Catalogação elaborada pelo Setor de Tratamento da Informação
Catalogação de Publicação na Fonte. UNILA - BIBLIOTECA LATINO-AMERICANA - CENTRAL

B674p
Bogado, Diana Leticia Molinas.
Percepciones y adaptación al cambio climático entre los agricultores familiares del Oeste de Paraná, Brasil / Diana Leticia Molinas Bogado. - Foz do Iguaçu, 2024.
46 fls.: il.

Universidade Federal da Integração Latino-Americana, Mestrado em Biodiversidade Neotropical, PROGRAMA DE PÓS-GRADUAÇÃO EM BIODIVERSIDADE NEOTROPICAL (PPGBN).
Orientador: Eleuterio, Ana Alice.

1. Trabalhadores rurais - Paraná. 2. Mudanças climáticas. 3. Percepção geográfica. I. Eleuterio, Ana Alice. II. Título.

CDU 323.3(816.2)

UNILA
Universidade Federal
da Integração
Latino-Americana

INSTITUTO LATINOAMERICANO DE
CIENCIAS DE LA VIDA Y LA
NATUREZA

PROGRAMA DE POSGRADO EN
BIODIVERSIDAD NEOTROPICAL

PERCEPCIONES Y ADAPTACIÓN AL CAMBIO CLIMÁTICO ENTRE LOS AGRICULTORES FAMILIARES DEL OESTE DE PARANÁ, BRASIL

DIANA LETICIA MOLINAS BOGADO

Foz do Iguaçu
2024

UNILA
Universidade Federal
da Integração
Latino-Americana

INSTITUTO LATINOAMERICANO DE CIENCIAS DE LA VIDA Y LA NATURALEZA

PROGRAMA DE POSGRADO EN BIODIVERSIDAD NEOTROPICAL

PERCEPCIONES Y ADAPTACIÓN AL CAMBIO CLIMÁTICO ENTRE LOS AGRICULTORES FAMILIARES DEL OESTE DE PARANÁ, BRASIL

DIANA LETICIA MOLINAS BOGADO

Disertación de maestría presentada al programa de Posgrado en Biodiversidad Neotropical, del Instituto Latinoamericano de Ciencias de la Vida y de la Naturaleza, de la Universidad Federal de Integración Latino-americana, como requisito parcial para la obtención del título de Maestría en Ciencias Biológicas.

Orientadora: Prof. Dr. Ana Alice Aguiar Eleuterio

Foz do Iguaçu
2024

DIANA LETICIA MOLINAS BOGADO

PERCEPCIONES Y ADAPTACIÓN AL CAMBIO CLIMÁTICO ENTRE LOS AGRICULTORES FAMILIARES DEL OESTE DE PARANÁ, BRASIL

Disertación de maestría presentada al programa de Posgrado en Biodiversidad Neotropical, del Instituto Latinoamericano de Ciencias de la Vida y de la Naturaleza, de la Universidad Federal de Integración Latino-americana, como requisito parcial para la obtención del título de Maestría en Ciencias Biológicas.

BANCA EXAMINADORA

____

Dra. Ana Alice Aguiar Eleuterio
Orientadora
UNILA

____

Dra. Maria Piquer-Rodriguez
Universidad de Berlin

____

Dr. Valdemar João Wesz Junior
UNILA

Foz do Iguaçu, 05 de septiembre de 2024.

AGRADECIMIENTOS

Agradezco en primer lugar a mi familia, a mis padres, Antonio y Norma. Gracias por su amor y apoyo incondicional, por confiar en mí y por los valores y principios que me han inculcado. Todo esto me ha permitido crecer y avanzar inlcuso en los momentos más difíciles. Los amo.

Agradezco a mis hermanas, Gloria, Noelia, Leticia, Mónica, a mi hermano Elias y a mi sobrina Victoria, además quiero mencionar a los más esperados, el bebé Diego Logan y la bebé Valery Yasmín. Ustedes son una gran fuente de inspiración en mi vida. Gracias por estar siempre presentes, por la complicidad. Son mi mejor ejemplo de amor, paciencia y perseverancia.

A mi colega Denis, agradezco tu constante presencia, especialmente durante este proceso. Tu apoyo y motivación en el desarrollo de esta investigación han sido fundamentales.

A Karina, sin duda, este proceso fue más llevadero gracias a tu acompañamiento y amistad. Gracias por ser mi cómplice en las alegrías y tristezas durante este tiempo.

A mi orientadora Ana Alice, agradezco tu guía y orientación. También mi gratitud al profesor Jonathan von Below por brindarme su apoyo, incluso a la distancia. Su colaboración fue clave para concluir este trabajo.

A mis colegas, amigos y a todas las personas que de alguna manera contribuyeron a la finalización de este proyecto, muchas gracias.

A los agricultores que participaron en las entrevistas y a los informantes locales que proporcionaron contactos en las comunidades donde se realizó esta investigación, infinitas gracias.

A la UNILA, por abrirme las puertas y la oportunidad de formarme. Gratitud.

Finalmente, Agradezco a mi Banca Examinadora. ¡MUCHAS GRACIAS!

MOLINAS BOGADO, Diana Leticia. Percepções e adaptação às mudanças climáticas entre agricultores familiares no oeste do Paraná, Brasil. 46 p. Dissertação de mestrado do Programa de Pós-Graduação em Biodiversidade Neotropical – Universidade Federal da Integração Latino-Americana, Foz do Iguaçu, Paraná 2024.

RESUMO

As mudanças climáticas afetam a capacidade dos sistemas alimentares de fornecer nutrição adequada a uma população em crescimento. Compreender as percepções dos agricultores familiares sobre as mudanças climáticas é fundamental para a implementação de estratégias de mitigação e resiliência. Esta pesquisa analisou como os agricultores familiares da região oeste do Paraná, Brasil, percebiam os efeitos das mudanças climáticas em suas atividades produtivas e como eles reagiam e se adaptavam a elas. Durante visitas a 85 propriedades rurais da região, foi aplicado um questionário estruturado com perguntas fechadas usando uma escala Likert de cinco pontos para avaliar as características da propriedade e os métodos de produção, os impactos das mudanças climáticas, as limitações de resposta e as estratégias de mitigação empregadas. Os resultados foram analisados por meio da Análise de Componentes Principais (ACP) e da análise de agrupamento hierárquico com teste V. Os agricultores perceberam fortemente o aumento das temperaturas e a redução das chuvas, mudanças que trouxeram mais doenças e pragas agrícolas, escassez de água e aumento dos custos com a compra de fertilizantes. Estratégias como o uso de matéria orgânica para cobertura do solo foram usadas para lidar com as temperaturas mais altas. Os agricultores foram agrupados em três grupos com base na análise hierárquica de grupos usando índices da ACP, juntamente com variáveis sociodemográficas e atividades produtivas: (i) Diversificação e limitações estruturais; (ii) Experiência e preocupações com a produtividade; (iii) Práticas sustentáveis e vulnerabilidade aos recursos. Os três grupos apresentaram características sociodemográficas e produtivas distintas que refletiam a heterogeneidade da agricultura familiar e a complexidade das respostas às mudanças climáticas. As limitações estruturais, a falta de acesso a recursos e a vulnerabilidade a eventos climáticos extremos foram desafios compartilhados entre os grupos. Este trabalho reforça a necessidade de desenvolver diretrizes específicas para políticas agrícolas, que levem à adoção de estratégias eficazes para a resiliência climática.

Palavras-chave: *Agricultor, inovação, percepção ambiental, resiliência, mitigação.*

MOLINAS BOGADO, Diana Leticia. Percepciones y adaptación al cambio climático entre los agricultores familiares del oeste de Paraná, Brasil. 46 p. Disertación de maestría del Programa de Postgrado en Biodiversidad Neotropical - Universidad Federal de la Integración Latinoamericana, Foz do Iguaçu, Paraná 2024.

RESUMEN

El cambio climático afecta a la capacidad de los sistemas alimentarios para proporcionar una nutrición adecuada a una población en crecimiento. Comprender las percepciones de los agricultores familiares sobre el cambio climático es crucial para implementar estrategias de mitigación y resiliencia. Esta investigación analizó cómo los agricultores familiares de la región occidental de Paraná, Brasil, percibían los efectos del cambio climático en sus actividades productivas, y cómo respondían y se adaptaban a ellos. Durante visitas a 85 propiedades rurales de la región, se aplicó un cuestionario estructurado con preguntas cerradas utilizando una escala de Likert de cinco puntos para evaluar las características de la propiedad y los métodos de producción, los impactos del cambio climático, las limitaciones de respuesta y las estrategias de mitigación empleadas. Los resultados se analizaron mediante análisis de componentes principales (ACP) y análisis jerárquico de conglomerados con prueba V. Los agricultores percibieron fuertemente el aumento de las temperaturas y la reducción de las precipitaciones, cambios que trajeron más enfermedades y plagas agrícolas, escasez de agua y aumento de los costes con la compra de fertilizantes. Para hacer frente al aumento de las temperaturas utilizaron estrategias como el uso de materia orgánica para cubrir el suelo. Los agricultores se agruparon en tres conglomerados a partir del análisis jerárquico de conglomerados utilizando índices de ACP, junto con variables sociodemográficas y actividades productivas: (i) Diversificación y Limitaciones Estructurales; (ii) Experiencia y Preocupaciones por la Productividad; (ii) Experiencia y Preocupación por la Productividad; (iii) Prácticas Sostenibles y Vulnerabilidad a los Recursos. Los tres grupos presentaban características sociodemográficas y productivas distintas que reflejaban la heterogeneidad de la agricultura familiar y la complejidad de las respuestas al cambio climático. Las limitaciones estructurales, la falta de acceso a los recursos y la vulnerabilidad a los fenómenos climáticos extremos fueron desafíos compartidos por los grupos. Este trabajo refuerza la necesidad de desarrollar directrices específicas para cada lugar en materia de políticas agrícolas, que conduzcan a la adopción de estrategias eficaces para la resiliencia climática.

Palabras clave: *Agricultor, innovación, percepción medioambiental, resiliencia, mitigación.*

MOLINAS BOGADO, Diana Leticia. ***Perceptions and adaptation to climate change among family farmers in western Paraná, 2024.*** *Brazil. 46 p. Master's dissertation of the Postgraduate Program in Neotropical Biodiversity - Federal University of Latin American Integration, Foz do Iguaçu, Paraná.*

ABSTRACT

Climate change impacts the ability of food systems to provide adequate nutrition to a growing population. Understanding family farmers' perceptions of climate change is crucial for implementing mitigation and resilience strategies. This research analyzed how family farmers in the western region of Paraná, Brazil, perceived the effects of climate change on their productive activities, and how they responded and adapted to them. During visits to 85 rural properties in the region, a structured questionnaire with closed questions using a five-point Likert scale was applied to assess property characteristics and production methods, impacts of climate change, response limitations, and mitigation strategies employed. Results were analyzed using Principal Component Analysis (ACP) and hierarchical cluster analysis with V-test. Farmers strongly perceived increased temperatures and reduced rainfall, changes that brought more agricultural diseases and pests, water scarcity, and increased costs with the purchase of fertilizers. Strategies such as the use of organic matter for soil cover were used to cope with higher temperatures. The farmers were grouped into three clusters based on hierarchical cluster analysis using indices from ACP, along with sociodemographic variables and productive activities: (i) Diversification and Structural Limitations; (ii) Experience and Concerns about Productivity; (iii) Sustainable Practices and Vulnerability to Resources. The three groups presented distinct sociodemographic and productive characteristics that reflected the heterogeneity of family farming and the complexity of responses to climate change. Structural limitations, lack of access to resources, and vulnerability to extreme weather events were challenges shared among the groups. This work reinforces the need to develop site specific guidelines for agricultural policies, which lead to the adoption of effective strategies for climate resilience.

