	10	50	−40	0.97, 1.37

PA*, Probability option A; PB1*, probability of winning the amount B1 of option B; PB2*, probability of winning the amount B2 of option B; CRRA*, Constant relative risk aversion.

Once the CRRA values are estimated, the choices made by each individual on each pair of options presented in the eight scenarios are taken, and their level of aversion to individual risk is estimated. The instructions and differences regarding the lotteries presented in each scenario were explained in detail to farmers. Then, they were given the sheet to make their choices. The level of individual risk was determined and the group results were subsequently aggregated.

By means of contingency tables and the analysis of variance by means of the ANOVA method, the relationship of the data with the variable response level of aversion to risk, presented by the farmers, is explored. Subsequently, the statistical technique of Principal Component Analysis (PCA) was used to reduce the dimensionality based on the estimation of correlations. The obtained results are interpreted, characterizing the farmers of the studied regions.

5. Results and Discussion

5.1. Results on the Level of Farmers' Risk Attitudes

The results of the estimated risk level using the MPL showed a score of about 0.32, which globally defines the studied population as slightly risk-averse, according to the aforementioned scale of Holt and Laury. The results presented in Figure 3 showed the distribution of the sample of farmers, according to the different estimated scores of the attitudes towards risk levels. According to the scale of Holt and Laury [28], the results showed that almost 34% of farmers are highly risk-averse, 7.57% are risk-neutral, and 22% of farmers are highly risk-tolerant. These results are similar to those of Trujillo et al. (2009) [64], Galarza (2009) [65], Pennings and Garcia (2001) [17] and Brick et al. (2011) [44], who found that farmers exhibited, in general, a risk-averse attitude.

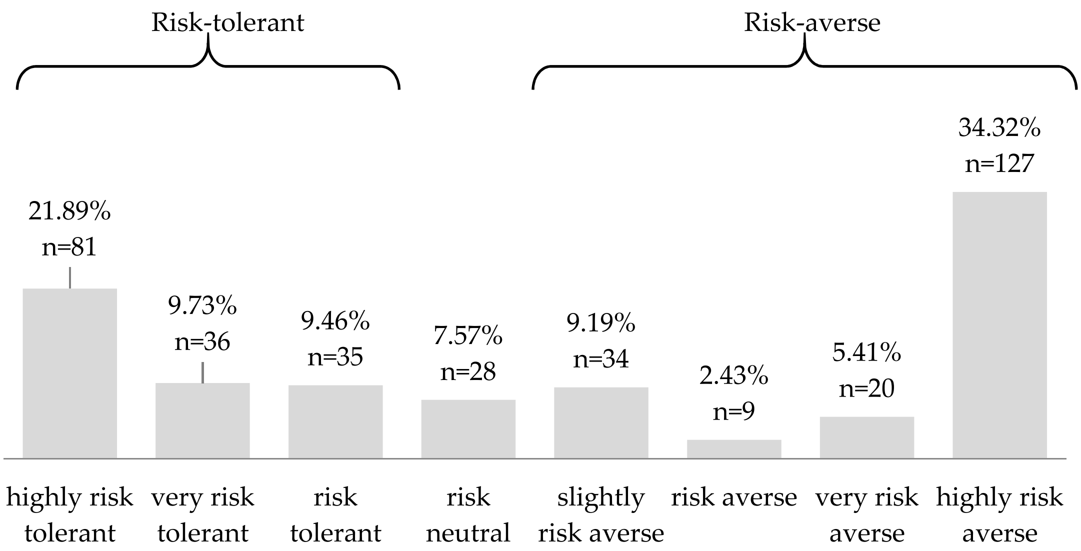

Figure 3. Distribution of the farmers according to their risk level. *n*: numbers.

5.2. Risk Heterogeneity Analysis

The risk response (risk-CRRA) is a categorical variable and represents the risk level of the farmers according to the scale used by Holt and Laury. The results of the heterogeneity analysis indicate that the variables related to the level of risk aversion are: The purpose of the subsidies received (p-value = 0.002), the gender of the agricultural producer (p-value = 0.046) and the age (p-value = 0.000). Results showed that women consider themselves a bit more risk-tolerant than their counterparts (percentage of men who tolerate risk = 39%, while the percentage of women who tolerate risk = 61%). The average level of estimated risk for women was −0.035, and the estimated risk level of men was 0.361. This result should be taken into account, particularly because women are responsible for 60% to 80% of the world's food, and they are better stewards of the environment [66]. Furthermore, women are more prone to participating in extensive activities related to agriculture and are more committed to farming activities. However, decisions that are related to farm development and improvement adoption are taken by men, excluding women in the decision-making process of a new agricultural system [67].

The variable collecting the main use of the subsidies was highly related to farmers' risk level. Farmers who receive economic support and use it in structural investment at the farm level are more risk-tolerant, while those who do not have an adverse profile to risk [68]. Age was also associated with the risk level, which is similar to the findings of Brick et al., in their experiment on African fishing communities [44]. In our case, we found that farmers "above 60 years of age" show that the experience acquired over time allows them to have a lower risk aversion on average, compared to farmers in the range of 41 to 60 years' old, who are more conservative, with a higher level of risk aversion.

Several pieces of agricultural economic research, which measured risk attitudes according to the expected utility theory, found that they are related to a set of farm and farmers' variables. Fahad et al. (2018) mentioned that factors, such as age, farming experience, and land size, may influence the farmers' decisions to contract crop insurance as a risk management strategy [14]. De Pinto et al. (2013) found that the implications for climate change mitigation projects are related to farmers' risk level [69]. Dörschner and Musshoff (2013) mentioned that the income variation and the farmers' risk attitudes can constitute an explanatory approach for the low acceptance of the actions that face the impact of climate change, showing that a better understanding of farmers' risk attitudes is necessary to make more effective agricultural policies [70].

The variables shown in Table 7, correspond to the attitudinal variables included in the heterogeneity analysis relating the risk level and attitudes associated with, and perception of, the environment and climate change.

Table 7. Variables related to the level of risk based on the ANOVA, classified by the type of information.

Type of Information	Variables
Utilized agricultural area	Number of hectares of rain fed crops
Volume of water used in irrigation	Volume of water irrigated (m^3/ha)
Income	Percentage of income from agriculture
Attitudes and Opinions towards the Environment (NEP Statements)	
A global ecological crisis is exaggerated	
The balance of nature supports the impact of industrialized countries	
Humans may be able to control nature	
Human ingenuity ensures that the earth is not uninhabitable	
The interference of the human being in nature has disastrous consequences	
The human being seriously abuses the environment	
The balance of nature is delicate and easily alterable	
We are approaching the limit number of people that the earth can hold	
The earth has limited resources	
The land has abundant resources, we just have to learn how to exploit them	
Sustainable development needs a balanced situation that controls industrial growth	
Attitudes towards Climate Change	
Level of disposition to perform only nightly irrigation	
Level of willingness to use low-polluting machinery	
Level of disposition to carry out agro ecological production	
Level of disposition to use of renewable energy sources	
Level of disposition not to burn biomass (stubble)	
Level of willingness to use non-nitrogenous fertilizers	
Level of willingness to use zero tillage	
Perception of Climate Change	
Level of impact of global warming on their crops	
Percentage of climate change influence on production costs	
Temperature increase	
More episodes of floods	
More episodes of hail	
More diseases and pests	
Weed increase	

Source: Own elaboration, based on the data provided by the interviewees.

Given that farmers perceive that they have a significant interest with respect to climate change, we reduced the dimensionality of this group of variables, seeking a minimum loss of information through a Principal Components Analysis (PCA). The objective is to determine a smaller set of unrelated variables that explain the existing relationships between the observed variables, identify the number of underlying variables, evaluate the individuals in relation to these new variables, and interpret the extracted component. Before starting the analysis, the Kaiser Meyer Olkin test (KMO) was applied to verify the applicability of the set of available variables. The results obtained, of 0.697 and 0.74, indicating that the relation of these is between medium and low.

The results of the PCA allowed two components to be identified, which explain 51% of the total variability. The first factor identified is defined by the climatic variables, such as floods, hail, diseases and pests. The second factor is defined by variables related to the impact of climate change on the farming activity, with variables related to weed increase, the impact of the global warming on crops and the influence of climate change on production. These results indicated that the first component characterizes the perception of farmers towards the negative weather patterns, and the second is related to the impact on their agricultural productivity.

The distribution of the point´s cloud, which represents the farmers in relation to the two main components and the variables previously described, is shown in Figure 4. Most of the risk-tolerant farmers (red points) are located to the right of the first dimension, exhibiting a higher perception of the weather patterns related to climate change, compared to the risk-averse farmers. This result is similar to the finding of Pomareda (2008) [71] and Brown et al. (2017), who found that effect of natural shocks affects risk attitudes and perceptions [72]. Furthermore, risk-tolerant farmers (red points) are more concentrated in the upper part of the second dimension, showing that they perceive to a greater extent that climate change has a high impact on their production. In this context, our results showed that the highly risk-tolerant farmers are those that are prone to using subsides in structural investment at the farm level. The results also showed that risk-neutral farmers do not have well-defined perceptions regarding climate change, nor the effects that climate change could have on their productivity.

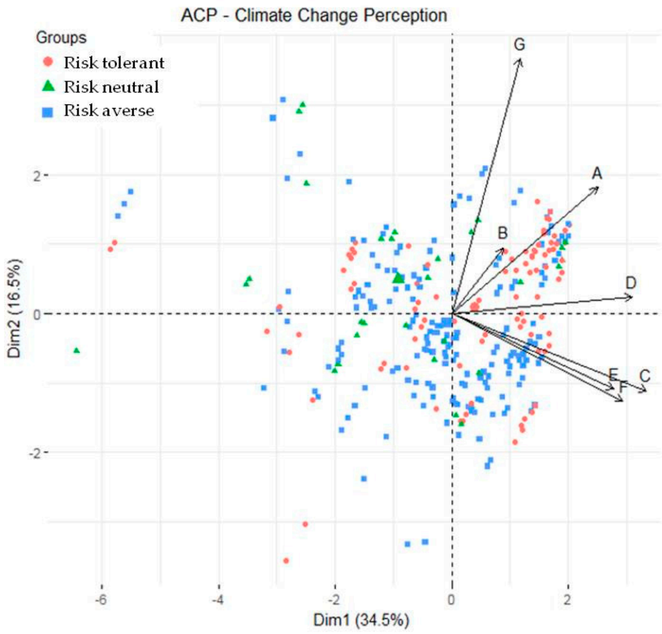

Figure 4. Distribution of farmers according to their perceptions of climate change. (**A**) Impact of global warming on their crops; (**B**) Percentage of climate change influence on production costs; (**C**) Temperature increase; (**D**) More episodes of floods; (**E**) More episodes of hail; (**F**) More diseases and pests; (**G**) Changes in weed development.

