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# Perceptions and adaptation to climate change among family farmers in western Paraná, Brazil

## Percepções e adaptação às mudanças climáticas entre agricultores familiares no oeste do Paraná, Brasil

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## 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. During visits to 85 rural properties, a structured questionnaire using a five-point Likert scale was administered to assess climate change impacts, response limitations, and mitigation strategies. Results were analyzed using Principal Component Analysis (PCA) and HCA. Farmers strongly perceived increased temperatures and reduced rainfall, which were associated with a higher incidence of agricultural pests and diseases, water scarcity, and increased production costs. The main adaptation strategies adopted included the use of organic matter for soil cover, irrigation, crop diversification, and organic fertilizers. Farmers were grouped into three clusters based on hierarchical cluster analysis using PCA indices, sociodemographic variables, and productive activities: (i) Diversification and Structural Limitations; (ii) Experience and Concerns about Productivity; and (iii) Sustainable Practices and Vulnerability to Resources. These groups presented distinct socioeconomic and productive characteristics, reflecting differences in vulnerability and adaptive capacity. Structural limitations, restricted access to financial resources, and limited technical assistance were common challenges among the groups. The findings reinforce the need for targeted public policies and technical support strategies to strengthen climate resilience in family farming systems.

**Keywords:** farmer; innovation; environmental perception; resilience; mitigation.

## RESUMO

As mudanças climáticas afetam a capacidade dos sistemas alimentares de fornecer nutrição adequada para 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 agricultores familiares da região oeste do Paraná, Brasil, perceberam os efeitos das mudanças climáticas sobre suas atividades produtivas e como responderam e se adaptaram a esses efeitos. Durante visitas a 85 propriedades rurais, foi aplicado um questionário estruturado utilizando escala Likert de cinco pontos para avaliar os impactos das mudanças climáticas, limitações de resposta e estratégias de mitigação adotadas. Os resultados foram analisados por meio de Análise de Componentes Principais (ACP) e análise de agrupamento hierárquico. Os agricultores perceberam fortemente o aumento das temperaturas e a redução das chuvas, associados ao aumento da incidência de pragas e doenças agrícolas, escassez de água e aumento dos custos de produção. As principais estratégias de adaptação adotadas incluíram o uso de matéria orgânica para cobertura do solo, irrigação, diversificação de cultivos e fertilizantes orgânicos. Os agricultores foram agrupados em três clusters com base na análise de agrupamento hierárquico utilizando índices da ACP, variáveis sociodemográficas e atividades produtivas: (i) Diversificação e Limitações Estruturais; (ii) Experiência e Preocupações com a Produtividade; e (iii) Práticas Sustentáveis e Vulnerabilidade aos Recursos. Esses grupos apresentaram características socioeconômicas e produtivas distintas, refletindo diferenças na vulnerabilidade e capacidade adaptativa. Limitações estruturais, acesso restrito a recursos financeiros e assistência técnica limitada foram desafios comuns entre os grupos. Os resultados reforçam a necessidade de políticas públicas direcionadas e estratégias de apoio técnico para fortalecer a resiliência climática nos sistemas de agricultura familiar.

**Palavras-chave:** agricultor; inovação; percepção ambiental; resiliência; mitigação.

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## 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 crop life cycles, plant growth rates, and soil water availability, as well as increased soil erosion. Indirect effects include the expansion of agricultural pests' distribution ranges, a higher probability of species invasions, an increased likelihood of wildfires, and longer, more intense droughts and floods, among others (Grimberg et al., 2018; Cheval et al., 2022).

Establishing adaptation strategies helps improve productivity, ensure access to water and food, and is crucial for reducing crop and other economic losses (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, diversifying, and adapting crop management (FAO, 2017). Adaptation can significantly reduce the economic and social costs associated with CC.

Research on CC provides information and methodological tools to improve natural resource management, foster innovative practices, and support decision-making (Brasil, 2021). In Brazil, national and regional policies that propose mitigation and adaptation strategies in different sectors are insufficient and receive few resources (Silva and Patrício, 2022). Recent studies also highlight that family farmers face structural, economic, and institutional limitations that hinder the implementation of climate adaptation strategies. In addition, the low integration between public policies, technical assistance, and sustainable rural development may increase the vulnerability of these farmers to extreme climatic events (Garcia and Buainain, 2024; Gonzalez et al., 2024). Appropriate and effective designs of policy interventions to support the resilience of family farming systems require understanding farmers' perceptions about the impact of CC on their productive activities and recognizing the adaptation strategies employed (Barokatuminalloh et al., 2021; Tesfaye et al., 2021; Gomm et al., 2024).