Keywords: *Farmer, innovation, environmental perception, resilience, mitigation.*

LISTA DE FIGURAS

LISTA DE TABLAS

SUMARIO

1. INTRODUCCIÓN.

En este trabajo realizamos una investigación sobre las percepciones de los agricultores familiares en la región oeste de Paraná respecto a los efectos del cambio climático en sus actividades productivas. La región en estudio posee un clima subtropical húmedo con temperaturas medias anuales entre 18°C y 22°C, y variaciones extremas de 15°C a 38,2°C. A pesar de contar con suelos altamente fértiles, se ven afectados por la deforestación, particularmente en el oeste, donde se prioriza la agropecuaria. Socioeconómicamente, la región esta influenciada por los sectores agrícolas y agroindustrial, con un enfoque particular en la agricultura familiar, la cual representa el 23% del valor total de la producción agrícola y ocupa el 27,3% del área total de los establecimientos agropecuarios.

Los efectos del cambio climático amenazan la capacidad de los sistemas alimentarios para garantizar la seguridad alimentaria. Las políticas nacionales y regionales, que buscan estrategias de mitigación y adaptación, suelen ser insuficientes y carecen de recursos adecuados para su implementación. Por ello, es crucial comprender las percepciones y realidades de los agricultores familiares para identificar patrones y desarrollar estrategias de adaptación que mejoren la productividad.

Para evaluar la percepciones y adaptación al cambio climático entre los agricultores familiares, se consideraron los municipios de Foz de Iguazú, Missal y Cascavel, que son clave en la producción de granos, frutas, hortalizas y ganado, y que cuentan con una infraestructura agrícola organizada en cooperativas y asociaciones. Se realizaron visitas a 85 propiedades rurales y se aplicó un cuestionario estructurado con preguntas cerradas, utilizando una escala Likert de cinco puntos. A través del análisis de componentes principales (ACP) y el análisis jerárquico de conglomerados, se identificaron patrones en las percepciones de los agricultores, así como las limitaciones y estrategias de mitigación empleadas. En la siguiente sección se presenta el manuscrito del artículo enviado a *Agriculture, Ecosystems & Environment*. Los resultados se presentan brevemente en las consideraciones finales.

2. ARTICULO CIENTIFICO

PERCEPTIONS AND ADAPTATION TO CLIMATE CHANGE AMONG FAMILY FARMERS IN WESTERN PARANÁ, BRAZIL

Molinas Bogado, Diana Leticia. Von Below, Jonathan, Eleuterio, Ana Alice.

Abstract. Climate change impacts the ability of food systems to provide adequate nutrition to a growing population. Understanding family farmers' perceptions of climate change is crucial for implementing mitigation and resilience strategies. This research analyzed how family farmers in the western region of Paraná, Brazil, perceived the effects of climate change on their productive activities, and how they responded and adapted to them. During visits to 85 rural properties in the region, a structured questionnaire with closed questions using a five-point Likert scale was applied to assess property characteristics and production methods, impacts of climate change, response limitations, and mitigation strategies employed. Results were analyzed using Principal Component Analysis (ACP) and hierarchical cluster analysis with V-test. Farmers strongly perceived increased temperatures and reduced rainfall, changes that brought more agricultural diseases and pests, water scarcity, and increased costs with the purchase of fertilizers. Strategies such as the use of organic matter for soil cover were used to cope with higher temperatures. The farmers were grouped into three clusters based on hierarchical cluster analysis using indices from ACP, along with sociodemographic variables and productive activities: (i) Diversification and Structural Limitations; (ii) Experience and Concerns about Productivity; (iii) Sustainable Practices and Vulnerability to Resources. The three groups presented distinct sociodemographic and productive characteristics that reflected the heterogeneity of family farming and the complexity of responses to climate change. Structural limitations, lack of access to resources, and vulnerability to extreme weather events were challenges shared among the groups. This work reinforces the need to develop site specific guidelines for agricultural policies, which lead to the adoption of effective strategies for climate resilience.

Keywords: Farmer, innovation, environmental perception, resilience, mitigation.

Introduction

Climate change (CC) poses significant concerns for agriculture (Cheval et al., 2022 as it impacts food systems' ability to provide food security for a growing population (Grimberg et al., 2018). The effects on food systems are diverse, both direct and indirect. Direct effects include changes in crops life cycles, plant growth rates, and soil water availability, and increased soil erosion. Indirect effects include the expansion of agricultural pests’ distribution ranges, higher probabilities of species invasion, increased likelihood of wildfires, longer and more intense droughts, floods, among others (Cheval et al., 2022; Grimberg et al., 2018; López and Hernández, 2016; Morales-Casco et al., 2016).

Establishing adaptation strategies helps improve productivity, ensure access to water and food, and is crucial for reducing crop and other economic losses (Morales-Casco et al., 2016; Neto et al., 2022). According to the Food and Agriculture Organization of the United Nations (FAO), adaptation strategies in the agricultural sector consist of implementing soil conservation practices, adjusting crop calendars, changing crops, diversification, and adapting crop management (Food and Agriculture Organization of United Nations, 2017). Adaptation can significantly reduce the economic and social costs associated with climate change (Galindo et al., 2014).

Research on climate change provide information and methodological tools to improve natural resource management, foster innovative practices, and support decision-making (Ministério da Agricultura, Pecuária e Abastecimento Brasil, 2021). In Brazil, national and regional policies that propose mitigation and adaptation strategies in different sectors are insufficient and receive few resources (Corrêa da Silva and Cartes Patrício, 2022). Appropriate and effective designs of policy interventions to support the resilience of family farming systems require understanding farmers’ perceptions about the impact of climate change on their productive activities and recognizing the adaptation strategies employed (Ayal and Leal Filho, 2017; Barokatuminalloh et al., 2021; Gomm et al., 2024; Tesfaye et al., 2021).

Studies show that perceptions of climate change can vary among farmers depending on their age, gender, location of residence (rural-urban), access to technical assistance, property size, and education level (Cheval et al., 2022; Karki et al., 2022; Lee et al., 2020; Ruíz et al., 2020; Schnegg et al., 2021). On the other hand, farmers face resource limitations such as input shortages, poverty, lack of access to water, and a lack of knowledge and information.

Addressing these issues is crucial once they represent significant barriers that hinder the adaptation process (Barokatuminalloh et al., 2021; Williams et al., 2019).

In this context, a study conducted on farmers knowledge about climate change in northeastern Brazil showed that those who were aware of its impacts tended to adopt more adaptive measures. Additionally, farmers' age and economic income significantly influenced the decision to adopt adaptive measures (Ayal and Leal Filho, 2017; Carlos et al., 2019). Furthermore, a study conducted by Pires et al. (2014) in the state of Minas Gerais, Brazil, has shown that farmers perceive changes in the climate, especially in precipitation patterns. However, the adaptive response of farmers to these changes can be low, as shown by a similar study in Africa, which found that farmers did not perceive changes in production, particularly in decreased crop yields, increased agricultural pests, and diseases (Barokatuminalloh et al., 2021). Understanding how local contexts and farming situations relate to climate change perception can help farmers better understand and choose appropriate adaptation strategies for their crops and systems (Lucero López et al., 2022).

It is crucial to acknowledge that climate change perception is not limited to temperature and precipitation, as most studies have suggested. Other climate events also have a significant impact on agriculture (Bhattacharya, 2019; Gomm et al., 2024), such as cold and heat waves, out-of-season rains, and droughts, which are often overlooked (Torres et al., 2019; Orimoloye et al., 2022). The most vulnerable farmers may also lack technical knowledge of proper agricultural practices, which are fundamental to achieve long-term resilience (Adhikari et al., 2015). In fact, family farmers are usually considered more susceptible to the effects of climate change due to their high dependence on climatic conditions, while receiving less support from public policies, as technical assistance and financing (López and Hernández, 2016).

While the definition of family farming varies from regions to countries, it often refers to a form of agricultural production characterized by family management. This work uses the definition adopted in Brazil, and stated by the Law 11.326/2006 (Brazil, 2006), which characterize family farming based on the following criteria: the predominance of family labor, and family management of the production unit, property smaller than four fiscal modules, and a minimum percentage of family income derived from that unit (Rambo, et al., 2016; Food and Agriculture Organization of the United Nations, 2017).

Regarding the agricultural sector in western Paraná, Bianchini and Picinatto (2020) found that over 90% of the cooperatives were in the initial or intermediate stages of development. This indicates that most cooperatives still need intensive technical assistance to improve their management processes. Additionally, they showed that cooperatives were diverse, required different support form public policies, while few had infrastructure for storage, processing, and distribution of products. The survival of family farming, in the face of the effects of climate change, requires a constant search for productive resources and efficient organizations (Corrêa da Silva and Cartes Patrício, 2022).

In this work, we analyze how family farmers in the western region of the state of Paraná, Brazil, perceive the effects of climate change on their productive activities. Specifically, we seek to (i) identify their perceptions of changes, the impacts, and the strategies they adopt to increase resilience; (ii) determine how respondents group in terms of their perceptions, the impacts, response limitations, strategies adopted, sociodemographic profiles and productive activities; (iii) assess congruences and differences between those groups to provide effective recommendations to increase resilience of family farming systems in the region.

Methods

Study Area

The study was conducted in the western region of Paraná, Brazil, specifically in the municipalities of Foz do Iguaçu, Missal, and Cascavel **(Fig. 1)**. The region is located on the third plateau of Paraná and covers an area of 22,851 km² (Instituto Brasileiro de Geografia e Estatística, 2022a). It borders the Iguaçu River to the south, the Piquiri River to the north, the Guarani River to the east, and the Paraná River to the west, establishing a border with Paraguay and Argentina. According to the 2022 IBGE census, it comprises 50 municipalities (Ipardes, 2022).

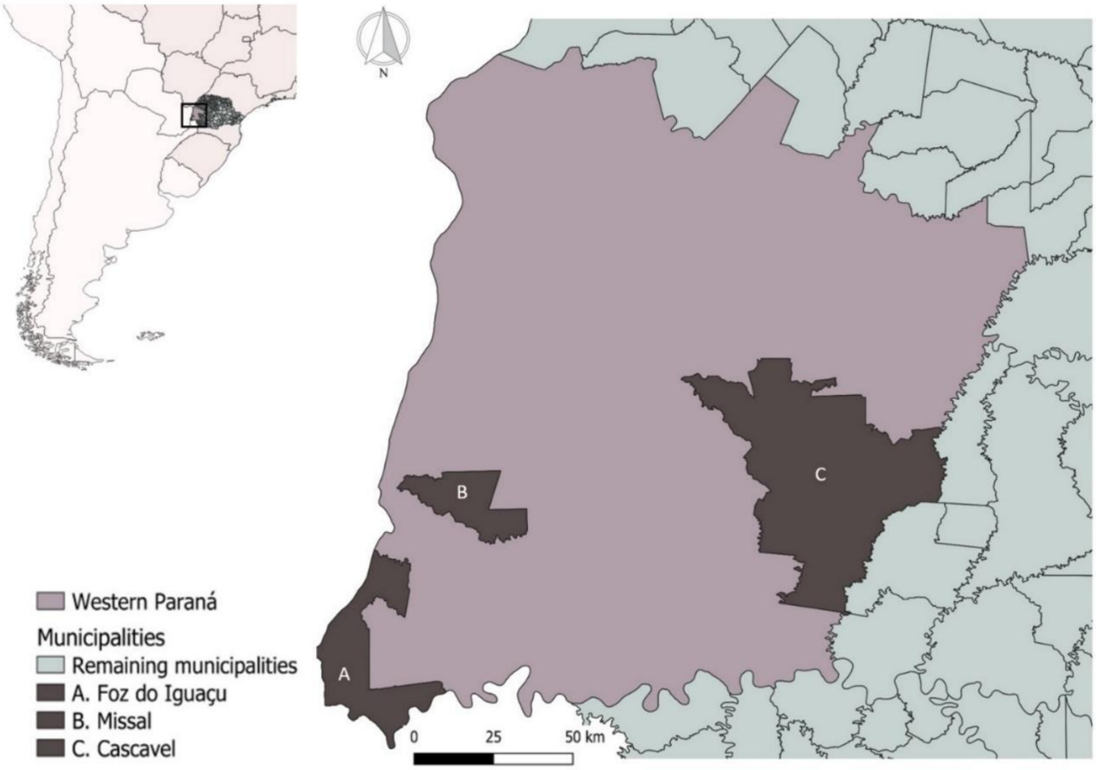

Fig. 1. Location of the Study Area in the Western Region of Paraná, Brazil, encompassing the municipalities of Foz do Iguaçu, Missal, and Cascavel.