The result of PCA, carried out on farmers' opinions and attitudes towards the environment, using the NEP scale and their relation to risk level, is presented in Figure 5. As can be seen, the first two components explain an accumulated variance of 47.4%. The first factor was principally defined by the variables, "The earth has limited resources" and "Sustainable development needs a balanced situation". This factor can be characterized as an ecocentric attitude. The second factor was mainly defined by the variables, "Humans may be able to control nature", "The balance of nature supports the impact of industrialized countries", and "Human ingenuity ensures that the earth is not uninhabitable," which are related to an anthropocentric attitude towards the environment [73].

Based on the points dispersion, the results showed that farmers with a risk-tolerant attitude (red points) have a positive perception regarding the aspects related to ecocentric attitudes. The risk-tolerant farmers are those that allow for better differentiation of the aspects related to their positive environmental opinions. They have a clearer vision of the aspects related to their positive environmental opinions. Furthermore, in this context, risk-tolerant farmers are willing to perform positive actions relating to the environment, such as using low-polluting machinery, not burning biomass (stubble) or using non-nitrogenous fertilizers (identified in Table 7), while there is no clear trend in the environment opinions of risk-averse farmers. However, their risk-averse attitude does not preclude their potential adoption of positive actions towards the environment, as stated in Dörshner and Musshoff (2013) [70].

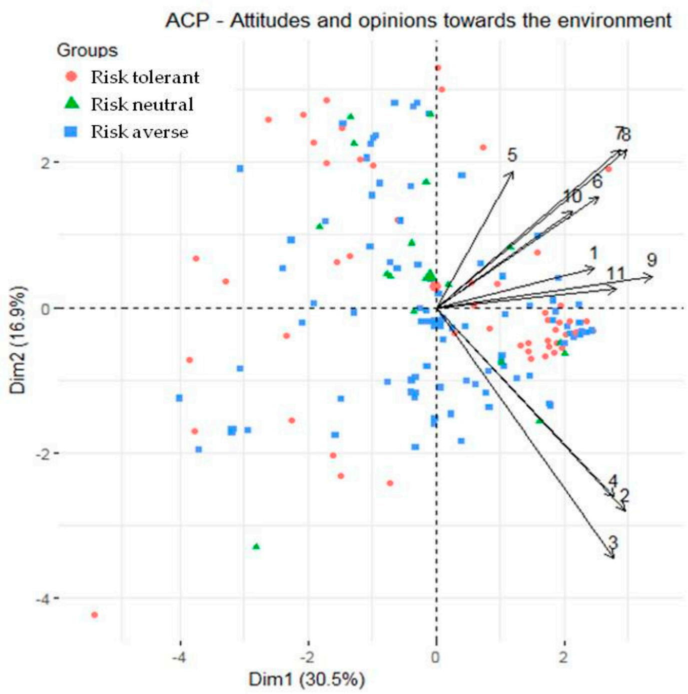

Figure 5. Distribution of farmers, interviewed according to their environmental opinions. (**1**) A global ecological crisis is exaggerated; (**2**) The balance of nature supports the impact of industrialized countries; (**3**) Humans may be able to control nature; (**4**) Human ingenuity ensures that the earth is not uninhabitable; (**5**) The interference of the human being in nature has disastrous consequences; (**6**) The human being seriously abuses the environment; (**7**) The balance of nature is delicate and easily alterable; (**8**) We are approaching the limit number of people that the earth can hold; (**9**) The earth has limited resources; (**10**) The land has abundant resources; we just have to learn how to exploit them; (**11**) Sustainable development needs a balanced situation.

6. Conclusions

There is a wide variety of stated methods for measuring the risk level in the agricultural sector, although the MPL method (lotteries) is shown to be a valid approach in the agricultural sector. It is characterized by its simplicity and is easily understood. Furthermore, its application does not require prior knowledge of the concepts of uncertainty and risk, nor extensive analysis of multiple statements. In general, in the studied area, farmers do not have high academic preparation, which makes the MPL a suitable method in this case. The MPL is a useful tool for comparing the stated risk attitudes of individuals who face the same lottery game.

The farmers in the studied region exhibited, in general terms, a risk-averse attitude, which is consistent with the main finding of other stated approaches to risk studies in the agriculture sector. Farmers recognize the importance of improving the commercialization of their crops and the effectiveness of treatments against diseases and pests. Farmers' perceptions of climate change were highlighted by the adverse effects on their output through higher disease and pest incidences on their crops, weed development increases, temperature increases and variations, and changes in the temporality of the rain periods.

The farmers´ characteristics, such as sex and age, were related to their stated risk level. An important finding to highlight is that women in the region were more risk-tolerant than men and were more prone to using public support to invest at the farm level. However, they are marginalized as decision-makers at the policy level and are therefore still less involved in the design and implementation of public policy in the agricultural sector, mainly due to cultural limitations. Our results also showed that farmers above 60 years old are more risk-tolerant than younger farmers.

As part of the findings of this research, risk-tolerant farmers were shown to be highly aware of the effects of climate change on production and were shown to agree with sustainable development statements concerning the environment, which may generate greater resilience in the region. Better involvement of these farmers in the process of generating agricultural public policies is recommended. Additionally, public policies should effectively target farmers with risk-averse attitudes in order to build confident relationships with them, which may improve their perceptions and adaptive capacities in relation to climate change.

One of the limitations of this paper is that the comparability of the results on the level of risk depends on the use of the MPL method under the same payment scheme, given that the difference in payments can generate heterogeneous results. Thus, for future research, it should be considered that the applicability and validity test using MPL could be verified by its application in other agricultural areas with similar characteristics. This would also corroborate and validate the results, generating a comparative map of attitudes towards risk and climate change perceptions.

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Author Contributions: M.A.O.T. conceived and designed the study, investigates, performed data collection, and wrote manuscript; Z.K. conceived and designed the research, made review and editing, participates in writing the manuscript and was the supervisor of all procedures; S.I.O.H. made the formal analysis of the data and participates in writing the manuscript.

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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.

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 et al., 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 and 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 et al., 2005). 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 et al., 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

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and animal farming in particular constitute an important source of greenhouse gas (GHG) emissions, which are closely related to climate change (Rivera and Di Paola, 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–1.0 °C for 2020 and of 2 °C–4 °C for 2080, variations in rainfall of + 10 % to -20 % by 2050, and a decrease in rainfall of 5%–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 (López, 2000).

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 et al., 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 and Cruz, 2018; López and Hernández, 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 and Kulshreshtha, 2017). 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 and Cruz, 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 and 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 and 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.

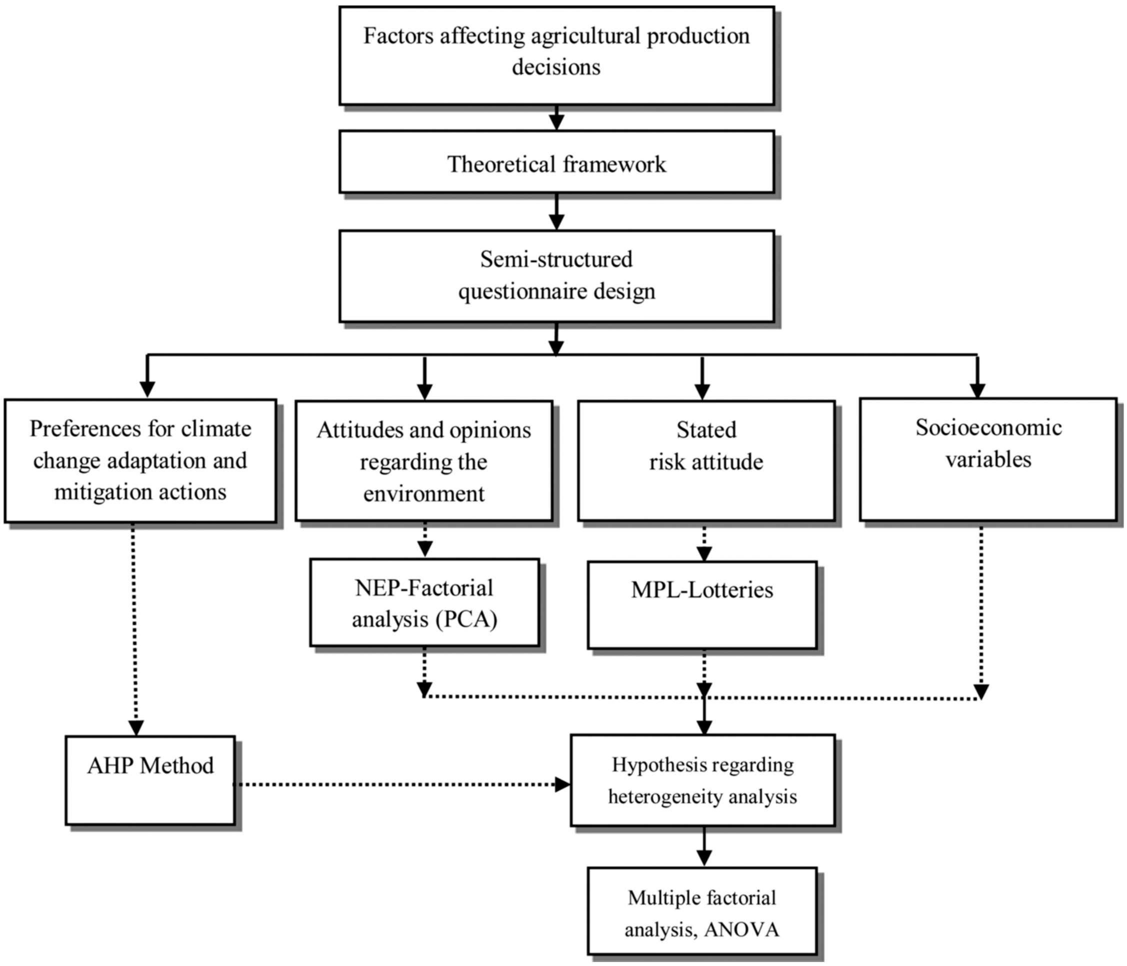

Fig. 1. Methodological research approach.