Studies show that perceptions of CC can vary among farmers depending on their age, gender, location of residence (rural-urban), access to technical assistance, property size, and education level (Lee et al., 2020; Schnegg et al., 2021; Cheval et al., 2022; Karki et al., 2022). On the other hand, farmers face resource limitations such as input shortages, poverty, limited access to water, and limited knowledge and information. Addressing these issues is crucial, as they pose significant barriers to adaptation (Williams et al., 2019; Barokatuminalloh et al., 2021). Understanding how local contexts and farming situations relate to perceptions of CC can help farmers better identify and choose appropriate adaptation strategies for their crops and systems (Lucero López et al., 2022).

CC perception is not limited to temperature and precipitation, since events such as heat waves, droughts, and irregular rainfall also significantly affect agriculture (Orimoloye et al., 2022; Gomm et al., 2024). Family farmers are often more vulnerable to these effects due to their strong dependence on climatic conditions and limited access to technical assistance and financial support. In Brazil, family farming is characterized by family-based management and labor, small properties, and family income linked to agricultural production, according to Law 11.326/2006 (Brasil, 2006).

Regarding the agricultural sector in western Paraná, Bianchini and Picinatto (2021) 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 and required different support from public policies, while few had infrastructure for the storage, processing, and distribution of products. The survival of family farming in the face of CC requires a constant search for productive resources and efficient organizations (Silva and Patrício, 2022).

In this work, we analyze how family farmers in the western region of the state of Paraná, Brazil, perceive the effects of CC 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 the resilience of family farming systems in the region.

## Methodology

### Study area

The study was conducted in the western region of Paraná, Brazil, specifically in the municipalities of Foz do Iguaçu, Missal, and Cascavel (Figure 1). The region is located on the third plateau of Paraná and covers an area of 22,851 km$^2$ (IBGE, 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 *Instituto Brasileiro de Geografia e Estatística* (IBGE) census, it comprises 50 municipalities (Ipardes, 2022).

The 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 (IBGE, 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 (Figure 1).

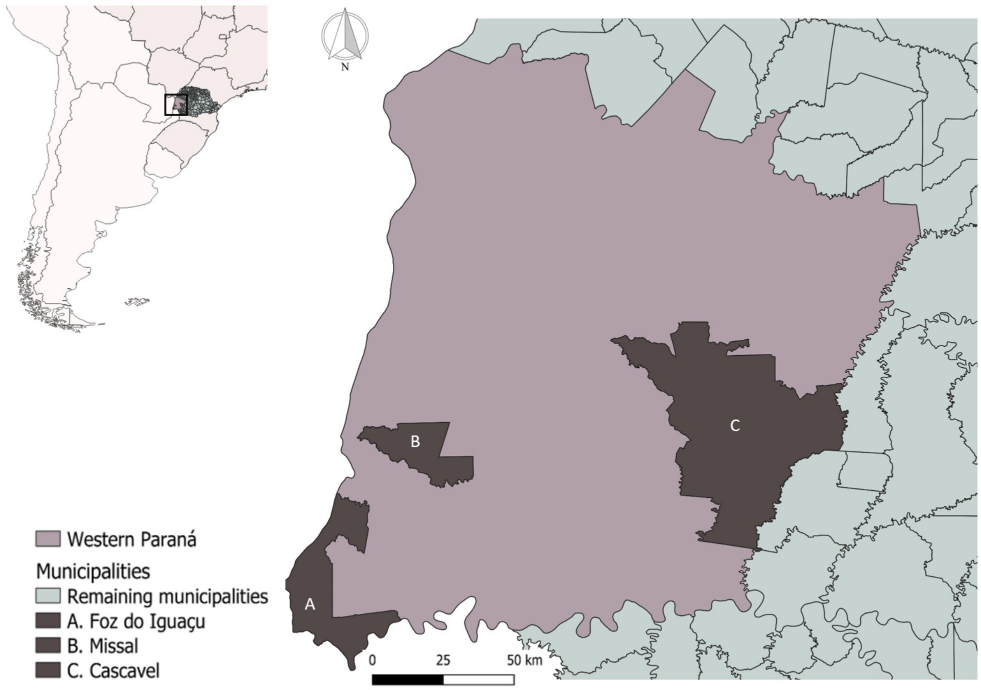


**Figure 1 – Location of the Study Area in the Western Region of Paraná, Brazil, encompassing the municipalities of Foz do Iguaçu, Missal, and Cascavel.**

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 (Dorner 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 (IBGE, 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.