Climate in the region is humid subtropical, with mean annual temperatures ranging from 18°C to 22°C. Temperatures fluctuate throughout the year, reaching highs of 38.2°C and lows of 15°C (Instituto Brasileiro de Geografia e Estatística, 2022a). There are no significant climatic differences among the regions where the municipalities are located, rather, minor variations are primarily influenced by altitude. Cascavel experiences the greatest altitudinal variation, ranging from 300 to 720 meters. Foz do Iguaçu follows with a variation of 260 to 600 meters, while Missal has an average altitude of 358 meters **(Fig. 1)**. The most common soil is "terra roxa", a well-drained and highly fertile soil considered among Brazil's most productive. The predominant land uses in the region are agriculture and pasture (Alvarez et al., 2013).

The region is heavily influenced by the agricultural and agro-industrial sectors, with a particular emphasis on family farming, which is prevalent throughout the micro-region (Dorne et al., 2016). According to the 2017 Agricultural Census, family farming in the western region accounts for approximately 23% of the total value of agricultural production and occupies 27.3% of the total area of agricultural establishments (Instituto Brasileiro de Geografia e Estatística, 2017). The municipalities studied are key agricultural and livestock hubs within the region. Each municipality possesses distinct geographic characteristics and natural resources that influence its production potential. The agricultural sector in these municipalities is organized in associations, cooperatives, and agrarian settlements, providing a valuable context for understanding the unique dynamics and challenges faced by small-scale producers in the region.

Foz do Iguaçu (25º00’.26º00’S, 54º00’.55º30’W) encompasses a territorial area of 609,192 km², with 165.50 km² dedicated to urban areas and 164.50 km² to rural areas (Fritzsons, et al., 2016; Gomes et al., 2020), encompasses a territorial area of 609,192 km², with 165.50 km² dedicated to urban areas and 164.50 km² to rural areas (Instituto Brasileiro de Geografia e Estatística, 2022a). Most of its territory is classified as urban (Sales, 2021). The municipality dedicates approximately 13,544 hectares to agricultural and livestock production, distributed among 568 establishments. The lands possess potential for the production of grains (soybean, corn), as well as fruits (melon, watermelon and tomato), sugarcane, peanut, and sweet potato (Instituto Brasileiro de Geografia e Estatística, 2017).

The municipality of Missal (25°01.661'S, 54°12.411'W) encompasses a territory of 324,397 km² (Fritzsons et al., 2016; Gomes et al., 2020). The region is considered a dairy basin in the western Paraná (Ipardes, 2022). Agricultural establishments occupy a total area of 26,953 hectares, distributed across 1,331 farms, with many agro-industries and cooperatives (Instituto Brasileiro de Geografia e Estatística, 2022b). Agricultural production includes grain crops such as corn, rice, wheat, and peanuts. Additionally, short-cycle and seasonal crops such as squash, pumpkin, peanuts, sugarcane, forage sugarcane, beans, and cassava are cultivated. Livestock raised in Missal are sheep, cattle, horses, pigs, donkeys, buffaloes, goats, quail, and poultry (Instituto Brasileiro de Geografia e Estatística, 2017). (Instituto Brasileiro de Geografia e Estatística, 2022b).

Cascavel (23º00’.24º00’S, 52º30’.54º00’W) is prominent for its significance in the agricultural sector, with grain production, poultry, pig, and fish farming, and beef and dairy cattle ranching among the main activities (Fritzsons et al., 2016; Gomes et al., 2020). The municipality dedicates 176,460 hectares to agriculture, distributed among 3,221 establishments. Cascavel covers approximately 12,823.490 km² and has an estimated population of 869,035 inhabitants (Instituto Brasileiro de Geografia e Estatística, 2022a). The region boasts fertile soils and favorable terrain, promoting agricultural and livestock activities.

Research Design

To assess the perception of climate change among family farmers in the western region of Paraná, Brazil, a structured questionnaire was administered to individuals over 18 years of age, regardless of gender, who were active producers present at the production unit at the time of the interview. In each municipality, farmers were associated to a cooperative (Family Farming Cooperative of Foz do Iguaçu (COAFFOZ), Foz do Iguaçu, and Family Farming Producers Cooperative of Missal (COOPER MISSAL), or were part of an agrarian reform settlement (Valmir Mota Settlement, Cascavel, whose farmers were also affiliated with various cooperatives). Approximately 160 and 94 families are associated to COAFFOZ and COOPER MISSAL, respectively, while the Valmir Mota Settlement was composed of 85 families, with land allotments ranging from 7 to 7.5 hectares per family.

The questionnaire was based on a quantitative approach, ensuring anonymity and utilizing pre-defined questions or statements **(Table S1)**. A 5-point Likert scale was used to indicate levels of agreement: 1- Strongly Disagree, 2- Disagree, 3- Neutral, 4- Agree, 5- Strongly Agree, and 6- No Response, ordered from least to most important. This approach allowed for the measurement of attitudes and understanding of the respondents regarding each statement (Dalmoro and Viera, 2013). The questionnaire focused on questions related to activities carried out on the property, perception of climate change, impacts, strategies employed to address these effects, and limitations or difficulties faced. Additionally, data on the respondent's profile, including gender, age, family income, education level, estimated property size, and location (rural or urban), and activities conducted on the property were collected **(Table S1)**.

This research was approved by the Research Ethics Committee on Human Subjects of UNIOESTE (CEP), through the Brazil Platform, under the protocol 6.107.219. Prior to each interview, participants were informed that their participation was anonymous and voluntary. Their informed consent was obtained through the Free and Informed Consent Form (TCLE).

Data collection took place between July and December 2023. Given the heterogeneity of the sample, preliminary contacts were made with key informants in each municipality, and visits were made to the cooperatives and settlement to present the research, solve doubts and schedule the interviews with local farmers. For participant selection, the snowball sampling method was employed (Alloatti, 2014). Initially, individuals working in technical assistance roles in the municipalities of Foz do Iguaçu and Missal were identified They, in turn, indicated other potential participants who could be included in the sample. In the case of the settlement, contact was established with designated leaders, who then identified individuals meeting the study criteria.

A total of 85 family farmers were interviewed, with 52 (61%) residing in the municipality of Foz do Iguaçu, 18 (21%) in Cascavel, and 15 (18%) in Missal. About 92% of the farmers lived in rural areas, where farms (*chacras*) and homesteads (*sitios*) were used for agricultural activities. However, some of those areas were officially classified as urban by local governments, for taxes purposes. The sample was balanced in terms of gender distribution, while most respondents had incomplete primary education and were more than 50 years old. Property sizes varied, ranging from 0.15-31 hectares (ha), with an average of 6.2 ha. Most farmers held land titles, and the most common activities on their properties were the cultivation of vegetables and fruits **(Table 1)**.

Table 1. Profile of Family Farmers Interviewed in the Municipalities of Foz do Iguaçu, Missal, and Cascavel, Brazil (N=85).

Profile of interviewees	Total respondents	Percentage
Gender		
Male	48	56%
Female	37	44%
Age Range		
18–29	13	15%
30–39	8	9%
40–49	18	21%
50–59	21	25%
60+	25	29%
Education Level		
Incomplete primary education	33	39%
Complete primary education	18	21%
Secondary education	16	19%
Technical education	5	6%
Higher education	12	14%
Postgraduate (any type)	1	1%
Activities ronducted		
Vegetable garden	78	92%
Fruit tree planting	78	92%
Flower planting	62	73%
Medicinal plant cultivation	62	73%
Agroforestry	54	64%
Beekeeping	35	41%
Poultry farming	69	81%
Pig farming	54	64%
Goat farming	10	12%
Other (Fish, Cattle, Rabbits)	26	31%
Family agro-industry	28	33%
Tourism and recreation	18	21%

Data Analysis

Preliminary dimensionality reduction analyses were conducted using Principal Component Analysis (ACP). The aim of this analysis was to take the original p variables, X1, X2, ..., Xp, and find combinations of them to produce indices Z1, Z2, …, Zp that were uncorrelated with each other. These indices optimally distribute the total variation, prioritizing the expression of the highest possible proportion of variation in Z1, followed by Z2, and so on (Perelman et al., 2023). To facilitate statistical analysis, the variables were abbreviated using acronyms

For this analysis, Likert scale variables (semi-quantitative) representing farmers' perceptions of climate change impacts were evaluated: RDL (Reduced Rainfall Days), AT (Increased Temperature), AITG (Increased Intensity of Storms), AIV (Increased Intensity of Winds), AIEE (Increased Intensity of Extreme Events), DCL (Decreased Rainfall Amount), CIES (Delayed Dry Season), CIEL (Delayed Rainy Season). Additionally, variables related to direct impacts on properties over the past five years were assessed: EA (Water Scarcity), DP (Decreased Production), RC (Delayed Harvest), PC (Partial or Total Crop Loss), AGAF (Increased Fertilizer Costs), AGAPH (Increased Pesticide or Herbicide Costs), AP (Problems Caused by Agricultural Pests), AE (Problems Caused by Plant Diseases). Finally, strategies employed to address impacts on properties were identified and evaluated: I (Irrigation), FO (Application of Organic Fertilizers), FS (Application of Synthetic Fertilizers), POH (Application of Organic Pesticides or Herbicides), PHS (Application of Synthetic Pesticides or Herbicides), MO (Organic Matter for Soil Cover), CQS (Crops to Improve Soil Quality), MP (Pruning Management), SFEP (Planting Flowers to Stimulate Pollination), SUPAC (Use of Seeds or Plants Adapted to Climate), SAOPN (Planting Trees with Other Native Plants), CPA (Consortiums between Plants and/or Animals), SA (Agroforestry Systems).

Regarding the contexts of the production units, the following limitations were assessed: CI (Input Costs), PP (Product Prices), AM (Market Access), APA (Access to Support Policies), TT (Land Tenure), TP (Property Size), CFP (Physical Conditions of the Property), PC (Climate Problems), AT (Technical Assistance), MO (Labor), AVE (Access and Drainage Routes), IF (Financial Instability), UAPV (Use of Agrochemicals in Neighboring Properties), MT (Machinery and Technology), AFCR (Financial Support and Rural Credit) from the questionnaire **(Table S1)**. The relationship between variables was analyzed using a correlation matrix. Eigenvectors and eigenvalues of each component were calculated to identify the contribution of each variable to the structure of the principal components. Only the first two principal components were retained for each set of variables. The lambda criterion was applied for component selection, retaining those with eigenvalues greater than one, ensuring that each component explained more than one variable. Furthermore, lambdas enable the observation of the weight each variable contributes to the principal components (Marulanda, 2017).

Next, a new database was constructed, incorporating all values of the indices resulting from ACP, the first two components for each variable, namely, PERCP.1 and PERCP.2, IMPCP.1 and IMPCP.2, ESTCP.1 and ESTCP.2, LIMCP.1 and LIMCP.2, corresponding to each interviewee, along with sociodemographic variables and productive activities. Subsequently, a hierarchical cluster analysis was performed using mixed-data factor analysis (AFDM) to identify the distribution of individuals into groups. This factor analysis is a principal component method that integrates qualitative and quantitative data (e.g., Likert scale) (Husson et al., 2026; Lê et al., 2008) **(Fig. 2)**. For this analysis, numerical variables were transformed into categorical variables. Variables such as age, education level, years on the property, property size, location, land ownership, production destination, and number of activities were categorized. The categories are described as follows: for gender, male and female; age, 18-29, 30-39, 40-49, 50-59, over 60 years; education level, incomplete primary education, complete primary education, secondary education, technical education, higher education, postgraduate; years of experience on the property, 1-9, 10-19, 20-29, 30-39, over 40 years; property size in hectares, 1-3, 4-10, 10-20, and over 20 ha; number of productive activities, 1-7, 8-14, over 15 activities; land tenure, title or concession, lease agreement with contract, and informal agreement; production destination, commercialization, own consumption, commercialization/own consumption.