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

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 (Fig. 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, 2015). 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 min 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.

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, 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 and Gil, 2012; Ndamani and 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)

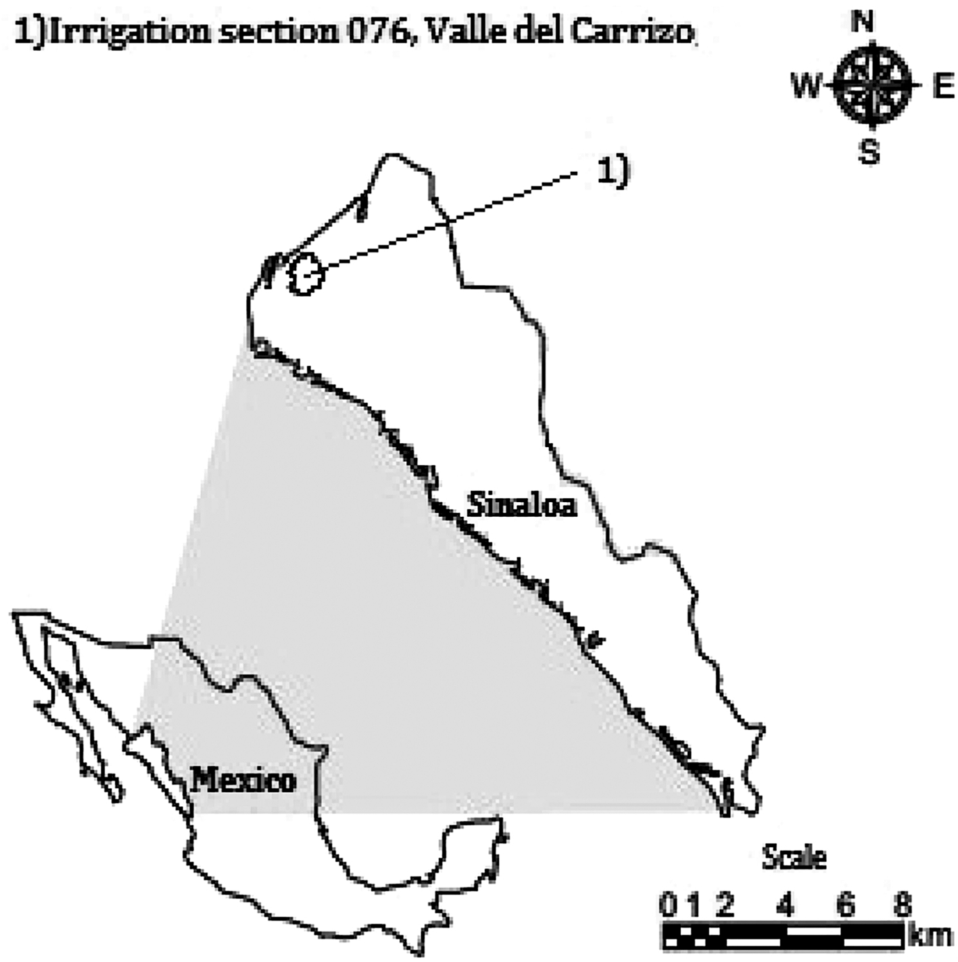

Fig. 2. Location of the study area.

problem definition and 2) structuring a decision model in the form of a hierarchy.

2.2.1. 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:

2.3. Adaptation measures

2.3.1. ***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., 2018).

2.3.2. ***A2.*** Change in crops

Niggol and Mendelsohn (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 and Mendelsohn, 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).

2.3.3. ***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).

2.3.4. ***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., 2013).

2.4. Mitigation measures

2.4.1. *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)

2.4.2. ***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)

2.4.3. ***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).

2.4.4. ***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).

2.4.5. Structuring a decision model as a hierarchy

Our hierarchical scheme (Fig. 3) prioritizes main criteria (adaptation and mitigation) and sub-criteria (actions) based on what is most accepted according to farmers' preferences.

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 (Fig. 3) using the verbal scale of paired comparisons proposed by Saaty (Table 1), from which the relative importance of alternative actions is then estimated.

For the upper cluster level, only one pairwise comparison is applied $[n{\cdot}(n\text{-}1)/2 = 2{\cdot}(2-1)/2 = 1]$ 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 $[n{\cdot}(n\text{-}1)/2 = 4{\cdot}(4-1)/2 = 6]$, 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):

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.

2.4.6. 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 $\widehat{W}_{iK}$ according to the preferences of each farmer using the Row Geometric Mean Method (RGMM) (Kallas and Gil, 2012).

The estimation of priorities ($\widehat{W}_{iK}$) 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.

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 = 4 × 4) as follows:

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

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

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

$$\widehat{W}_{ik} = \sqrt[n]{\prod\nolimits_{i=1}^{i=n} \hat{a}_{ijk}} \tag{1}$$

The previously estimated weights are normalized to the unit.

$$\sum_{i=1}^{i=n} \hat{w}_{ik} = 1 \tag{2}$$

2.4.7. 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:

$$CR = CI/RI; \tag{3}$$

where CI is the Consistence Index obtained as:

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{4}$$

where n = is the number of alternatives andλ_{max} is the maximum value of components of the eigenvector obtained as:

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

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

A value of CR lower than 10 % indicates satisfactory consistency for the pairwise comparisons (Siraj et al., 2015). The AHP is also

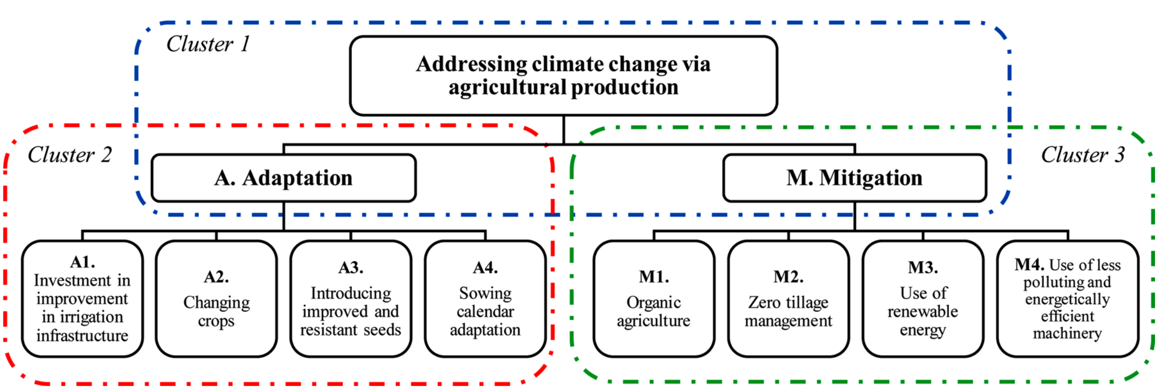

Fig. 3. Decision hierarchy model and identification of clusters that form the decision hierarchy model.

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.

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 ($\widehat{W_{ik}}$) were aggregated across farmers to obtain a synthesis of weights for each set of criteria ($\widehat{W_i}$). 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 and Peniwati, 1998):

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

2.5. 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 and San Juan, 2005; Dunlap et al., 2000; Lezak and 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 6).

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.

2.6. 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., 2012; 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 and Garcia, 2001; Jianjun et al., 2015; Orduño et al., 2019). 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 and Lusk, 2012; Brick et al., 2012).

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).

2.7. 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).

Table 2
Paired comparisons included in the questionnaire.

Comparison of measures (*cluster 1*)																		
A. Adaptation Measures	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	M. Mitigation Measures
A. Comparison of adaptation actions (*cluster 2*)																		
A1. Investment in the improvement in irrigation infrastructure	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A2. Change in crops
A1. Investment in the improvement in irrigation infrastructure	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A3. Introduce improved and resistant seeds
A1. Investment in the improvement in irrigation infrastructure	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A4. Adaptation of the sowing calendar
A2. Change in crops	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A3. Introduce improved and resistant seeds
A2. Change in crops	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A4. Adaptation of the sowing calendar
A3. Introduce improved and resistant seeds	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A4. Adaptation of the sowing calendar
M. Comparison of mitigation actions (*cluster 3*)																		
M1. Organic agriculture	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	M2. Zero tillage management
M1. Organic agriculture	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	M3. Use of renewable energy
M1. Organic agriculture	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	M4. Use of less polluting and energetically efficient machinery
M2. Zero tillage management	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	M3. Use of renewable energy
M2. Zero tillage management	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	M4. Use of less polluting and energetically efficient machinery
M3. Use of renewable energy	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	M4. Use of less polluting and energetically efficient machinery

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 $\hat{a}_{12} = 9$	$\hat{a}_{21} = 1/9$	9 $\hat{a}_{13} = 9$	$\hat{a}_{31} = 1/9$	9 $\hat{a}_{14} = 9$	$\hat{a}_{41} = 1/9$	2 $\hat{a}_{23} = 2$	$\hat{a}_{32} = 1/2$	2 $\hat{a}_{24} = 2$	$\hat{a}_{42} = 1/2$	$\hat{a}_{34} = 1/2$	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.

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

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 Fig. 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).

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 (Fig. 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.

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.

4. Ecocentric and anthropocentric environmental attitudes

The farmers' distribution according to the reduced NEP scale can be observed in Fig. 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

Table 5
. Statements of the New Ecological Paradigm Scale.