In western Paraná, the municipalities of Foz do Iguaçu, Missal, and Cascavel present distinct agricultural profiles. Foz do Iguaçu combines urban areas with agricultural and livestock production, including grain production, fruit cultivation, and short-cycle crops. Missal stands out for dairy production and diversified family farming associated with cooperatives and agro-industries, while Cascavel is an important regional agricultural hub characterized by grain production and integrated poultry, swine, and cattle systems (IBGE, 2017, 2022a, 2022b; Gomes et al., 2020; Ipardes, 2022).

## Research design

To assess perceptions of CC among family farmers in the western region of Paraná, Brazil, a structured questionnaire was administered to individuals aged 18 or older, regardless of gender, who were active producers present at the production unit at the time of the interview. In each municipality, farmers were associated with a cooperative: the *Cooperativa da Agricultura Familiar de Foz do Iguaçu* (COAFFOZ) [Family Farming Cooperative of Foz do Iguaçu], Foz do Iguaçu, and the *Cooperativa de Produtores da Agricultura Familiar de Missal* (COOPER MISSAL) [Family Farming Producers Cooperative of 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 with COAFFOZ and COOPER MISSAL, respectively, while the Valmir Mota Settlement comprises 85 families, with land allotments ranging from 7 to 7.5 hectares per family.

The questionnaire was based on a quantitative approach, ensured anonymity, and used predefined questions or statements (Table 1). 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 respondents' attitudes and understanding regarding each statement (Dalmoro and Vieira, 2013). The questionnaire focused on activities carried out on the property, perceptions of CC, 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 1).

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. Before each interview, participants were informed about the Free and Informed Consent Form (TCLE), emphasizing that their participation was anonymous and voluntary, and that they had the option to provide or not provide any information requested in the questionnaire. Their informed consent was obtained verbally, confirming their agreement to participate in the interview. Participant anonymity and confidentiality were guaranteed throughout all stages of the research. No personally identifiable information was collected, and participation was voluntary, with the right to refuse or discontinue participation at any time. 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 conducted to the cooperatives and settlement to present the research, address questions, and schedule 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. To minimize selection bias associated with snowball sampling, participants were recruited through different entry points, including cooperatives, technical assistance agents, and settlement leaders from different municipalities. Despite these efforts, limitations related to non-probabilistic sampling may remain.

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 2).

## Data analysis

Preliminary dimensionality reduction analyses were conducted using Principal Component Analysis (PCA). 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 and Puhl, 2023). To facilitate statistical analysis, the variables were abbreviated using acronyms.

For this analysis, Likert-scale (semi-quantitative) variables representing farmers' perceptions of CC impacts were evaluated, along with variables of direct impacts on properties over the last five years and the strategies adopted to address them. We also considered contextual limitations of the production units. The variables and acronyms are detailed in Table 1. 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 PCA, 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 (HCA) 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) (Lê et al., 2008; Husson et al., 2016) (Figure 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.

**Table 1 – Structured questionnaire used to assess CC perceptions, impacts, adaptation strategies and limitations among family farmers 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 farmers 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 force | | | | | | |
| 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.** | |
| Name | |
| Property address (include neighborhood and municipality) | |
| Phone or other contact method | |
| CAR number (if available) | |
| Gender (F = female / M = male / O = other) | |
| Age | |
| Does your main family income come from activities on the property? (Y/N) | |
| 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) | |
| Number of years on the property | |
| Estimated size of the property (convert to hectares) | |
| Location (R = rural area / U = urban area) | |
| Place of residence: 1 = Production unit (PU) / 2 = Outside the PU | |
| Land title: 1 = Own title / 2 = Lease with contract / 3 = Informal agreement / 4 = Grant / 5 = Other | |
| Main purpose of production (1 = commercialization / 2 = self-consumption or family consumption) | |
| Number of people residing on the property | |

| | |
|---|---|
| Number of people who worked on the property in the last year | |
| Number of hired workers in the last year | |
| 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 | |
| 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 | |
| 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) | |