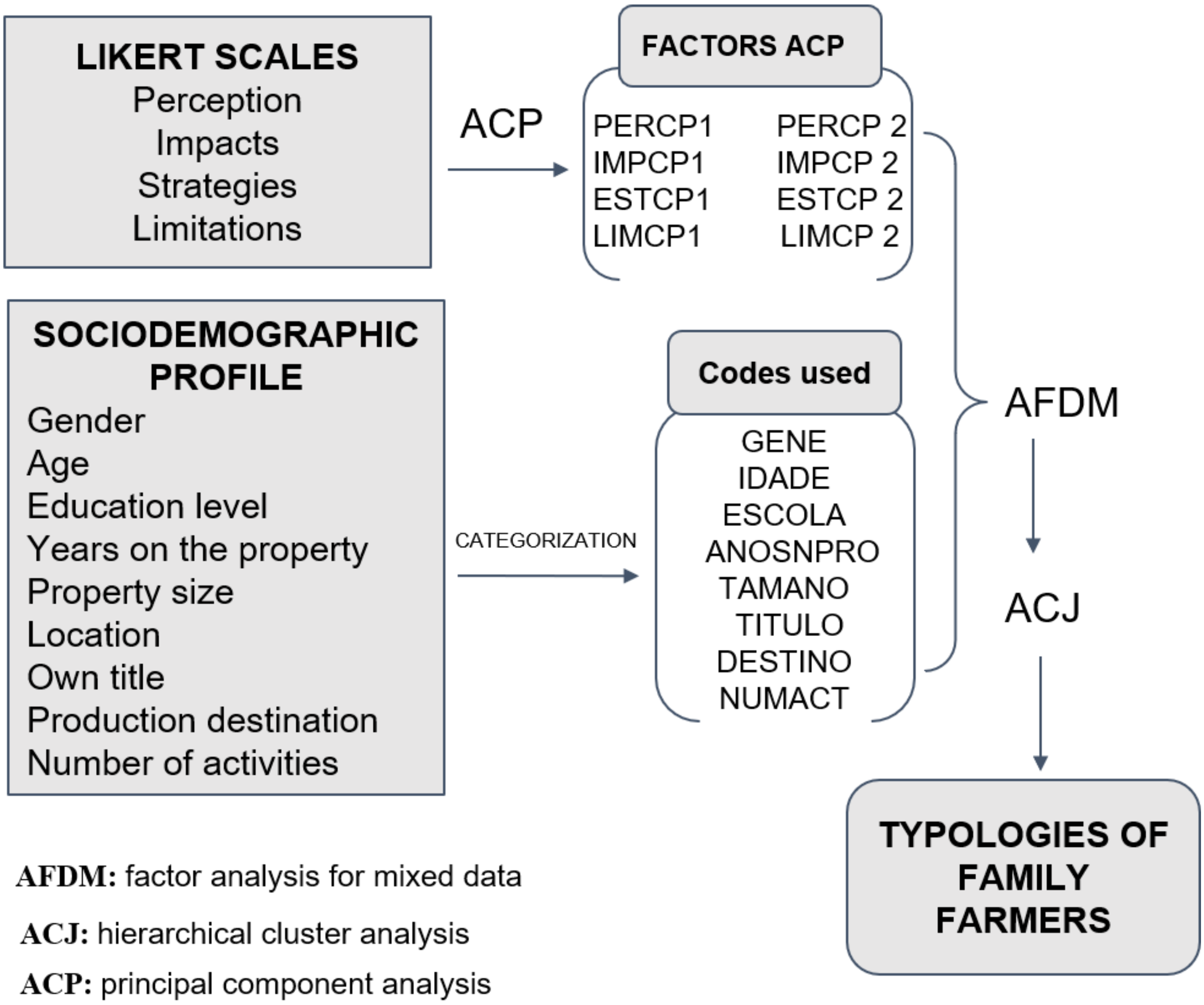

Fig 2. Flow chart for data processing and analysis. A Principal Component Analysis (ACP) was applied to the data obtained from responses to statements evaluated according to a Likert scale to obtain factors (quantitative). From the sociodemographic profiles, a categorization (qualitative) was performed. By combining both data sets, a Factor Analysis for Mixed Data (AFDFM) followed by Hierarchical Cluster Analysis (ACJ) was carried out, resulting in the typology of family farmers.

Hierarchical methods are widely used by ecologists for this type of data (Perelman et al., 2023). These techniques optimize criteria associated with each step of agglomeration and provide, in addition to the groups, the relationships between similar groups that make up the hierarchy. Furthermore, their use is based on their ability to generate optimal classifications based on internal proximity and separation between groups. The paragons obtained from this technique are proportional to the groups, meaning that groups are defined based on individuals who best represent the characterization. Larger groups present greater variation.

A V-test was conducted to evaluate the deviation between qualitative and quantitative variables, based on how these variables behaved within the groups. Values greater than two with a positive sign, and chi-squared values with a p-value less than 5% ($p < 0.05$), were considered significant (Lebart et al., 1995; Lê et al., 2008). The V-test measures how well a category represents a group of individuals. A positive value means the category is more relevant or common for that group. The higher the V-test value (especially if it's greater than two), the better the category fits those individuals. If the value is negative (or less than two), it is interpreted as low significance (Lebart et al., 1995). This analysis provides an understanding of the significance of the categories in the cluster analysis, identifying the individuals who best represent each group. It allows for a comparison of the emerging clusters and the general characteristics shared among them.

Statistical analyses were performed using the R programming language. For Principal Component Analysis (ACP), the FactoMineR package was used. For factor analysis of mixed data and cluster analysis, the "Factoshiny" package, which is part of the FactoMineR package, was used (Husson et al., 2026; Lê et al., 2008) was utilized in R.

Results

Perception of Climate Change

Most farmers perceive various effects of climate change on their productive activity. Among the effects that had the greatest agreement (agree or strongly agree) are the increase in temperature (82%), the occurrence of fewer rainy days (76%), the delay of the dry and rainy seasons (64%), the increase in the intensity of storms or hail (59%), the increase in the intensity of winds (63%), the decrease in the amount of rain (54%), and, to a lesser extent, the increase in the intensity of extreme events (49%) **(Fig. 3a).**

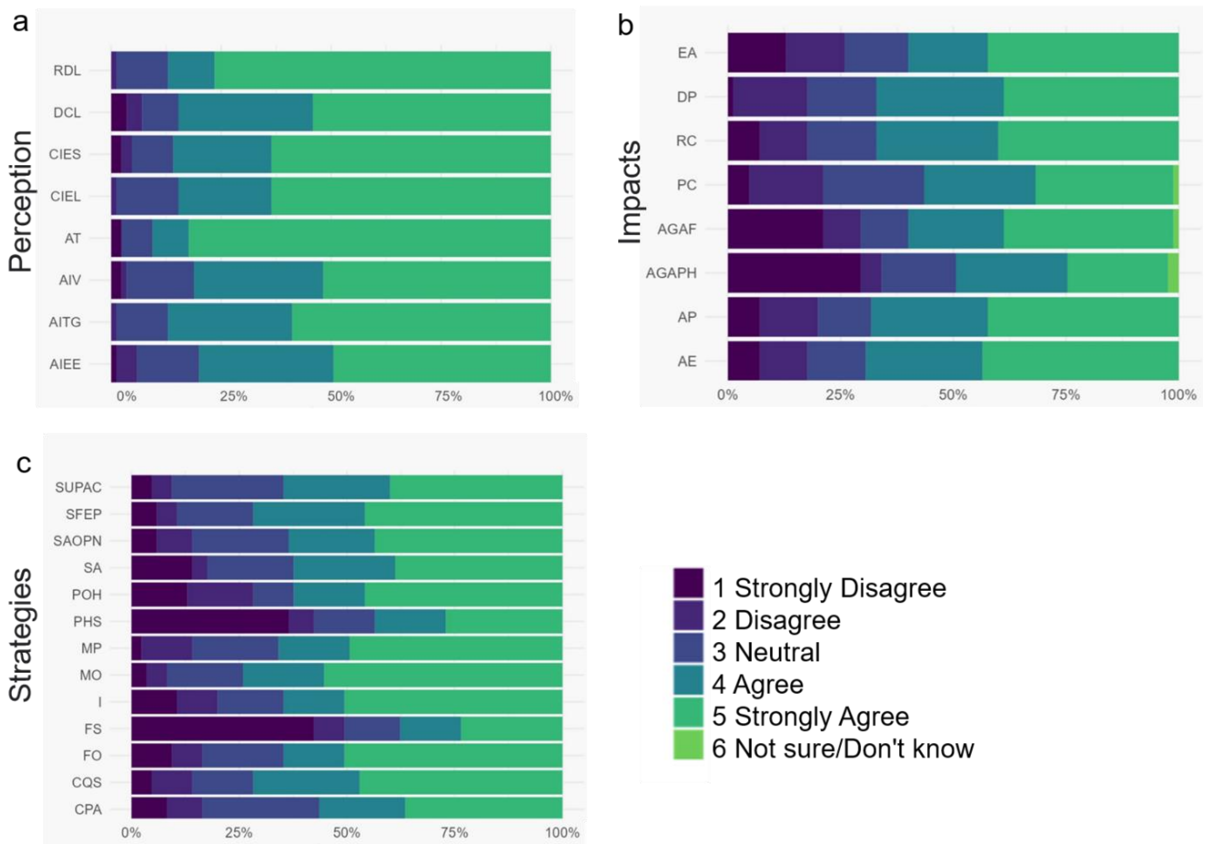

Fig. 3. Effects of climate change on family farming in western Paraná, Brazil. **(a)** Perception of climate change; **(b)** Perceived impacts on the property during the last five years; **(c)** Strategies used to cope with the impacts caused on the property. Responses were evaluated according to a Likert scale. The acronym extensions are in **Table S1**.

Regarding the impacts of climate conditions on their properties, farmers reported an increase in problems caused by plant or animal diseases (44%), an increase in problems caused by agricultural pests (42%), water scarcity (41%), and increased fertilizer costs (38%). Delayed harvest (36%) and decreased production (35%) were also commonly reported. Fewer farmers mentioned having experienced partial or total loss of their crops (31%), and increased costs for pesticides or herbicides (21%) (Fig. 3b).

To cope with the effects of climate change, farmers employed several strategies, such as using organic matter for mulching or direct planting (55%), irrigating (52%), applying organic fertilizers (51%), pruning (49%), using crops to improve soil quality (47%), planting flowers to stimulate crop pollination and the application of pesticides or herbicides (46%), increasing the use of plants that are more resilient to water stress or other changes in climate (40%), implementing agroforestry systems (39%), consortia between plants and/or animals

(36%) and the planting of trees with other native plants (32%), and finally the applying pesticides or herbicides of synthetic origin (28%) or synthetic fertilizers (24%) (Fig. 3c).

Dimensional Reduction Analysis

Regarding the principal component analysis (PCA), for perception of climate change **(Fig. 4a)**, the first component groups 59.7% of explained variability, lambda $\lambda>1$ (4.78), related to the variables AIEE, AIV, DCL, AITG and CIES, which refers to the increase in intensity of extreme events, frost, storms, hail, winds, changes in the amount of rain, the beginning of the rainy and dry seasons. On the other hand, the second component explains 12.9% of the variation of the data, lambda $\lambda>1$ (1.03), being mainly influenced by the variables CIEL, CIES and DCL, indicating alterations (delay or advance) of the onset of the rainy season, the onset of the dry season and decrease in the amount of rain **(Table. S2, A)**. These two components explain about 72% of the variability in the data.