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

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 %	

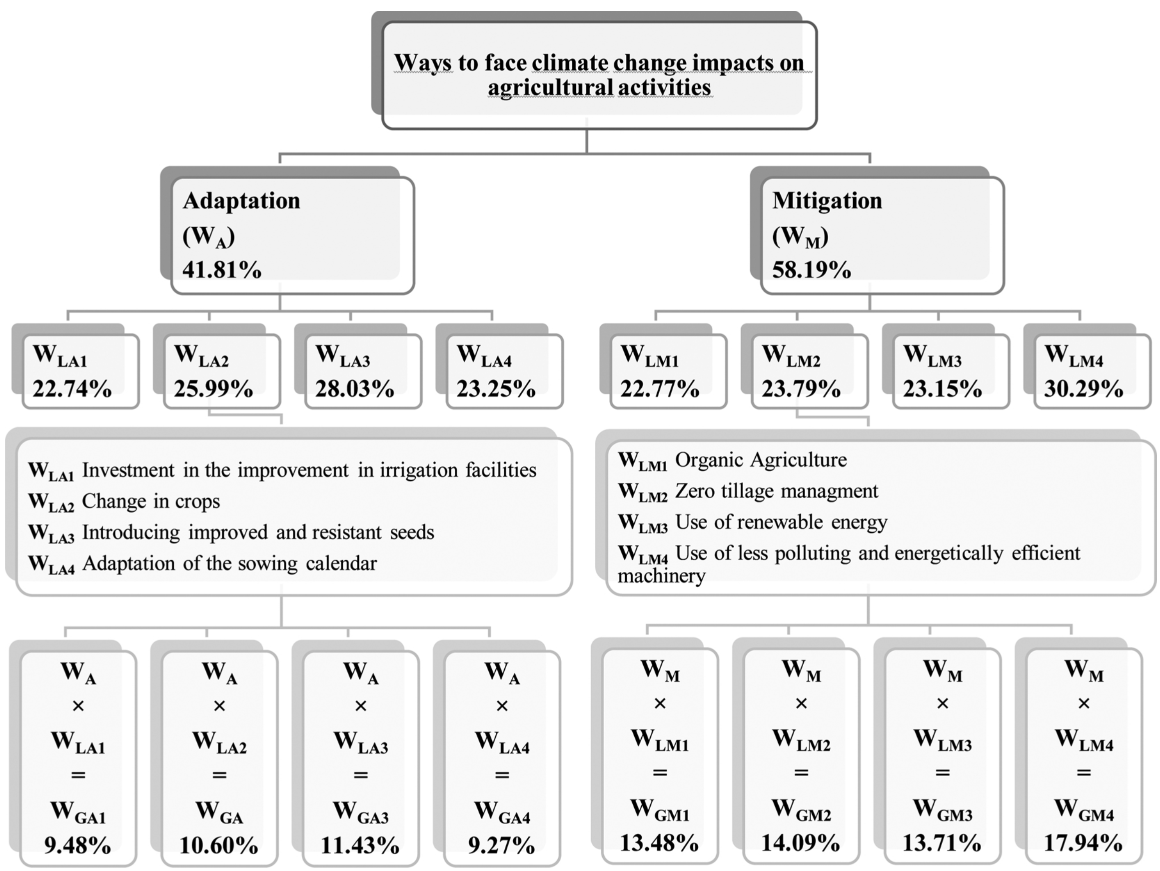

Fig. 4. Average relative relevance weights determined by AHP analysis according to farmers' opinions (WA: local weight of adaptation measures group, WM: local weight of mitigation measures group, WLA: local weight of a specific (n) adaptation measure, WLM: local weight of a specific (n) mitigation measure,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

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.

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

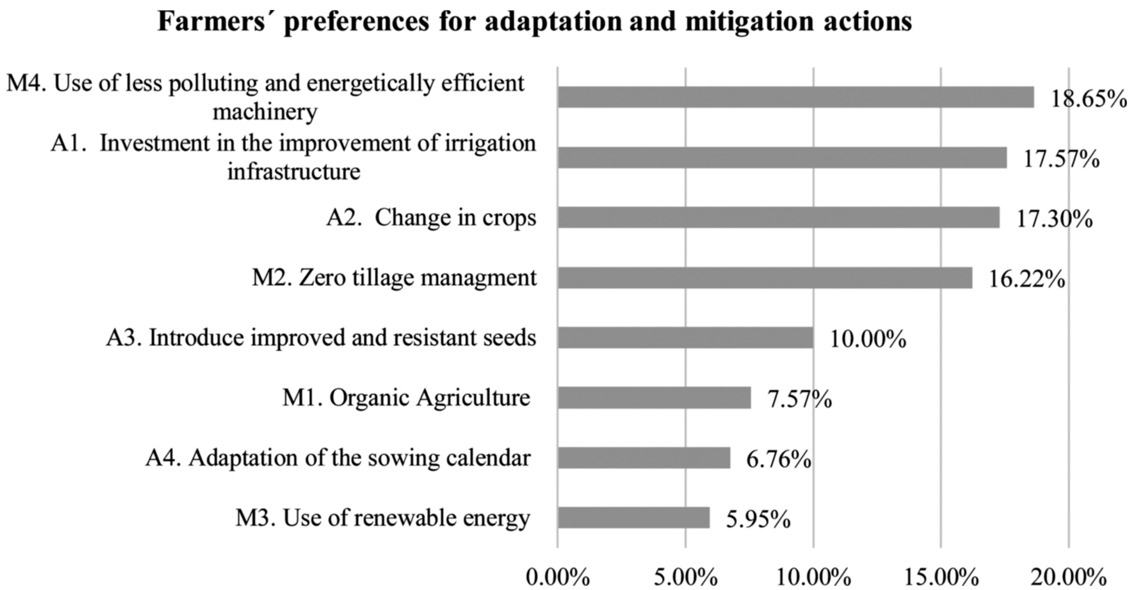

Fig. 5. Farmers' preferences for climate change adaptation and mitigation actions.

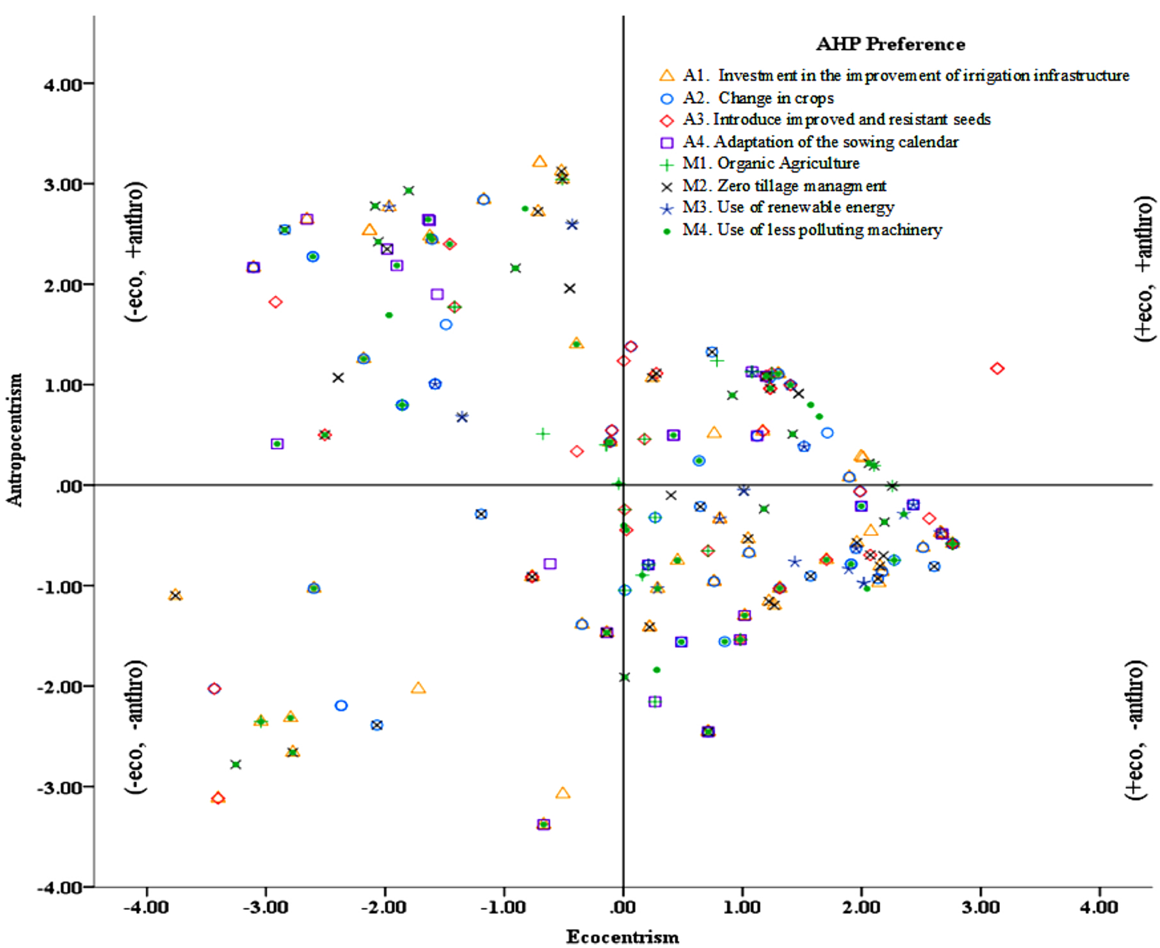

Fig. 6. Farmers' distributions on the reduced NEP scale, ecocentric and anthropocentric dimensions, and relations to farmers´ preferences for climate change adaptation and mitigation actions. + eco denotes that farmers agree with ecocentric attitudes, -eco denotes that farmers disagree with ecocentric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

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 (Fig. 7) show that the ecocentric and anthropocentric dimensions are closely related to the farmer's preferences. The mitigation and adaptation actions presented in Fig. 7 are ordered according to their relative importance as discussed in Fig. 6. An interpretation of the results shown in Fig. 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 Fig. 7 show that farmers with the most ecocentric attitudes (+ eco, -anthro) exhibited the strongest preferences for *the use of renewable energy* (M3).

4.1. 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.

4.2. 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 40–60 years of age prefer the "change in crop" approach, and farmers over 60 years of age prefer "zero tillage management."