**Table 2 – 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 conducted** | | |
| 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% |

Hierarchical methods are widely used by ecologists for this type of data (Perelman and Puhl, 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 stems from their ability to generate optimal classifications according to internal proximity and separation between groups. Each group obtained from this technique is a representative group (paragons), meaning that groups are

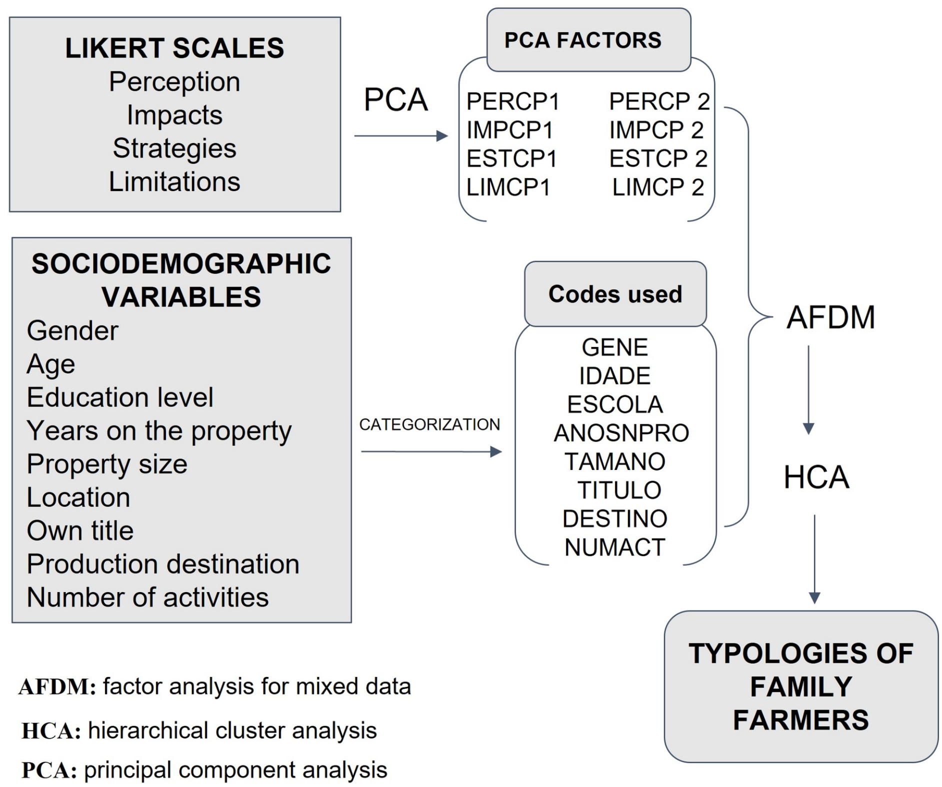


**Figure 2 – Flow chart for data processing and analysis. A PCA was applied to the data obtained from responses to statements evaluated according to a Likert scale to obtain factors (quantitative). From the sociodemographic profiles, a categorization (qualitative) was performed. By combining both data sets, an AFDM followed by HCA was carried out, resulting in the typology of family farmers.**

defined based on individuals who best represent the characterization. Larger groups present greater variation.

A V-test was conducted to assess the deviation between qualitative and quantitative variables, based on how they behaved within the groups. For qualitative variables, the observed and expected frequencies of each category within the group are calculated, while for quantitative variables, the group mean is compared to the general mean, adjusted for the standard deviation and sample size. Values greater than two with a positive sign (overrepresented category) or less than two (underrepresented category) were considered significant, with a p-value less than 5% ($p < 0.05$) (Lebart et al., 1995; Lê et al., 2008), indicating that the category or variable significantly characterizes the group. 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 clarifies the significance of the categories in the cluster analysis and identifies the individuals who best represent each group. It allows for a comparison between the emerging clusters and the general characteristics they share.

Statistical analyses were performed using the R programming language. For PCA, 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 (Lê et al., 2008; Husson et al., 2016).