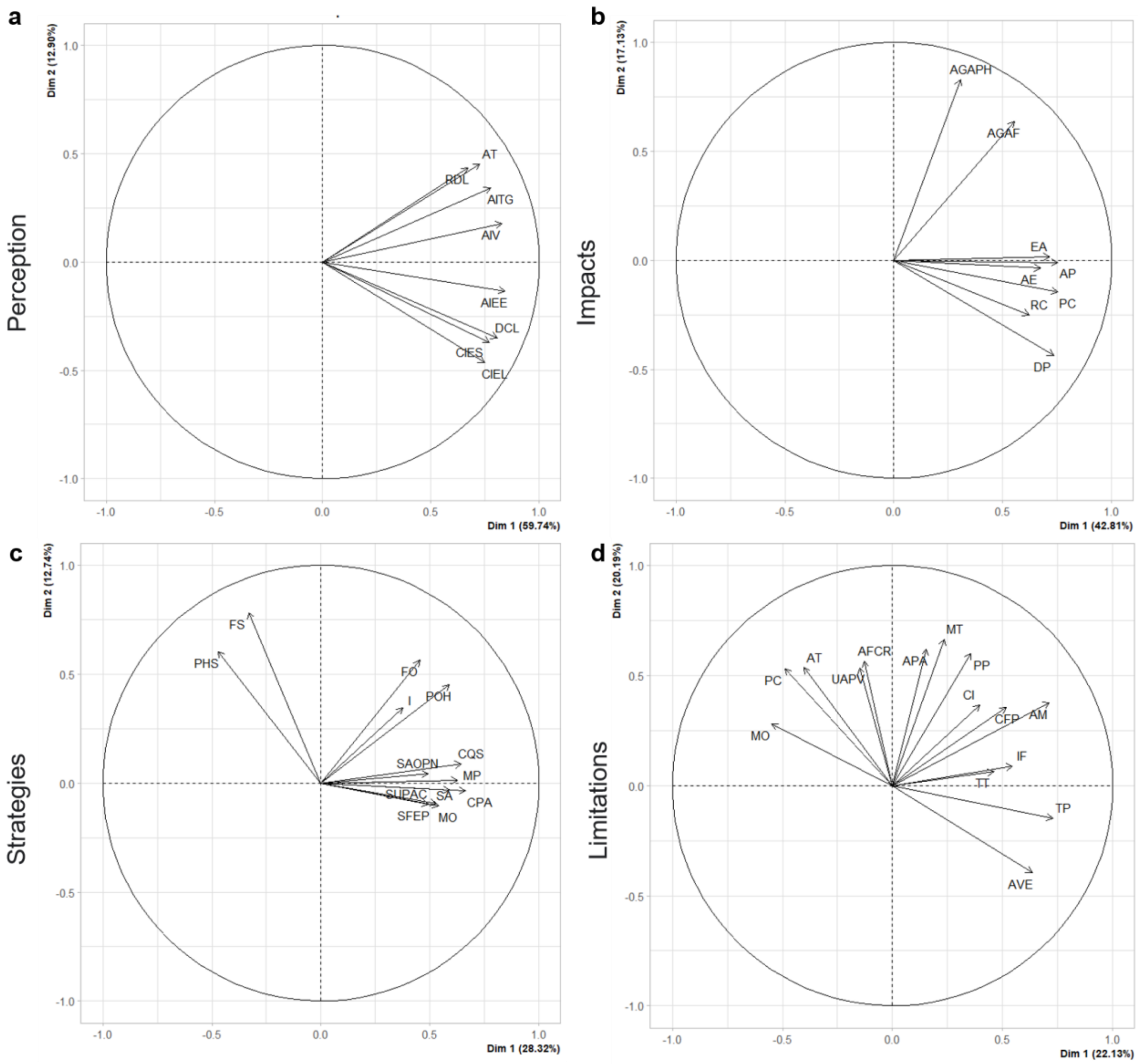

Fig. 4. Principal Component Analysis (ACP): (a) Perception of climate change; (b) Climate change impacts; (c) Adaptation strategies; (d) Constraints and difficulties. The axes show the eigenvalues of the first two axes that best represent each component. See Table S1 for description of acronyms and Table. S2, A, B, C, D for the eigenvalues of each principal component.

For the perception of climate change impacts (Fig. 4B), the first component explains 42.8% of the variation of the data; lambda $\lambda>1$ (3.43) and was positively related to the variables DP, PC, AP, EA, RC, AE, AGAF; and AGAPH, which refer to the decrease in production, loss of harvest, increase of problems caused by pests, delay of harvest, increase of expenses, especially in synthetic inputs. On the other hand, the second component explained 17.1%, lambda $\lambda>1$ (1.37), related to the variables AGAPH and AGAF, which represent increased expenses with fertilizers, pesticides and herbicides, and scarcity or lack of water (Table S2, B). These two axes explained about 60% of the variability in the data.

Regarding the strategies used (Fig. 4c), the first component explained 28.3% of the variation in the data, lambda $\lambda>1$ (3.68), and was positively related to the variables CPA, SA, POH, MP, SUPAC, MO, associated with service crops, crops to improve soil quality, plant-animal consortia and diversification, agroforestry systems, use of organic inputs, pruning management, use of seeds or plants adapted to the climate and organic matter cover or direct seeding. On the other hand, the second component explained 12.7% of the variation of the data, lambda $\lambda>1$ (1.65), and was related to the variables FS, PHS, FO, POH, I, CQS, SAOPN, which refer to the use of synthetic fertilizers, synthetic pesticides or herbicides, organic fertilizers, organic pesticides or herbicides, crops to improve soil quality, pruning, planting of trees or other native plants and irrigation (Table S2, C). These two axes explained about 41% of the variability in the data.

For constraints and difficulties (Fig. 4d), component one explained 22.1% of the variation in the data, lambda $\lambda>1$ (3.37), and was positively related to the variables AM, TP, CFP, AVE, IF, TT, which represent access to markets, property size, physical conditions of the property (soil, relief, access to water), access roads to the property and for the transport of products, financial instability and land tenure. On the other hand, the second component explained 20.1 % of the variation in the data, lambda $\lambda>1$ (2.79), and was positively related to the variables MT, PC, PP, APA, TT, AFCR, AT, MO, which refer to climate-related problems, regular access to technical assistance, labor, and financial support and rural credit (Table S2, D). These two axes explained about 42% of the variability in the data.

Hierarchical Cluster Analysis and V-test

According to the cluster formation, three clusters were identified (Figs. S1, S2). Each cluster describes the individuals (farmers) that best represent them, i.e., defined based on individuals that represent better characterization, larger groups, more variation. The first cluster (hereafter, Diversification and Structural Limitation) was the most representative. In this group there was a male predominance and a wide diversity of ages, from 25 to 62 years old, educational levels ranging from complete primary education to technical and higher education, and property sizes, from small plots of 0.4 ha to 20 ha. All individuals had land tenure and were involved in commercialization activities, performing a range of 8-15 activities. Regarding the

V.test, for qualitative variables, this group was characterized by high values in the LIMCP.1 (Table 2), i.e., composed of farmers facing challenges related to access to markets, size and physical conditions of the property, and financial stability, reflecting structural and economic difficulties. For quantitative variables, the modal class indicated that 83.3% of people carried out more than 15 productive activities (Tables S3, S4).

Table 2. V.test analysis of the influence between qualitative and quantitative variables of the groups, resulting from the Cluster analysis. Darker colors represent V-test ≥ 2, medium colors 1 ≤ V-test < 2, and lighter colors V-test <1.

Variables	Cluster 1	Cluster 2	Cluster 3
Qualitative Variables			
LIMCP.1	3.08	-3.6	0.44
IMPCP.2	1.22	2.61	-3.26
ESTCP.1	-3.76	-4.53	7.03
PERCP.1	-7.91	1.87	5.14
IMPCP.1	-2.28	-2.27	3.86
LIMCP.2	1.5	-2.75	3.61
Quantitative Variables			
Number of productive activities: More than 15	3.03	-1.31	-1.72
Destination of production: Commercialization	2.53	-1.02	-1.13
Ownership of the property: Own title	2.53	-0.47	-1.62
Destination of production: Commercialization/ Consumption/Consumo	-2.16	0.16	1.59
Age: Over 60	-2.2	0.61	1.28
Land ownership: Concession	-2.3	0.19	1.71
Years of experience: Over 40	-0.15	2.92	-2.52
Age: 18-29	1.9	-2.29	0.06
Property size: 1-3ha	0.69	-2.29	1.35
Years of experience: 1-9	-137	-1,37	2.34
Property size: 10-20ha	1.67	1.01	-2.39

The second cluster (hereafter, Experience and Concerns about Productivity) comprised both male and female individuals ranging in age from 42 to 68 years, with educational levels ranging from incomplete primary education to complete primary education and ownership experience ranging from three to 50 years. The properties varied in size from 2.1 to 22.7 ha, suggesting differences in production capacity. In addition, most farmers held title to land, while some held titles by concession. They were engaged in marketing activities, although some also produced for their own consumption, performing a range of 8-11 activities. The results of the

V-test analysis showed that farmers in this cluster had concerns about climate change impacts, high values for variable IMPCP.2 (Table 2), problems caused by pests and crop loss, affected by loss of productivity and inability to acquire external inputs. Regarding the quantitative variables, the modal class indicated that 57.1% of the people had more than 40 years on the property (Tables S3, S4).

The third cluster (hereafter, Sustainable Practices and Vulnerability to Resources) was mostly composed of men between 26 and 62 years of age, with incomplete primary education and 5 to 20 years of farming experience, with landholdings ranging from 0.15 to 1 ha. They owned their land and carried out between 12 and 13 agricultural activities. The test analysis showed that the cluster was characterized by the variables ESTCP.1, PERCP.1, IMPCP.1 and LIMCP2 **(Table 2)**. They stood out for adopting strategies related to sustainable practices, such as service crops, such as planting flowers to stimulate pollination, plant and animal consortia, and diversification. They perceived changes in the amount of rainfall and the onset of the rainy season as more immediate. They were concerned about increased expenditures on synthetic inputs. Their constraints included climatic problems, access to technical assistance, labor and financial support. For quantitative variables, the modal class indicated that 77, 7% of people had farming experience on the property ranging from one to nine years **(Tables S3, S4)**.

Discussion

Farmers in the western Paraná region perceived a wide range of climatic variations, such as increased temperature and changes in dry and rainy seasons in the last five years, which can be associated with climate change effects (Cheval et al., 2022; López and Hernández, 2016; Nicholls and Altieri, 2019; Viguera, 2017). The impacts of climate change were felt in both the short and long terms, for example, rising temperatures had consequences that result in more frequent and intense heat waves, which directly affected agricultural production and food security (Fourment et al., 2020). Although farmers recognized the effects of climate change, their decisions to adopt sustainable agricultural practices were limited by the lack of economic resources, financial support, and the absence of adequate technical assistance. This shows that initiatives to support climate resilience in family farming are not adequately reaching all groups of farmers in the study region.

The effects of climate change vary by geographic region, influencing responses and the strategies adopted by farmers (Marshall et al., 2014). To better understand how family farmers in western Paraná perceive and adapt to climate change, it is crucial to analyze the composition and responses of the three clusters identified in this work. The clusters reflected the heterogeneity of family farming in western Paraná and the complexity of responses to climate change. While there were some adaptation strategies in place, structural constraints, lack of access to resources, and vulnerability to extreme weather events represented shared challenges. The Diversification and Structural Constraints cluster faced significant structural constraints. Limited access to markets, property size and financial instability hindered their ability to invest in more effective technologies and adaptation strategies. Lack of capital and access to loans are common obstacles for family farmers, limiting their ability to respond to climate challenges (Burney et al., 2014; Gori Maia et al., 2018; López and Hernández, 2016; Nicholls and Altieri, 2019).

Already, the Experience and Productivity Concerns cluster was primarily affected by the impacts of climate change on productivity. Crop failure and the inability to purchase inputs were challenges that directly affected the livelihoods of farmers belonging to the group. Accumulated experience can be valuable for implementing traditional adaptation strategies. For example, the longer they practice agriculture, the more likely they are to observe changes in climatic conditions (Alhassan and Harun, 2024), but lack of access to financial and technological resources, limits their ability to respond to extreme weather events (Burney et al., 2014; Gori Maia et al., 2018). On the other hand, this group of farmers showed a low educational level (Phung and Dao, 2024 which could imply a lack of deeper knowledge related to climate change, which in turn would reduce the likelihood of implementing adaptation measures (Barokatuminalloh et al., 2021; Hyland et al., 2019). According to De Matos Carlos et al. (2020), there is a positive correlation between the adoption of adaptation practices and the perception of climate change.

Finally, the Sustainable Practices and Resource Vulnerability cluster stood out for adopting adaptation strategies based on sustainable practices. While the use of these practices is crucial for the agroecosystem resilience, the group faced limitations in access to technical assistance, labor and financial support. Socioeconomic characteristics and resource availability influence the choice of adaptation strategies, and lack of support can increase farmers' vulnerability to climate change (Ali 2021; Abdula and Huffman, 2014). Consequently, extreme weather events also affected the availability of labor, making it difficult for farmers to work the land or harvest their crops, and this resulted in the need to occasionally seek off-farm labor opportunities to increase family income.