5. Discussion

5.1. 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

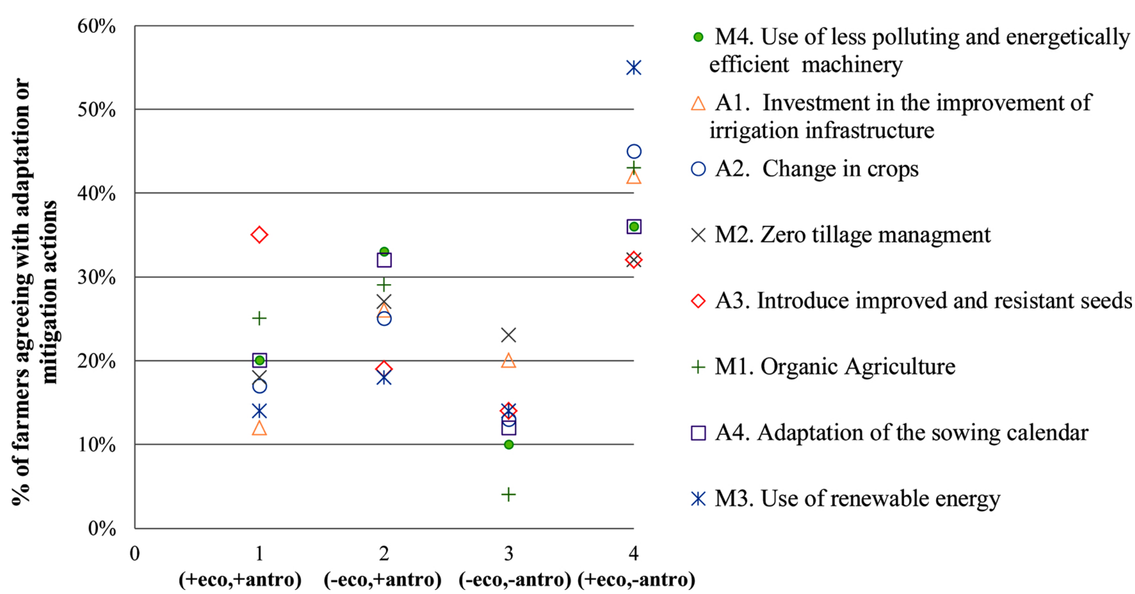

Fig. 7. Farmers' distribution by preferences according to a combination of their positive or negative views of ecocentric and anthropocentric attitudes (4 quadrants).

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 and 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 et al., 2009a, 2009b) 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 and 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 and 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 et al., 2009a, 2009b 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 and 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.

5.2. 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).

5.3. 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 (López and 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., 2019).

5.4. 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 and 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 and 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).

6. 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.

Author statement

I am writing to return the 3th revised version of the Manuscript identified as LUO_2019_108 entitled: "Farmers' environmental perceptions and preferences regarding climate change adaptation and mitigation actions – towards a sustainable agricultural system in México", for further consideration in Land Use Policy Journal.

We have made all changes according to the reviewers' suggestions and comments. In the revised manuscript we kept the track control activated, so you can see all changes made on last sent version.

Attached, you can see the revised manuscript and a set of responses to the reviewer's comments. We appreciate your willingness to consider this new revision.

While we hope these changes have alleviated the referee concerns, we stand ready to make additional changes if needed.

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Declaration of Competing Interest

The authors report no declarations of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.landusepol.2020.105031.

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3.3. Tercera Publicación: Is Technical Efficiency Affected by Farmers' Preference for Mitigation and Adaptation Actions against Climate Change? A Case Study in Northwest Mexico

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Is Technical Efficiency Affected by Farmers' Preference for Mitigation and Adaptation Actions against Climate Change? A Case Study in Northwest Mexico

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Abstract: Climate change has adverse effects on agriculture, decreasing crop quality and productivity. This makes it necessary to implement adaptation and mitigation strategies that contribute to the maintenance of technical efficiency (TE). This study analyzed the relationship of TE with farmers' mitigation and adaptation action preferences, their risk and environmental attitudes, and their perception of climate change. Through the stochastic frontier method, TE levels were estimated for 370 farmers in Northwest Mexico. The results showed the average efficiency levels (57%) for three identified groups of farmers: High TE (15% of farmers), average TE (72%), and low TE (13%). Our results showed a relationship between two of the preferred adaptation actions against climate change estimated using the analytical hierarchy process (AHP) method. The most efficient farmers preferred "change crops," while less efficient farmers preferred "invest in irrigation infrastructure." The anthropocentric environmental attitude inferred from the New Ecological Paradigm (NEP) scale was related to the level of TE. Efficient farmers were those with an anthropocentric environmental attitude, compared to less efficient farmers, who exhibited an ecocentric attitude. The climate change issues were more perceived by moderately efficient farmers. These findings set out a roadmap for policy-makers to face climate change at the regional level.

Keywords: technical efficiency; adaptation and mitigation preferences; climate change perception; environmental attitudes; farmers' risk attitude

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1. Introduction and Objectives

For a growing number of researchers and policy-makers, the sustainable development of present and future societies, depends on paying immediate attention to the environmental problems related to climate change [1,2]. The uncertainty of changes generated by this phenomenon exposes the environment to high vulnerability [3]. Article 1 of the United Nations Framework Convention on Climate Change (UNFCCC) states that climate change is "attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that adds to the natural variability of the climate observed during comparable periods of time" [4]. There are different strategies to address the adverse effects and impacts of climate change, and these can be realized by adopting two approaches: Adaptation and mitigation actions. Agriculture is one of the most sensitive sectors to climate change. Any variation in climate systems has a significant potential impact on productivity and on the processes related to farming activities [5]. Therefore, adaptation and mitigation actions can be implemented as differentiation strategies to reduce the risk of food insecurity [6] and production variability [7]. Adaptation is the ability to adjust to the impacts of climate change in the short term of natural or human systems [8]. Mitigation refers to actions aimed at reducing greenhouse gas emissions, with agriculture being an important source of the generation of these emissions [9].

Agriculture is of vital importance for the development of countries, especially developing nations, where the economy and family subsistence are based on food production and agricultural activities [10], given that in countries with lower incomes, 63% of the economically active population are employed in agriculture, while in developed countries only 3% are engaged in the agricultural sector [11]. Therefore, identifying the most preferred adaptation and mitigation actions turns out to be highly valuable. These preferences not only depend on farming activities, regions, and farmers' characteristics [12], but also could be related to technical efficiency (TE) at the farm level [13]. Agricultural TE implies obtaining the maximum production or output by using the minimum resources or input [14]. TE can be positively or negatively affected [15,16] by farmers' decisions and preferences when adopting adaptation and mitigation actions. The agricultural TE level is related to the type of irrigation, sowing calendar, quality of seeds, water infrastructure, technology and machinery, quality of the land, and fertilizer use. It can also be related to farmers' risk and environmental attitudes, preferences for investment decisions, and socioeconomic characteristics, among other variables [16,17]. In this context, it is also assumed that TE at the farm level can be related to farmers' perception of climate change [18] and socioeconomic characteristics, among other variables.

The aim of this study is fourfold: First, to measure the level of technical efficiency using the parametric stochastic production frontier (SPF) method in order to identify its relationship to farmers' stated preferences for several climate change adaptation and mitigation actions, using the analytical hierarchy process (AHP). We seek to identify the direction and magnitude of the relationship between TE and farmers' preferences [13,19]. The second objective is to analyze the relationship between the level of TE and farmers' environmental attitude defined in two main dimensions, anthropocentric and ecocentric, using the New Ecological Paradigm (NEP) scale. The aim is to identify whether agricultural producers at a higher level of efficiency have an anthropocentric attitude [20]. The third objective is to establish whether there is a relationship between the level of TE and the stated risk attitude estimated using the multiple price list (MPL) method, also known as the lottery approach. The aim is to identify whether the most efficient farmers are risk-tolerant [21]. The fourth objective is to analyze the relationship between TE and the farmers' perception of climate change. The aim is to explore whether farmers who have a greater perception of the variation of climate change are more technically efficient [22].

The case study of the irrigation district DR076 belongs to the state of Sinaloa, the leading nationwide in grains, vegetables, and fruit production that supply several national and international markets. According to the FAO (2011), Sinaloa was considered the granary of Mexico, after its crops production accounted for 75% of the country's production. Given that in the study region there is no literature about TE at the farm level and its relationship with farmers' preferences when it comes to mitigation and adaptation actions, as well as with their environmental attitudes and risk behavior, this research aims to provide new knowledge that may help policy-makers to identify more effective strategies, involving stakeholders in creating agricultural and rural development policies.

Climate change is negatively affecting current agricultural systems, especially the rural areas in the developing countries due to their economic vulnerability and dependency on farming activities. The studied region shows similar features and characteristics with other agricultural regions in Mexico and agricultural systems worldwide. These similarities can be characterized in terms of the related adverse effects of climate change as well as farmers' characteristics and crops production systems. The results of this study provide evidence that support the idea that farmers' preferences for the adaptation and mitigation actions against climate change is related to their technical efficiency. These preferences' patterns can provide the decision makers with valuable information that allow them to identify effective policy measures replicable in other similar farming systems.

Description of the Study Area

Irrigation District DR076, Valle del Carrizo, is located in the state of Sinaloa, Mexico, bordered on the north by the state of Sonora, on the south by the Sierra Madre Occidental, and on the west by the Gulf of California. Its geographic location is at latitude 26°05′ north and longitude 108°53′ west, including part of the municipalities of Ahome and El Fuerte [23]. Its main economic activity is crop and livestock production; cereals such as wheat and corn are the most important crops, at 76% and 8% of total cultivated area, respectively [24]. The DR076 irrigation district is characterized by an extreme climate, in which atypical conditions have been highlighted in recent years, with high levels of precipitation in short periods of time as well as low temperatures [25]. This has repercussions on the technical efficiency of crop production and represents a threat to the food security of the region and the country [26].

2. Materials and Methods

2.1. Survey Data

This study reports on the findings of a survey carried out with 370 agricultural producers from DR076, whose sample size was determined based on the formula of finite populations, with a confidence level of 95% and a confidence interval of 4.99% [27]. The survey was designed with an interdisciplinary perspective, including economic, social, and demographic aspects. It included a wide set of questions grouped according to the farmers' socioeconomic characteristics, characteristics of their agricultural land and the types of crops [28], and their preference regarding the implementation of mitigation or adaptation actions related to reducing the effects of climate change using the AHP technique. Farmers' attitudes and opinions that define their behavior toward the environment were also determined using the NEP scale. Furthermore, their stated attitude about risk and perception of climate change–related impacts were identified (see Figure 1). The survey was administered by undergraduate students of the Intercultural Autonomous University of Sinaloa and was conducted from October to December 2017. The questionnaire was approved by the ethics committee of the Intercultural Autonomous University of Sinaloa and was conducted according to ethical principles in social science, with specific care taken to protect personal information according to national regulations. Before the survey was conducted, farmers signed a consent form and received an explanation of the questionnaire.