## Results

### Perception of climate change

Most farmers perceived various effects of CC on their productive activities. 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%), and the increase in the intensity of winds (63%) (Figure 3a).

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%) (Figure 3b). To cope with the effects of CC, 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

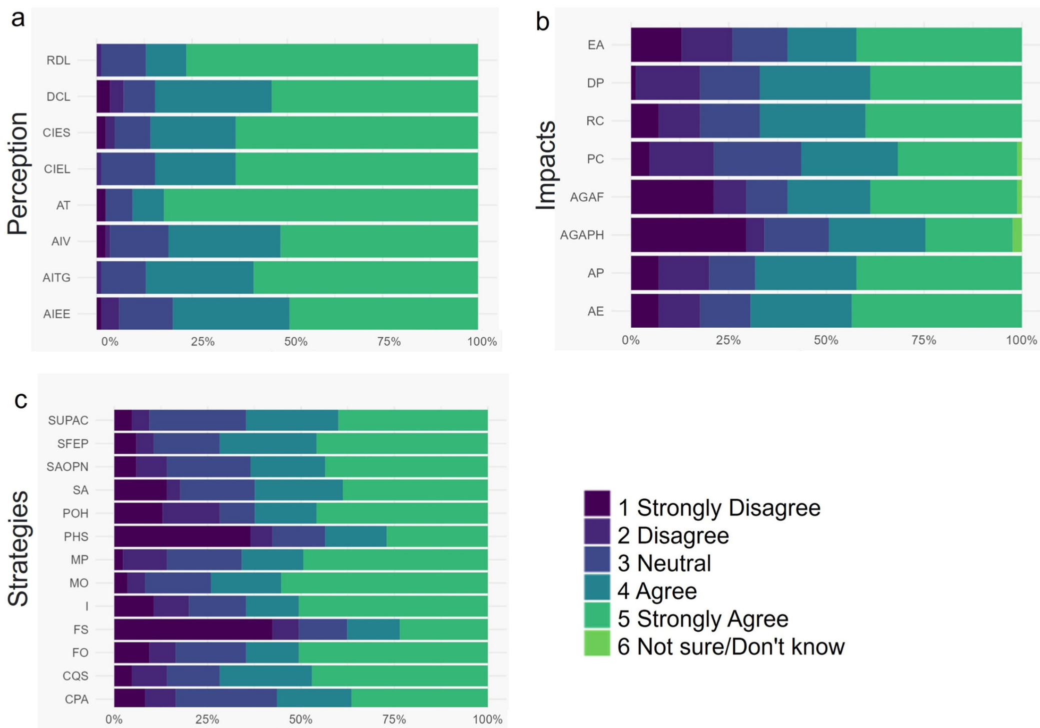


**Figure 3 – Effects of CC on family farming in western Paraná, Brazil. (a) Perception of CC; (b) Perceived impacts on the property during the last five years; (c) Strategies used to cope with the impacts caused on the property. Responses were evaluated according to a Likert scale. The acronym extensions are presented in Table 1.**

to stimulate crop pollination and the application of pesticides or herbicides (46%) (Figure 3c).

## Dimensionality reduction analysis

Regarding the PCA, for perception of CC (Figure 4a), the first component accounts for 59.7% of the explained variability, lambda $\lambda>1$ (4.78), and is related to the variables AIEE, AIV, DCL, AITG, and CIES, which refer 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), and is 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 a decrease in the amount of rain (Table 3A). These two components explain about 72% of the variability in the data.

For the perception of CC impacts (Figure 4b), the first component explained 42.8% of the variation in 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), and was related to the variables AGAPH and AGAF, which represent increased expenses with fertilizers, pesticides, and herbicides, and scarcity or lack of water (Table 3B). These two axes explained about 60% of the variability in the data.

Regarding the strategies used (Figure 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 3C). These two axes explained about 41% of the variability in the data.