Among the support policies that can benefit the groups, the importance of promoting crop diversification stands out. Diversification can mitigate risks and uncertainties associated with climatic and biological factors (Ali, 2015). It represents an effective strategy to achieve multiple objectives, such as increasing income, improving economic conditions, food security, generating employment opportunities, and promoting more efficient use of resources such as land and water (Khan et al., 2021). This not only strengthens farmers' resilience, but also boosts sustainable agricultural development and improves the environment. Moreover, the adoption of technologies and programs associated with innovative agricultural practices, such as efficient soil and water management, intercropping, the use of improved varieties, crop rotation, and the implementation of early warning systems for extreme weather events, have been shown to increase agricultural productivity and mitigate CC impacts (Alhassan and Haruna, 2024; Khan et al., 2021; Paut and Tchamitchian, 2019). Diversification is manifested in various forms, such as the integration of crops with animals and trees, and the use of low-input agroecological systems, minimizing the use of chemical fertilizers and taking advantage of natural resources. These practices increase the diversity and complexity of agroecosystems, improving soil quality, plant health and crop productivity (Nicholls and Altieri, 2019 In addition, greater diversity in agroecosystems can buffer the effects of changes in precipitation and temperature (Meshesha et al., 2022).

Even so, the traditional strategies employed by farmers to face challenges may be insufficient to react to the impacts of extreme weather events (Milanés, 2021). These events may result in an increase in plant and animal diseases, pest problems, and increased need of fertilizer supply, as reported by farmers. Therefore, new strategies must be developed, and constantly refined to combine new solutions with existing ones to improve resistance to adverse weather conditions. In fact, in the state of Paraná, there are public policies and services that support family agricultural cooperatives, such as the Cooperativism Law and the COOPERA PARANÁ program, in addition to the Technical Assistance and Rural Extension Law (ATER) (Corrêa da Silva and Cartes Patrício, 2022). However, there are still barriers related to the lack of integration between public policies and projects designed to foster adaptation to climate change (Milanés, 2021). In addition, the current technical assistance, i.e., the advice they receive does not adequately include climate risk issues, focusing on production management.

To support the resilience of family farming and promote the permanence of people in the countryside, it is essential to implement policies and programs tailored to the specific needs of each group. For the Diversification and Structural Constraints Group, it is necessary to encourage the creation of short commercialization circuits that increase the acceptance of family farming products at the local and regional scales. This will help reduce dependence on intermediaries and improve access to fair markets. It is also crucial to offer differentiated financing programs, such as lines of credit with affordable interest rates and flexible payment terms, suited to the needs of family farmers with properties of different sizes. In addition, training in business management, cooperativism and associativism should be promoted to improve organizational and collective bargaining capacity.

For the Experience and Concerns Group on Productivity, it is necessary to facilitate access to adaptation technologies, such as efficient irrigation systems, climate-resistant seeds and tools for pest and disease management. Specialized technical assistance in sustainable soil and water management practices should also be provided to improve productivity and resilience to extreme weather events. Agricultural insurance should be more accessible and protect farmers against losses due to adverse weather conditions.

As for the Sustainable Practices and Resource Vulnerability Group, it is important to strengthen rural extension services, increasing the availability of technicians to advise on agroecological practices, pest management and crop diversification. Training programs in agroecology, integrated pest management, soil and water conservation, and other sustainable practices that improve resilience to climate change should be implemented. In addition, the creation of local seed banks with climate-adapted and disease-resistant varieties, together with economic incentives or access to markets for farmers who adopt agroecological practices, will contribute significantly to the sustainability and resilience of family farming.

Conclusions

This work provided a comprehensive view on the perception of farmers in the municipalities of Foz do Iguaçu, Missal and Cascavel on climate change, in addition to the impacts on the property and the strategies adopted. Understanding perceptions is crucial to develop relevant and practical adaptive measures. Although farmers adopted many strategies to cope with the effects of climate change, financial constraints and lack of technical assistance significantly influenced the choice of sustainable farming practices. The adoption of innovative agricultural technologies comes with management and sustainability challenges, but proper technical assistance and financial support can help farmers manage their resources and market their products more efficiently. In addition, the implementation of sustainable practices, the construction of agricultural systems that can withstand extreme weather conditions, as well as the conservation and efficient use of resources, are essential to ensure long-term agricultural viability and environmental protection. These findings contribute significantly to strengthen climate resilience and guide the design of policies and programs that promote the adaptation of agricultural communities to sustainable practices. Also, the results reinforce the importance of making relevant and substantial investments in agricultural development, considering the variability in yields, constraints and the capacity of households to ensure their food security in the midst of the global crisis.

References

Abdulai, A., Huffman, W., 2014. The adoption and impact of soil and water conservation technology: an endogenous switching regression application. Land Econ. 90, 26–43. https://doi.org/10.3368/le.90.1.26

Adhikari, U., Nejadhashemi, A.P., Woznicki, S.A., 2015. Climate change and eastern Africa: A review of impact on major crops. Food and Energy Security. 4, 2015. https://doi.org/10.1002/fes3.61

Alhassan, U., Haruna, E.U., 2024. Rural farmers' perceptions of and adaptations to climate change in Sub-Saharan Africa: Does climate-smart agriculture (CSA) matter in Nigeria and Ethiopia? Environmental Economics and Policy Studies. 26, 1-40. https://doi.org/10.1007/s10018-023-00388-8

Ali, J., 2015. Adoption of diversification for risk management in vegetable farming. International. Journal of Plant Sciences. 21, 9-20. https://doi.org/10.1080/19315260.2013.813891

Alloatti, M.N., 2014. A discussion on the snowball technique from the experience of international migration research. In: IV Latin American Meeting of Social Science Methodology (Costa Rica, August 27-29, 2014).

Alvarez, C.A., Stape, J.L., Sentelhas, P.C., de Moraes Gonçalves, J.L., Sparovek, G., 2014. Köppen's climate classification map for Brazil. Meteorologische Zeitschrift. 22711-728. https://doi.org/10.1127/0941-2948/2013/0507

Ayal, D., Leal Filho, W., 2017. Farmers' perceptions of climate variability and its adverse impacts on crop and livestock production in Ethiopia. Journal of Arid Environments. 140, 20-28. https://doi.org/10.1016/j.jaridenv.2017.01.007

Barokatuminalloh, Y.P., Mulyaningsih, T., Daerobi, A., 2021. Perception and Adaptation Capacity of Farmers to Climate Change. Annals of the Romanian Society for Cell Biology. 5373–5382.

Bhattacharya, A., 2019. Global climate change and its impact on agriculture. Changing climate and resource use efficiency in plants. 1, 1-50. https://doi.org/10.1016/B978-0-12-816209-5.00001-5

Bianchini, V., Picinatto, A., 2021. Cooperativismo da Agricultura Familiar – Relevância, Gargalos e Potencialidades. Relatório da Pesquisa FAO TCP BRA 3702, Curitiba.

Brazil. 2021. Estratégias de adaptação às mudanças do clima dos sistemas agropecuários brasileiros. MAPA/SENAR, Brasília. https://www.gov.br/agricultura/pt-br/assuntos/sustentabilidade/planoabc-abcmais/publicacoes/estrategias-de-adaptacao-as-mudancas-do-clima-dos-sistemas-agropecuarios-brasileiros.pdf

Brazil. 2006. Lei nº 11.326, de 24 de julho de 2006: Dispõe sobre a Política Nacional de Agricultura Familiar e dá outras providências. Planalto. https://www.planalto.gov.br/ccivil_03/_ato2004-2006/2006/lei/l11326.htm

Burney, J., Cesano, D., Russell, J., Lèvre La Rovere, E., Corral, T., Coelho, N.S., Santos, L., 2014. Climate change adaptation strategies for smallholder farmers in the Brazilian Sertao. Climatic Change. 126, 45-59. https://doi.org/10.1007/s10584-014-1186-0

Carlos, S.D.M., Cunha, D.A.D., Pires, M.V., 2019. Does knowledge about climate change imply adaptation? An analysis of farmers in the Brazilian Northeast. Revista de Economia e Sociologia Rural. 57, 455-471. https://doi.org/10.1590/1806-9479.2019.187600

Cheval, S., Bulai, A., Croitoru, A.-E., Dorondel, S., Micu, D., Mihăilă, D., Sfîcă, L., Tișcovschi, A., 2022. Climate change perception in Romania. Theoretical and applied climatology. 149, 1-20. https://doi.org/10.1007/s00704-022-04041-4

Corrêa da Silva, H.B., Cartes Patrício, C., 2022. Fortalecimento da agricultura familiar e desenvolvimento sustentável - Cooperativismo, ater e pesquisa agropecuária, e ater digital pós-COVID-19. Brasília, FAO, SEAB/PR and IAPAR EMATER. https://openknowledge.fao.org/server/api/core/bitstreams/6d6724b8-a021-4dd8-a4f4-035d36b94384/content

Dalmoro, M., Vieira, K., 2013. Dilemmas in the construction of Likert-type scales: do the number of items and the layout influence the results? Revista Gestão Organizacional, 6, 161-174.

De Matos Carlos, S., Da Cunha, D.A., Pires, M.V., Do Couto-Santos, F.R., 2020. Understanding farmers' perceptions and adaptation to climate change: the case of Rio das Contas basin, Brazil. GeoJournal. 85, 805-821. https://doi.org/10.1007/s10708-019-09993-1

Dorner, S.H., Wissmann, M.A., Silveira, T.M.S., Schimidt, C.M., 2016. Cooperação científica: uma análise da rede formada pelos pesquisadores do Programa de Pós-Graduação em Desenvolvimento Regional e Agronegócio da Unioeste. Revista Capital Científico-Eletrônica. 14, 76-92. https://doi.org10.5935/2177-4153.20160014

Food and Agriculture Organization of United Nations, 2017. Tracking adaptation in agricultural sectors: Climate change adaptation indicators. http://www.fao.org/3/ai8145e.pdf (accessed 18

June 2022).

Fourment, M., Ferrer, M., Barbeau, G., Quénol, H., 2020. Local perceptions, vulnerability and adaptive responses to climate change and variability in a winegrowing region in Uruguay. Environ. Manage. 66, 590-599. https://doi.org/10.1007/s00267-020-01330-4

Fritzsons, E., Wrege, M.S., Mantovani, L.E., 2016. Relação entre altitude e temperatura: uma contribuição ao zoneamento climático no estado de Santa Catarina, Brasil. Revista Brasileira de Climatologia. 18, 80-92. http://dx.doi.org/10.5380/abclima.v18i0.39471

Galindo, L.M., Samaniego, J., Alatorre, J.E., Carbonell, J.F., 2014. Study of climate change in Latin America: Processes of adaptation to climate change. Analysis of Latin America. ECLAC (ed.). San Joaquín, Santiago, Chile. Project document collection 647.

Gomes, J.B.V., Wrege, M.S., Holler, W.A., Bognola, I.A., 2020. General characteristics of the municipalities of the Paraná 3 Basin and Palotina, in: Gomes, J.B.V., Wrege, M.S. (Eds.), Municipios formadores da Bacia do Paraná 3 e Palotina: estudos de clima, solos e aptidão das terras para o cultivo do eucalipto, Embrapa, Brasília, pp. 11-16.

Gomm, X., Ayalew, B., Hylander, K., Zignol, F., Börjeson, L., Tack, A. J., 2024. From climate perceptions to actions: A case study on coffee farms in Ethiopia. Ambio. 53, 1-13. https://doi.org/10.1007/s13280-024-01990-0

Gori Maia, A., Cesano, D., Miyamoto, B.C.B., Eusebio, G.S., Silva, P.A.D.E.O., 2018. Climate change and farm-level adaptation: the Brazilian Sertão. Int J Clim Chang Strateg Manag, 10, 729-751. http://dx.doi.org/10.1108/IJCCSM-04-2017-0088

Grimberg, B., Ahmed, S., Ellis, C., Miller, Z., Menalled, F., 2018. Climate change perceptions and observations of agricultural stakeholders in the Northern Great Plains. Sustainability. 10, 1687. https://doi.org/10.3390/su10051687

Husson, F., Josse, J., Le, S., Mazet, J.Y., Husson, MF., 2016. Package ‘factominer’. An R package. 96, 698.