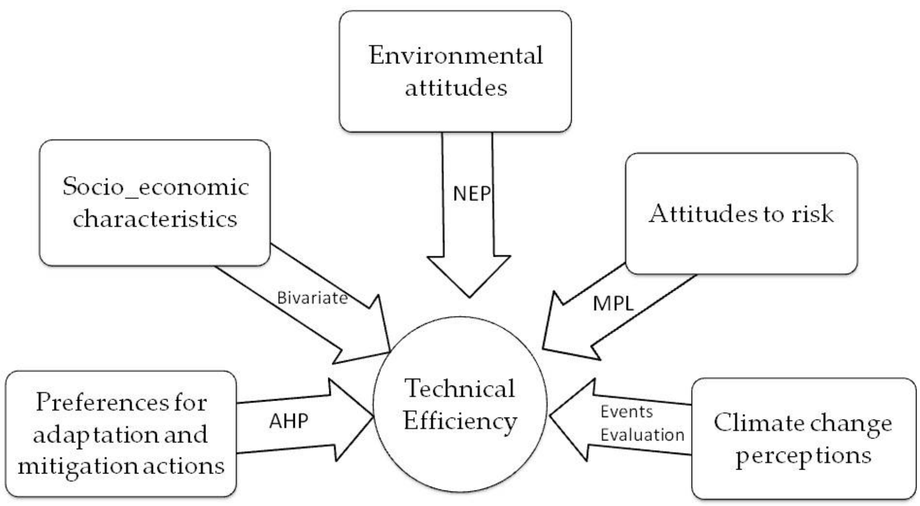

Figure 1. Methodological approach.

2.2. Technical Efficiency

The parametric stochastic production frontier (SPF) was used to estimate the technical efficiency (TE) scores. This approach was simultaneously proposed by Aigner et al. (1977) and Meeusen and Van den Broeck (1977) [29,30]. The SPF model can be specified as

$$Y_i = f(X_i; \beta) \exp(e_i); e_i = v_i - u_i, i = 1, 2, \ldots, N \quad (1)$$

The dependent variable (Y_i) is expressed in currency units, Mexican pesos (Mex$), and represents the total farm income. Among the inputs considered as explanatory variables is the total land devoted to crop production (X_1), measured in hectares. Total labor inputs (X_2) is composed of family and hired labor, representing the number of employees on the farm. (X_3) defines expenditure on seeds, expressed in Mex$. Chemical inputs ($X_4$) aggregates the value of fertilizers and crop-protection products used in the production process. Farming overhead (X_5) includes irrigation, energy, fuel, and other expenses and is also measured in monetary units.

Using these variables, TE scores were computed as an output-oriented measure and defined as the ratio of observed output to the corresponding SFP, with values in the range of zero to one [31]. According to the estimated TE values, farmers were grouped into three groups, taking account of the mean and one unit upward and downward standard deviation to establish farmers with low, medium, and high efficiency.

2.3. Farmers' Preferences for Climate Change Mitigation and Adaptation Actions

Taking a multicriteria approach to decision-making problems, farmers' preferences for different climate change adaptation and mitigation actions were identified using the analytical hierarchy process (AHP). This technique is widely used in the resolution of problems of an agrarian and environmental nature [32]. The AHP was developed by Saaty in the 1970s [33]. This tool has a mathematical approach that breaks down any problem into parts or clusters and analyzes them in a hierarchical structure. It allows the assessment of quantitative and qualitative criteria using a common scale [34]. The hierarchical modeling carried out in AHP allows the conversion of subjective evaluations according to the relative importance between different attributes or criteria into a set of weights or global weights to facilitate decision-making.

According to the AHP, the criteria (in our case mitigation and adaptation actions) are compared using a pairwise approach, in which the researcher estimates the relative importance of each criterion in order to identify the best alternative as a solution to the problem proposed. By applying the AHP, it was possible to perform an analysis of each option in relation to the others through paired comparisons, facilitating an estimation of farmers' preferences.

The methodological structure of this tool is given by three stages: Modeling, evaluation, and prioritization. During the modeling stage, the problem is defined (i.e., identification of farmers' preferences for mitigation and adaptation actions). In this case, the appropriate criteria were identified from a literature review [12]. The identified criteria are shown in Table 1.

Table 1. Criteria of climate change impact reduction.

A Adaptation Measures [35]	M Mitigation Measures [36]
A1 Invest in improved irrigation facilities [37]	**M1** Use organic agriculture [38]
A2 Change crops [39]	**M2** Use zero tillage management [40]
A3 Introduce improved and resistant seeds [41]	**M3** Use renewable energy [42]
A4 Adapt the sowing calendar [43]	**M4** Use low-polluting emission and energy-efficient machinery [44]

Accordingly, the decision model was structured in the form of a hierarchy, grouping the clusters into different levels (Figure 2), which were used to carry out the paired comparisons of the elements of each cluster based on the verbal scale.

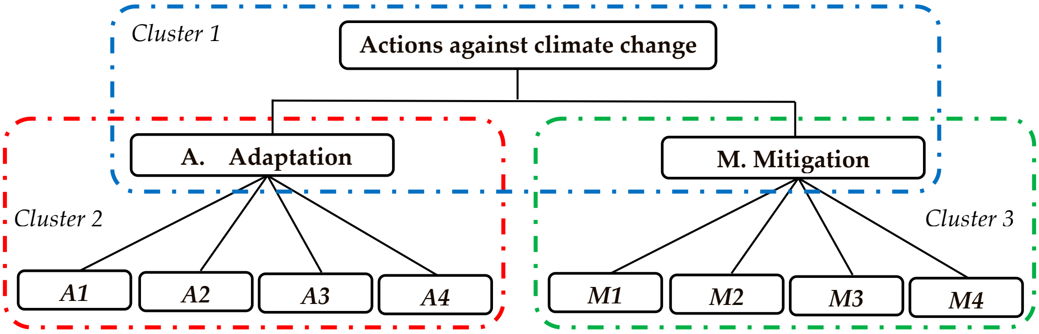

Figure 2. Identification of clusters that make up the decision hierarchy model [8].

The comparison structure has a pair of criteria (A and M) and a scale in both directions from one to nine; this allows establishing which of the two criteria was preferred and a measure of the relative importance of the preferred criterion (see Table 2).

Table 2. Structure of comparison scale between criteria (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

Scale: One means that both criteria have the same importance, two means that the selected criterion has slightly higher importance than the other, up to nine, which means the selected criterion has absolute importance with respect to the other [45].

Once the hierarchy is structured, the actions corresponding to the assessment stage are carried out. This stage corresponds to administering the questionnaire, when the interviewees are asked for the degree of importance they assign to their preference in each pair of criteria in each cluster, identified as mitigation or adaptation actions. (The complete experimental design of the paired comparisons question can be seen in the questionnaire, available in the Supplementary Materials, question 36.)

The third stage is prioritization and synthesis. At this stage, the farmers' expressed preferences in the paired comparisons $\hat{a}_{ik}$ are used to construct the Saaty matrix ($\hat{A}_k$) of each cluster, with dimensions $n \times n = 4 \times 4$ (where n corresponds to the number of actions within the cluster) and the vector of eigenvalues with the normalized weights corresponding to the cluster in question, which serve to obtain the relative importance, also known as the priority or local weight $\hat{w}_{ik}$ of the attribute, according to the weighting of judgments issued by the individual (k), which can be estimated by means of the row geometric mean method (RGMM), which will allow multifunctionality assessment to be carried out. The estimation of relative importance ($\hat{w}_{ik}$) was carried out using the Super Decisions software [46]. The verification of farmers' consistency using the consistency ratio [47] showed an average value less than 10%, which is acceptable according to the AHP literature [48]. Finally, in order to obtain the general results of the weight of each attribute, the process was repeated for each individual who was part of the sample (k = 1 to 370).

2.4. Farmers' Environmental Attitudes and Opinions by NEP Scale Method

Given current environmental concerns, the study of human attitudes and behaviors toward the environment has become increasingly relevant. These environmental attitudes or opinions can be approximated and expressed by positive or negative evaluations of the relationships between humans and the natural environment [49,50]. There are several methods and scales to approximate individuals' attitudes toward the environment. The Environmental Concerns alternative is a scale that pays specific attention to issues related to transportation, environmental pollution, biodiversity protection, and natural resource use, as well as consumption behavior [51]. The Proactive—Reactive Environmental Management scale is another alternative that allows the evaluation of different environmental practices, in which the proactive actions are aimed at modifying the processes that negatively affect the environment and the reactive ones are aimed at repairing current negative effects [52].

Among the array of alternative methods to measure environmental attitude, the New Ecological Paradigm (NEP) scale is one alternative that can be adapted to identify the psychological tendency reflecting the relationship that humans have with the environment [53,54] in an economic context, such as agricultural production. Individuals' attitudes can be identified as latent environmental dimensions principally reflecting an ecocentric or anthropocentric perspective. An ecocentric attitude is related to statements in which someone expresses a vision in favor of nature, considering that humans cause disequilibrium by their use of the environment, while an anthropocentric attitude considers that the environment can support the intensive use of natural resources, expressed through statements in which humans are said to have supremacy [55]. In this study, we used an NEP scale composed of 16 statements in order to analyze farmers' environmental attitudes. The agreement level for each statement was measured according to a 9-point Likert-type scale, where one represents total disagreement with the statement, five corresponds to a neutral opinion, and nine represents total agreement with the statement. The statements used in the experimental design to identify farmers' latent environmental dimensions can be seen in the questionnaire, available in the Supplementary Materials, question 27.

2.5. Farmers' Risk Attitude Using the MPL Lottery Method

Decision-making under uncertainty depends to a large extent on the risk attitude of economic agents. It is related to each person's behavior and influenced by socioeconomic factors and experiences [56]. In the agricultural field, the decisions made by farmers are affected by their level of aversion to or tolerance of risk that is related to their farm management and crop cultivation strategy and periodicity. They are also related to farmers' attitudes toward the environment and their perception of climate change [12].