Hyland, J.J., Jones, D.L., Parkhill, K.A., Barnes, A.P., Williams, A.P., 2016. Farmers’ 21 perceptions of climate change: identifying types. Agr Hum Values. 33, 323-339. https://doi.org/10.1007/s10460-015-9608-9

Instituto Brasileiro de Geografia e Estatística, 2017. Foz do Iguaçu Census. https://cidades.ibge.gov.br/brasil/pr/foz (accessed 18 June 2022).

Instituto Brasileiro de Geografia e Estatística, 2022a. Cascavel. https://cidades.ibge.gov.br/brasil/pr/cascavel/panorama (accessed 15 February 2022).

Instituto Brasileiro de Geografia e Estatística, 2022b. Produção agropecuária. https://www.ibge.gov.br/explica/producao-agropecuaria/pr (accessed 29 January 2024).

Ipardes, 2022. Profile of two municipalities. http://www.ipardes.gov.br/perfil_municipal/MontaPerfil.php?codlocal=164&btOk=ok

(accessed 15 February 2022).

Karki, G., Bhatta, B., Devkota, N.R., Acharya, R.P., Kunwar, R.M., 2022. Climate change adaptation (CCA) research in Nepal: implications for the advancement of adaptation planning. Mitigation and adaptation strategies for global change. 27, 1-13. https://doi.org/10.1007/s11027-021-09991-0

Khan, N., Ray, R.L., Sargani, G. R., Ihtisham, M., Khayyam, M., Ismail, S., 2021. Current progress and future prospects of agriculture technology: Gateway to sustainable agriculture. Sustainability. 13, 4883. https://doi.org/10.3390/su13094883

Lê, S.; Josse, J.; Husson, F., 2008. FactoMineR: an R package for multivariate analysis. Journal of statistical software. 25, 1-18. https://doi.org/10.18637/jss.v025.i01

Lebart, L., Piron, M., Morineau, A. 1995. Statistique exploratoire multidimensionnelle. Dunod, Paris.

Lee, K., Gjersoe, N., O'neill, S., Barnett, J. 2020. Youth perceptions of climate change: a narrative synthesis. Wires Clim Change. 11, e641. https://doi.org/10.1002/wcc.641

López, A.J., Hernández, D. 2016. Climate change and agriculture: a review of the literature with emphasis on Latin America. Economic Quarterly. 4, 459-49. https://doi.org/10.20430/ete.v83i332.231

Lucero López, C.Y., Castruita Esparza, L.U., Legarreta González, M.A., Olivas García, J.M., Uranga Valencia, L.P., Lujan-Álvarez, C. 2022. Impact of climate change on agriculture in Irrigation District 005 Chihuahua, Mexico. Revista mexicana de ciencias agrícolas. 13, 1003-1014. https://doi.org/10.29312/remexca.v13i6.2881

Marshall, N.A., Stokes, C.J., Webb, N.P., Marshall, P.A., Lankester, A.J. 2014. Social vulnerability to climate change in primary producers: A typology approach. Agr Ecosyst Environ. 186, 86-93. https://doi.org/10.1016/j.agee.2014.01.0042014

Marulanda, N., 2017. Principal Component Analysis on the adoption of Environmental Management Systems in Higher Education Institutions. Revista Espacios. 38.

Meshesha, A.T., Birhanu, B.S., Bezabih, A.M., 2022. Effects of perceptions on adoption of climate-smart agriculture innovations: empirical evidence from the upper Blue Nile Highlands of Ethiopia. Int J Clim Change Strateg Manag. 14, 293-311. http://dx.doi.org/10.1108/IJCCSM-04-2021-0035

Milanés, O.A.G., 2021. A gr icultur a f amiliar y la adaptación al cambio climático en COAPROCOR - Paraná, Brasil. Editora Científica Digital, Guarujá.

Morales-Casco, L.A., Zúniga-González, C.A., 2016. Impacts of climate change on agriculture and food security. Iberoamerican Journal of Bioeconomy and Climate Change. 2, 269-291. https://dx.doi.org/10.5377/ribcc.v9i17.16207

Neto, A.I.S., Fraga, R.E., Schiavetti, A., 2022. Tradition and trade: culture and exploitation of avian fauna by a rural community surrounding protected areas in the south of Bahia's State, Northeastern Brazil. Journal of Ethnobiology and Ethnomedicine. 18, 1-14. https://doi.org/10.1186/s13002-022-00515-x

Nicholls, C.I., Altieri, M.A., 2019. Agroecological bases for the adaptation of agriculture to climate change. Cuadernos de Investigación UNED. 11, 55-61.

Orimoloye, I.R., Belle, J.A., Orimoloye, Y.M., Olusola, A.O., Ololade, O.O., 2022.Drought: a common environmental disaster. Atmosphere. 13, 111. https://doi.org/10.3390/atmos13010111

Paut, R., Sabatier, R., Tchamitchian, M., 2019. Reducing risk through crop diversification: An application of portfolio theory to diversified horticultural systems. Agricultural systems. 168, 123-130. https://doi.org/10.3390/atmos13010111

Perelman, S, B.; Puhl, L. E., 2023. Abordaje multivariado en estudios botánicos y ecológicos. Darwiniana, nueva serie. 11, 391-426. https://doi.org/10.14522/darwiniana.2023.111.1086

Phung, Q.; Dao, N., 2024. Farmers' Perceptions of Sustainable Agriculture in the Red River Delta, Vietnam. 10, 1-14. https://doi.org/10.1016/j.heliyon.2024.e28576

Pires, M.V., Cunha, D.A., Reis, D.I., Alexandre, B., 2014. Farmers' perceptions and adaptation strategies to climate change in Minas Gerais State, Brazil. Revista de Ciências Agrárias (Portugal). 37, 431-440.

Rambo, J.R., Tarsitano, M.A.A., Laforga, G., 2016. Family farming in Brazil, a concept under construction: a trajectory of struggles, a thriving history. Revista de Ciências Agro-Ambientais. 14.

Ruiz, I., Faria, S.H., Neumann, M.B., 2020. Climate change perception: driving forces and their interactions. Environmental Science & Policy. 108, 112-120. https://doi.org/10.1016/j.envsci.2020.03.020

Sales, R.L.A., 2021. Agricultura urbana e periurbana em Foz do Iguaçu: análise das Capacidades Estatais, percepção dos burocratas. Universidade Federal da Integração Latino-Americana.

Schnegg, M., O'Brian, C.I., Sievert, I.J., 2021. It's our fault: a global comparison of diferent ways of explaining climate change. Human Ecology. 49, 327-339. https://doi.org/10.1007/s10745-021-00229-w

Tesfaye, A., Amare, A. Megerssa, G.R., 2021. Smallholder coffee producer's perception to climate change and variability: the evidence from Mana district, South-Western Ethiopia. Geo Journal. 87, 4901-4912. https://doi.org/10.1007/s10708-021-10537-9

Torres, M., Howitt, R., Rodrigues, L., 2019 Analyzing rainfall effects on agricultural income: Why timing matters. Economia. 20, 1-14. https://doi.org/10.1016/j.econ.2019.03.006

Viguera, B., 2017. Impacts of climate change on agriculture in Central America, mitigation and adaptation strategies Module 2.

Williams, P.A., Crespo, O., Abu, M., 2019. Adapting to changing climate through improving adaptive capacity at the local level – The case of smallholder horticultural producers in Ghana. Climate Risk Management. 23, 124-135. https://doi.org/10.1016/j.crm.2018.12.004

3. CONSIDERACIONES FINALES

En este estudio, identificamos patrones en las percepciones de los agricultores, así como las limitaciones y las estrategias de mitigación utilizadas. Los agricultores percibieron cambios como el aumento de las temperaturas y la reducción del número de días de lluvia, lo que impactó negativamente en la producción agrícola, generando problemas de enfermedades y plagas, escasez de agua y mayores gastos en fertilizantes. Además, agrupamos a los agricultores en tres conglomerados distintos, basados en características sociodemográficas y actividades productivas: (i) Diversificación y limitaciones estructurales; (ii) Experiencia y preocupaciones por la productividad; (iii) Prácticas sostenibles y vulnerabilidad a los recursos. Estos grupos reflejaban la heterogeneidad y complejidad de la agricultura familiar en la región y los retos comunes, como las limitaciones estructurales y la vulnerabilidad a los fenómenos meteorológicos extremos.

Este trabajo representa una contribución importante al campo y a futuras investigaciones, ya que proporciona información empírica crítica para la elaboración de políticas públicas que subsidien la implementación de estrategias efectivas para promover la sustentabilidad en regiones vulnerables. Además, proporciona datos específicos sobre el impacto del cambio en las actividades productivas de personas involucradas en cooperativas, asociaciones y asentamientos agrarios. Cabe destacar que, en la región estudiada, la realidad de los agricultores familiares no ha sido investigada en este contexto, lo que añade un valor significativo a este trabajo.

4. ANEXO: MATERIAL SUPLEMENTAR

1. **Table S1.** Interview

RESEARCH "Effects of Climate Change and Adaptation of Family Farming in Western Paraná, Brazil"

PART 1. ACTIVITIES CARRIED OUT ON THE PROPERTY

1. Mark all activities carried out on the property (No = 0 / Yes = 1)

1. Vegetable garden		6. Beekeeping		11. Other livestock (specify all)	
2. Orchard		7. Poultry farming		12. Family agribusiness	
3. Planting flowers		8. Pig farming		13. Tourism and recreation	
4. Planting for medicinal purposes		9. Goat farming			
5. Agroforestry		10. Cattle farming			

PART 2. LIMITATIONS AND DIFFICULTIES

2. The following question aims to assess the main difficulties listed by the farmer on their property. Respond by ranking from 1 to 5, from least to most important (where 1 = least important and 5 = most important), the following alternatives.

1. The main difficulties I encounter today in agricultural activity are:	1	2	3	4	5	6. Don't want to / I don't know how to answer / Does not apply
CI. Price of the products needed for production						
PP. Selling price of the products I produce						
AM. Access to markets						
APA. Access to policies supporting rural producers						
TT. Land ownership and property rights						
TP. Size of the property						
CFP. Physical conditions of the property (soil, terrain, water access)						
PC. Climate-related issues						
AT. Regular access to technical assistance						
MO. Labor forcé						
AVE. Access roads to the property and for product distribution						
IF. Financial instability						
UAPV. Use of pesticides on neighboring propertie						
MT. Machinery and appropriate technologies						

AFCR. Financial support and rural credit						

PART 3. PERCEPTION ABOUT THE CLIMATE

3.In this section, questions will be asked regarding how the farmer understands the climate in the region where they live and/or produce. Evaluate the following statements, indicating your level of agreement from 1 to 5, where 1 = strongly disagree, 2 = disagree somewhat, 3 = neutral, 4 = agree somewhat, 5 = strongly agree.

1. Over the past five years, I have noticed changes in climatic conditions in the region where I live regarding:	1	2	3	4	5	6. Don't want to / I don't know how to answer / Does not apply
RDL. Reduction in the number of rainy days						
AT. Increase in temperature						
AITG. Increase in the intensity and/or occurrence of storms or hail						
AIV. Increase in wind intensity						
AIEE. Increase in the intensity and/or occurrence of extreme events (e.g., frosts)						
DCL. Decrease in the amount of rainfall						
CIES. Change (delay or advancement) in the start of the dry season						
CIEL. Change (delay or advancement) in the start of the rainy season						

2. The changes listed in the previous question regarding the last five years have caused the following problems on my property:	1	2	3	4	5	6. Don't want to / I don't know how to answer / Does not apply
EA. Scarcity or lack of water						
DP. Decrease in production						
RC. Delay in harvest						
PC. Loss of part or all of the harvest						
AGAF. Increase in expenses for purchasing fertilizers						
AGAPH. Increase in expenses for purchasing pesticides or herbicide						
AP. Increase in problems caused by agricultural pests						
AE. Increase in problems caused by plant or animal diseases						

3. Have been using the following strategies to deal with the climate-related problems (that I mentioned in the previous question):	1	2	3	4	5	6. Don't want to / I don't know how to answer / Does not apply
I. Irrigation						
FO. Application of organic fertilizers						
FS. Application of synthetic fertilizers						
POH. Application of organic pesticides or herbicides						
PHS. Application of synthetic pesticides or herbicides						

MO. Use of organic matter for mulching or no-till farming						
CQS. Use of crops to improve soil quality						
MP. Pruning management						
SFEP. Planting flowers to stimulate pollination						
SUPAC. Use of climate-adapted seeds or plants						
SAOPN. Planting trees or other native plants						
CPA. Implementation of intercropping between plants and/or animals						
SA. Implementation of agroforestry systems						

PART 4. INTERVIEWEE PROFILE

The following are some questions about you and your property.