The multiple price list (MPL), also known as a "lottery," is one of the tools most recently used to identify farmers' stated attitudes about risk under uncertainty (i.e., the level of risk tolerance or aversion). It relates levels of risk with reward or loss in a lottery. According to this method, an array of eight questions is proposed as lottery scenarios, with a pair of hypothetical alternatives from which to select, option A and option B, both with constant probabilities in each scenario. Option A (the safe option) determines the level of risk aversion, and depending on the number of scenarios in which the interviewee selects this option, once he/she decides to change to option B (the risky option), the interview must be stopped to avoid inconsistencies. If a farmer selects the risky option (option B) in the first scenario, it indicates that he/she is tolerant of risk; if the farmer selects option A in the first three scenarios and it then changes to option B in scenario four, it indicates that he/she has a neutral attitude toward risk; and a risk-averse farmer will choose the safe option (option A) in all scenarios [57]. According to the Holt and Laury scale, a risk-tolerant person corresponds to a risk coefficient from −1.75 to less than −0.15, a risk—neutral person corresponds to a risk coefficient from −0.15 to less than 0.14, and a risk—averse person corresponds to a risk coefficient of 0.14 or greater [58]. The experimental design used to identify the declared level of risk can be seen in the Supplementary Materials, question 35.

2.6. Farmers' Perceptions of Climate Change

The perception of climate change in farming activities is based on an analysis of the variability of phenomena such as increased temperature; varied levels and timing of rainfall; decreased soil fertility; increased periods of drought; decreased yields; increased drought episodes, frosts, floods, hailstorms, and plagues; and changes in vegetation [59]. Farmers' perceptions of climate change are also relevant as they are related to their farming decisions and practice [60]. Statements related to these phenomena identified from the literature [61–69] were used to evaluate farmers' agreement or disagreement using a Likert-type scale ranging from one to nine, where one corresponds to absolute disagreement and nine corresponds to absolute agreement with the statement. The proposed statements allow an assessment of farmers' opinions on issues such as the instability of meteorological factors and events related to climatic conditions.

3. Results and Discussion

3.1. Technical Efficiency

Results show that the average TE estimate is 0.57, indicating that farmers reach 57% of their maximum potential output, and the majority of them have average efficiency scores (72% moderately efficient, 13% low TE score, and 15% high TE score). Moreover, results suggest that farmers could increase their output by 43% on average if they used available resources more effectively with the same production technology. Thus, there is a large opportunity to improve TE by a more rational and less arbitrary use of inputs that would reduce production costs and contribute to the farm's livelihood.

It is considered that low efficiency may be associated with a misuse of existing technology, so optimization has to do with, among other things, optimizing the irrigation infrastructure, focused on substantially reducing water and energy consumption [70], given that, generally, energy consumption can be considered one of the most significant expenses associated with agricultural production. Additionally, reducing energy consumption would bring economic savings and reduce polluting emissions in the environment, resulting in a more sustainable form of agriculture.

Results also show that farmers who use family labor to a greater extent instead of hiring labor dedicated exclusively to agricultural activities have less technical efficiency, which indicates a need for greater professionalization and specialization of the people in charge of tasks in the field. This result differs from that obtained in a study [71], in which the presence of family labor greatly improved technical efficiency [72]. This difference could be attributed to the size of the farm, which in our case study was about 10.60 ha on average. When the size of the farm increases, more specialized labor is required and family labor may not be able to satisfy the need. In any case, it is important to note that Marquez et al. (2013) also indicate that the significance of this relationship can also be related to the methodological framework used to estimate TE.

Another action that we believe contributes to an improvement of technical efficiency is changing crops, given that the type of crop defines the amount of resources required, such as water, fertilizers, labor, machinery, etc. [73]. In addition, implementing more ecological techniques such as zero tillage contributes to increased technical efficiency due to a decreased use of energy resources and labor on the farm [74] (unlike conventional agriculture, which uses intensive tillage, significantly increasing costs for energy consumption, causing additional soil erosion, runoff, and pollution by sediment, with fertilizers and pesticides that will impact the subsoil and aquifers).

3.2. Adaptation and Mitigation Preferences

The results of the analysis of preferences estimated by the AHP method (Table 3) reveal that mitigation actions (M = 58.19%) were relatively more preferred compared to adaptation ones (A = 41.81%). The highest in relative importance compared to other actions is the mitigation alternative "use low-polluting emission and energy-efficient machinery" (M4 = 17.94%). These results, in relation to climate change impact reduction, show that mitigation actions must be a priority, as also affirmed by Bragado (2016) [75]. The second most popular option was the alternative "use zero tillage management" (M2 = 14%), and the third was "use renewable energy" (M3 = 13.71%).

Table 3. Farmers' prioritization of different actions (relative relevance) faced by the impact of climate change on their activities.

Criteria.	Local Weight (Cluster 1)		Attributes	Local Weight	Global Weight
				(Cluster 2)	**Cluster 1 × Cluster 2**
Adaptation	41.81	A1	Invest in improving irrigation facilities	22.74%	9.27%
		A2	Change crops	25.99%	10.60%
		A3	Introduce improved and resistant seeds	28.03%	11.43%
		A4	Adapt sowing calendar	23.25%	9.48%
			Local Total	100.00%	–
				(Cluster 3)	**Cluster 1 × Cluster 3**
Mitigation	58.19	M1	Use organic agriculture	22.77%	13.48%
		M2	Use zero tillage management	23.79%	14.09%
		M3	Use renewable energy	23.15%	13.71%
		M4	Use low-polluting emission and energy-efficient machinery	30.29%	17.94%
			Local Total	100.00%	–
				Global total	100.00%

According to the relative relevance assigned to adaptation and mitigation options (see Figure 3), we identified how many farmers in the sample assigned the highest global weight to each option. The action most preferred by farmers to reduce the effects of climate change was M4, "Use low-polluting emission and energy-efficient machinery," a mitigation action; the second and third preferred actions were A1, "Invest in improved irrigation infrastructure," and A2, "Change crops," both adaption options.

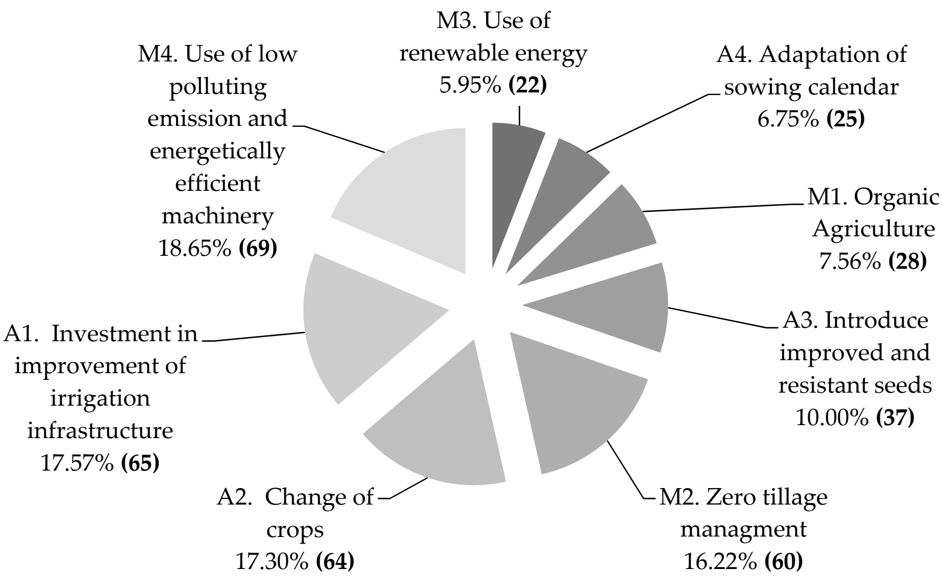

Figure 3. Distribution of farmers' preferences for climate change adaptation and mitigation actions.

3.3. Environmental Attitudes

According to the analysis of environmental attitudes, the NEP scale showed that two-thirds of farmers had a positive position on the environment, emphasizing their ecocentric attitude (see Figure 4), which means that most farmers consider nature to be a good thing that should be protected regardless of whether it generates direct benefits or not, such as through responsible consumption and use of clean energy. Furthermore, farmers expressed a higher preference for maintaining environmental resources and the regeneration of natural processes. The remaining farmers had an undefined position on the environment. They expressed agreement with affirmations where the importance of nature is highlighted and with affirmations that defend the human right to use environmental resources. However, in other cases, both affirmations received a high level of disagreement, showing an unclear relationship. There is no conclusive opinion on the environment, that is, they generally do not have a clear environmental opinion; they agree with some ecocentric attitudes and anthropocentric attitudes, or they absolutely disagree with both [76].

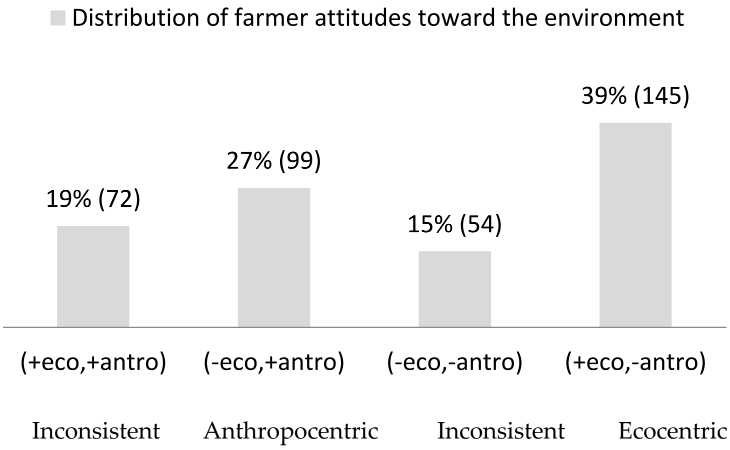

Figure 4. Farmers' environmental attitudes.

3.4. Risk Attitudes

Through the analysis of risk attitudes using the MPL method, it was observed that according to the scale proposed by Holt and Laury [58], approximately 51% of farmers had an attitude of risk aversion, while 41% were risk-tolerant and 8% had a neutral attitude about risk. The estimated average of the farmers' risk level had a value of 0.32, placing the farmers studied as slightly averse to risk according to the scale. This result is consistent with results on the level of risk aversion obtained in other studies, such as Pennings and Garcia (2001) and Brick et al. (2012) [57,77].