1. Name	
2. Property address (include neighborhood and municipality)	
3. Phone or other contact method	
4. CAR number (if available)	
5. Gender (F = female / M = male / O = other)	
6. Age	
7. Does your main family income come from activities on the property? (Y/N)	
8. Highest completed level of education: 1 = Incomplete elementary school / 2 = Elementary school / 3 = High school / 4 = Technical education / 5 = Higher education / 6 = Postgraduate education (any type)	
9. Number of years on the property	
10. Estimated size of the property (convert to hectares)	
11. Location (R = rural area / U = urban area)	
12. Place of residence: 1 = Production unit (PU) / 2 = Outside the PU	
13. Land title: 1 = Own title / 2 = Lease with contract / 3 = Informal agreement / 4 = Grant / 5 = Other	
14. Main purpose of production (1 = commercialization / 2 = self-consumption or family consumption)	
15. Number of people residing on the property	
16. Number of people who worked on the property in the last year	
17. Number of hired workers in the last year	
18. Producer's associations (check all that apply): 1 = Cooperative / 2 = Association / 3 = Union / 4 = Social movements / 5 = Consumer networks (e.g., CSA) / 6 = Other / 7 = Cooperative and association	
19. Services available on the property (indicate all that apply): 1 = Electricity / 2 = Phone or cellular signal / 3 = Internet / 4 = Basic sanitation / 5 = Drinking water supply / 6 = Health services / 7 = All of the above	

20. Water source for production (indicate all that apply): 1 = Public network / 2 = Spring, pond, river, or well on the property / 3 = Spring, pond, river, or well off the property / 4 = Rain / 5 = Other (specify)	

2. Principal Component Analysis (ACP)

Table. S2. Eigenvalues resulting from the PCA for Perception of climate change(A), climate change impacts (B), adaptation strategies (C) and constraints and difficulties (D).

A	**Perception**		**B**	**Impacts**	
Variable	CP1	CP2	Variable	CP1	CP2
RDL	0,31	-0,43	EA	0,39	0,01
AT	0,33	-0,44	DP	0,4	-0,37
AITG	0,36	-0,34	RC	0,34	-0,21
AIV	0,38	-0,17	PC	0,41	-0,12
AIEE	0,39	0,13	AGAF	0,3	0,54
DCL	0,37	0,35	AGAPH	0,17	0,71
CIES	0,35	0,36	AP	0,41	-0,01
CIEL	0,34	0,46	AE	0,34	-0,03
Lambda λ>1	4,78	1,03	Lambda λ>1	3,43	1,37
% Variance Cumulative	0,60	0,73	% Variance Cumulative	0,43	0,60
C	**Strategies**		**D**	**Limitations**	
Variable	CP1	CP2	Variable	CP1	CP2
I	0,19	0,26	CI	0,21	0,2
FO	0,24	0,43	PP	0,19	0,33
FS	-0,17	0,61	AM	0,4	0,15
POH	0,31	0,35	APA	0,2	0,33
PHS	-0,25	0,47	TT	0,31	-0,01
MO	0,28	-0,09	TP	0,37	-0,12
CQS	0,34	0,07	CFP	0,33	0,16
MP	0,33	0,02	PC	-0,25	0,34
SFEP	0,26	-0,08	AT	-0,05	0,32
SUPAC	0,28	-0,08	MO	-0,25	0,22
SAOPN	0,26	0,04	AVE	0,35	-0,27
CPA	0,35	-0,02	IF	0,34	0,04
SA	0,31	-0,02	UAPV	0,02	0,3
			MT	0,1	0,37
			AFCR	-0,06	0,33
Lambda λ>1	3,68	1,65	Lambda λ>1	3,37	2,79
% Variance Cumulative	0,28	0,41	% Variance Cumulative	0,22	0,41

3- Cluster Analysis

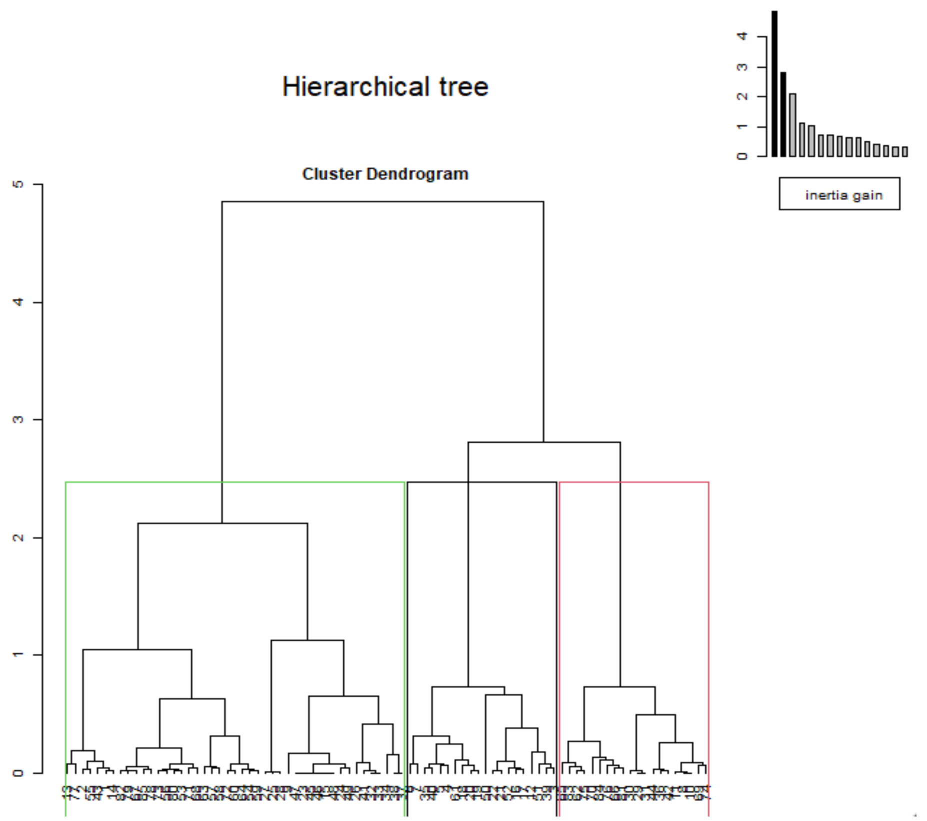

Fig. S1. Representation of the hierarchical tree by means of a dendrogram.

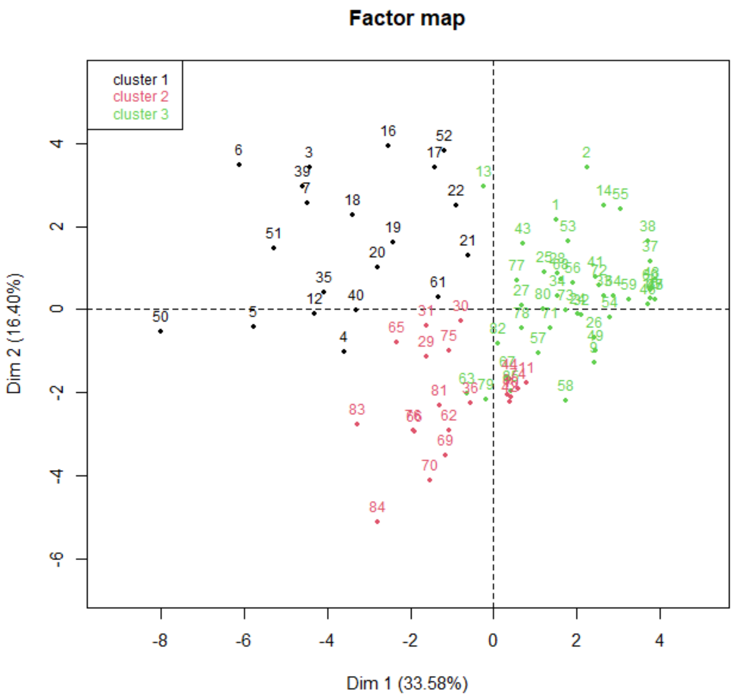

Fig. S2. Representation of the formation of three clusters by ascending hierarchical classification of individuals.

Table. S3. Results of v.test analysis, on the influence between the qualitative variables of the groups, resulting from Cluster 1, 2, 3 analysis.

Qualitative Variables						
Variables	**v.test**	**Mean in category**	**Overall mean**	**Sd in category**	**Overall sd**	**p.value**
Cluster 1						
LIMCP1	3.082	1.106	2.41	0.89	1.82	2.050
IMPCP.1	-2.276	-0.823	-3.71	1.52	1.839	2.279
ESTCP.1	-3.756	-1.409	5,18	1.317	1.90	1,72
PERCP.1	-7.911	-3.38	8,20	1.586	2.173	2.54
Cluster 2						
IMPCP.2	2.614	0.59	-2.20	1.10	1.63	8.941
IMPCP.1	-2.269	-0.82	-3.71	1.281	1.839	2.32
LIMCP.2	-2.749	-0.89	-3.44	1.224	1.659	5.97
LIMCP.1	-3.603	-1.29	2.41	1.696	1.824	3.14
ESTCP.1	-4.525	-1.69	5.18	0.92	1.907	6.039
Cluster 3						
ESTCP.1	7.037	1.38	5,18	1.284	1.907	1.95
PERCP.1	5.135	1.148	8,20	0.76	2.173	2.81
IMPCP.1	3.863	0.73	-3,71	1.870	1.839	1.122
LIMCP.2	3.613	0.61	3,44	1.767	1.659	3.032
IMPCP.2	-3.25	-0.390	-2,20	1.203	1.163	1.12

Table S4. Results of v.test analysis, on the influence between the quantitative variables of the groups, resulting from Cluster 1, 2, 3 analysis.

Quantitative Variables					
Variables	**Cla/Mod**	**Mod/Cla**	**Global**	**p.value**	**v.test**
Cluster 1					
Number of productive activities: More than 15	83.33	25	7,06	0.002481	3.025
Destination of production: Commercialization	30.158	95	74.11	0.011529	2.526
Ownership of the property: Own title	30.158	95	74.11	0.011529	2.526
Destination of production: Commercialization/ Consumption/Consumo	0.000	0	14.11	0.0306	-2.16
Age: Over 60	800.00	10	29.411	0.0276	-2.20
Land ownership: Concession	500.00	5	23.529	0.0215	2.29
Cluster 2					
Years of experience: Over 40	5.714	40	16.47	0.00353	2.916
Age: 18-29	0.000	0	15.29	0.022	-2.286
Property size: 1-3ha	1.333	30	52.94	0.0215	-2.290
Cluster 3					

Years of experience: 1-9	7.777	31.111	21.17	0.0019	2.341
Property size: 10-20ha	1.818	1.818	4.444	0.0164	-2.398
Years of experience: Over 40	2.142	6.666	1.647.059	0.0118	2.516

4- Photos taken on the farms of family farmers with respect to productive activities.

Fig. S3. Images captured at the farms of family farmers in Foz do Iguaçu, Missal and Cascavel. **(a, b)** Crop diversity in a family garden. **(c)** Irrigation system implemented in the family farms, which improves water use efficiency. **(d)** Fruit production, such as strawberries.

Fig. S4. Images captured in the farms of family farmers in Foz do Iguaçu Missal and Cascavel. **(a)** Composting of organic residues, used as fertilizer. **(b)** Use of shade nets in the farms, being a technique that protects crops from climate impact. **(c)** Tomato plantation, affected by recent droughts, reducing yield and fruit quality. **(d)** Implementation of hydroponic systems, a technique that improves crop growth**.**