3.5. Climate Change Perceptions

The results of the analysis of climate change perceptions show that farmers perceived a high degree of variation in all climate phenomena presented in the experimental design, according to the answers given during the interview using a 9-point Likert-type scale, where one is absolute disagreement and nine absolute agreement with the statement. Most important was the increasing incidence of diseases and pests (8.23), followed by increased weed problems (7.92), increased temperature (7.46), and the presence of frost episodes (5.98).

3.6. Socio-Economic Characteristicvs

Finally, the TE efficiency was related to the socio-economic variables (age, education level, income and percentage of income coming from agricultural activities, origin of their agricultural training education, number of generations devoted to agriculture and property management regime). Results showed that age, property regime and the percentage of income coming from agriculture were significantly related to TE. Young farmers that are owner of their agricultural land with more than 50% of their income coming from agriculture activities are more technically efficient. These results are in line to the finding in Guesmi et al., (2010) and Perdomo and Mendieta (2007) highlighting the age and income variable as determinant factors of TE [31,78].

3.7. Technical Efficiency with Regard to Farmers' Preferences, Risk, and Environmental Attitudes and Climate Change Perceptions

As commented above, technical efficiency scores were related to farmers' preferences for adaptation and mitigation actions, environmental attitudes, risk attitude, and climate change perceptions. An analysis of heterogeneity was made by ANOVA and PCA to statistically contrast whether any of these results characterizing farmers' attitudes were related to their level of TE.

Results showed two clearly independent dimensions (see Figure 5) that explain 52.28% of the total variance. In Figure 5, the horizontal axis represents climate change perception. Farmers on the right side are more sensitive and farmers on the left side are less sensitive to climate change problems. The vertical axis represents TE, environmental attitudes, and preferences for significant actions against climate change. Farmers on the upper part are more efficient compared to the lower part. The same description also holds for anthropocentric and ecocentric attitudes. Finally, the preference for crop changes is located on the opposed side of the preference for improving irrigation systems as adaptation actions.

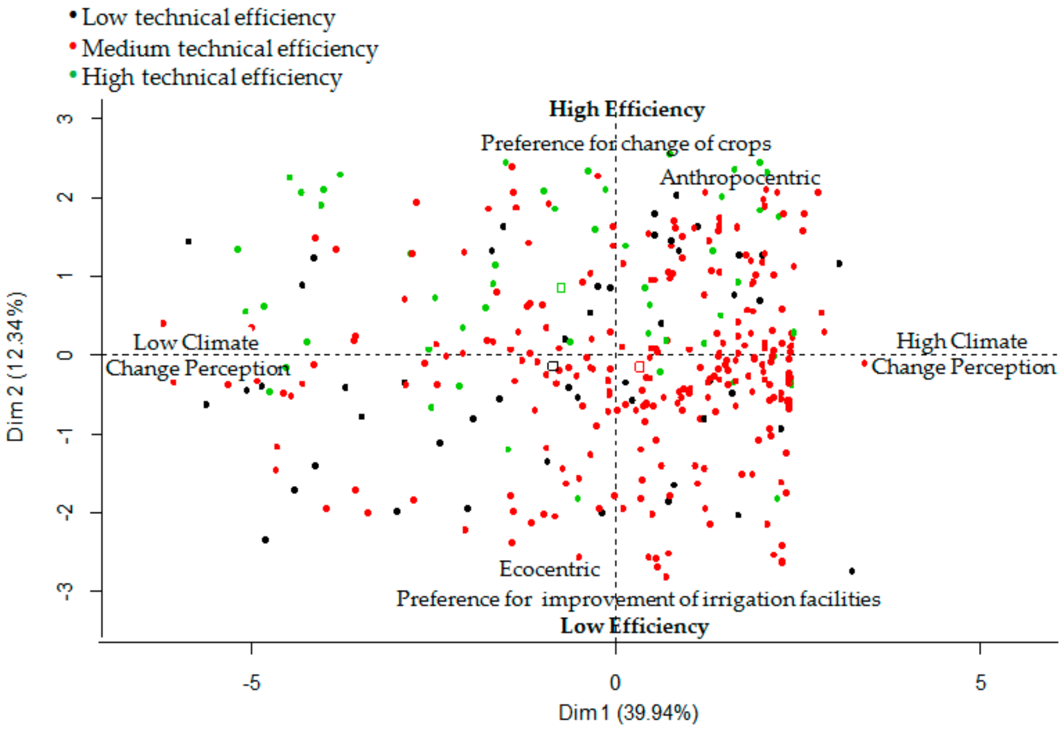

Figure 5. Technical efficiency as related to farmers' preferences, environmental attitudes, and climate change perception.

Results show that the most efficient farmers (green dots) preferred the "change crops" adaptation action, highlighting the importance of adopting new, productive, low-water-demand and disease-resistant varieties to face climate change. According to Estrada et al. (2006), crops must be diversified to maximize yields, yet generally farmers do not diversify but specialize in a specific crop, citing economic factors for this decision [79]. These farmers exhibited an anthropocentric attitude toward the environment, highlighting relatively less sensitivity to climate change issues. In particular, lower perception was found regarding the variation of environmental phenomena such as droughts and freezing episodes. Derived from previous results, as also commented by Ovares (2016), climate change perception is related to anthropocentric attitudes [80], and we can argue that a lack of environmental interest or ignorance of the effects of production activities on the environment is related to unawareness of climate variation. In this context, it is necessary to identify whether technical efficiency has been achieved to the detriment of the environment.

Farmers with lower technical efficiency (black dots), preferred the investment in irrigation facilities as an adaptation action and exhibited ecocentric attitude. This low level of TE could be related to their extensive production system and to the type of farming managements. These include the adoption of low soil degradation strategy by applying zero or low tillage agriculture, low use of phytosanitary and following a natural crop rotation. The less efficient farmers are taking advantage of the available natural resources with low adopting level of technological innovations. This result is similar to the finding of Alvarez and Del Corral (2010) who stated that farmers adopting intensive agriculture technology are more productive and more technically efficient than the extensive ones [81]. In this context, the decision-making of ecocentric farmers is driven not only by their economic objectives but also by the environmental one. They tend to preserve the environment as an input of their activities that ensure the generation of a satisfactory income [28]. The ecocentric farmers could adopt agricultural technologies that positively impact their productivity and are environmental friendly [82], such as the adoption of efficient irrigation system. From a sustainable agriculture point of view, a balance is required between their economic, social and environmental components. Otherwise, any other position in favour of only one of these factors it supposes the detriment of the rest.

Their perception of climate change was not clearly defined, with a slight tendency toward low perception levels. According to these results, we can deduce that the main problem faced by less efficient farmers is the availability of water, or specifically the need to optimize its use, given the high cost of water in the production of crops. Irrigation systems are a key element in achieving high technical efficiency in agricultural production [83]. The unclear position regarding climate change does not allow them to identify that the cost derived from water consumption is due to the increased use of water because of variation in the climate (greater evapotranspiration due to increased temperature, lower humidity in soil as a result of drought). The effects of climate change, identified by farmers mainly as increasing temperature and increased incidence of diseases and pests and weed problems, were perceived to a greater extent by moderately efficient farmers.

Finally, according to the results of this study, non significant evidence was found for a relationship between the stated attitude about risk and technical efficiency. This could be related to the nature of the data, with relatively homogeneous outcomes, with most producers in the region being risk averse and moderately efficient.

4. Conclusions

Rural areas that are vulnerable to the impacts of climate change, where agriculture plays a relevant economic role, show the importance of implementing region-specific adaptation and mitigation strategies to improve the level of technical efficiency at the farm level. Adopting these actions does not imply greater technification of the field, but better use of currently available resources and inputs by introducing alternative farm management systems such as using organic agriculture and zero tillage, adapting the sowing calendar, and changing crops.

The effects of climate change on agro systems depend on the type of agricultural production system implemented. Thus, it is necessary to adapt these systems according to the changing requirements of the natural environment caused by climatic variation, in order to increase production capacity through the optimal use of available resources, resulting in a higher level of technical efficiency.

Our results suggest a need to take advantage of available resources in order to face the adverse effects of climate change. Adopting the use of improved seeds and changing crops are among the most important actions according to farmers' preferences. Agricultural policy-makers must generate incentives for farmers in the region to adopt these types of adaptation actions, and disseminate technical information on best practices to encourage them to put these actions into practice.

In relation to farmers with less technical efficiency, whose environmental attitude was more ecocentric, their ecological efficiency should also be accounted for through more sustainable use of water resources, as this is one of the main factors that negatively affects agricultural performance.

In the agricultural sector, the economic policies that are implemented must be aimed at increasing the income and improving the livelihoods of rural households in order to improve their capacities and productive assets through the sustainable use of resources. Our results show that competent authorities need to include several actions that could represent a roadmap in the region studied. First, there is a need to conduct research regarding the impacts of climate change on agriculture in the region from a multidisciplinary perspective, in order to identify the impact of implementing adaptation and mitigation actions on agricultural productivity patterns. Second, this research highlights the importance of identifying crop varieties that are better adapted to the new climatic conditions in the region. The adoption of this measure should be accompanied by dissemination campaigns to share experiences from other farmers and offer information on the economic, social, and environmental benefits of adopting these practices. Third, training schemes on agricultural practices of adaptation and mitigation should be generated by agricultural associations to improve the rational use and conservation of natural resources, in order to reduce the risk aversion and increase the likeliness of implementing the new practices. Finally, economic incentive programs should be established that could help farmers to introduce new sustainable management practices at the farm level that increase their productivity and respect the environment, specifically mitigation actions.

In this study, one of the limitations was related to the data collection process in terms of the veracity of the economic information gathered from farmers. Some producers were not able to provide all the needed information and others refrained from responding reliably to the questions, due to either a lack of understanding or lack of interest. For further research, it could be interesting to include variables accounting for social and environmental externalities in the calculation of efficiency to better highlight a more sustainable indicator.

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Author Contributions: M.A.O.T. conceived and designed the study, investigated, performed data collection, and wrote the manuscript; Z.K. conceived and designed the research, reviewed and edited, participated in writing the manuscript and was the supervisor of all procedures; S.I.O.H. made the formal analysis of the data and participated in writing the manuscript; B.G. participated in analysis of the data.

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