For constraints and difficulties (Figure 4d), the first component 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

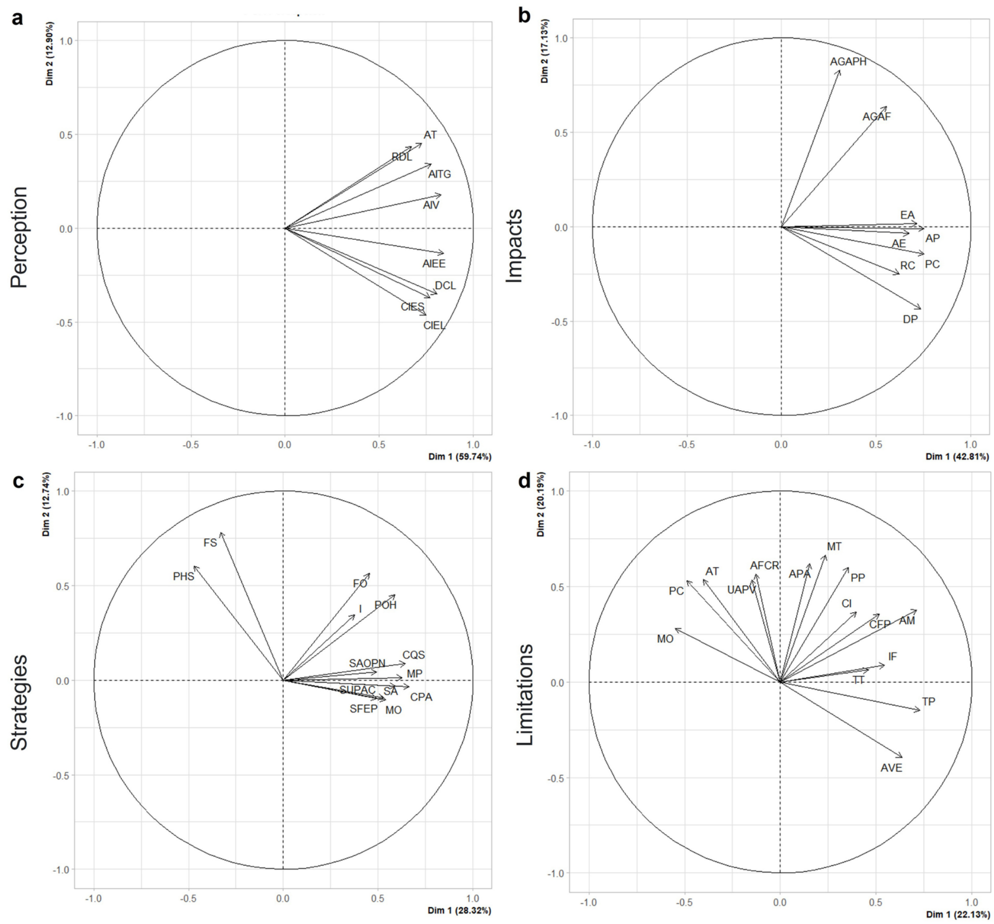


**Figure 4 – PCA: (a) Perception of CC; (b) CC impacts; (c) Adaptation strategies; (d) Constraints and difficulties. The axes show the eigenvalues of the first two axes that best represent each component. See Table 1 for a description of acronyms and Table 3 for the eigenvalues of each principal component.**

**Table 3 – Eigenvalues resulting from the PCA for Perception of CC (A), CC 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 |

tenure. On the other hand, the second component explained 20.1% of the variation in the data, lambda λ>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 3D). 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 (Figures 5 and 6). Each cluster is characterized by the individuals (farmers) who best represent it; larger groups exhibited greater variation.

The first cluster (hereafter, Diversification and Structural Limitation) was the most representative. In this group there was a male predominance and a wide age diversity, with individuals aged 25 to 62 years, 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 4), 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 respondents carried out more than 15 productive activities (Tables 5 and 6).

The second cluster (hereafter, Experience and Concerns about Productivity) comprised both male and female individuals aged 42 to 68 years, with educational levels ranging from incomplete to complete primary education and ownership experience ranging from 3 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 CC impacts, with high values for the variable IMPCP.2 (Table 4), 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 respondents had more than 40 years on the property (Tables 5 and 6).

The third cluster (hereafter, Sustainable Practices and Vulnerability to Resources) was mostly composed of men aged 26 to 62 years, with incomplete primary education and 5 to 20 years of farming experience, and landholdings ranging from 0.15 to 1 ha. They owned their land and carried out between 12 and 13 agricultural activities. The V-test analysis showed that the cluster was characterized by the variables ESTCP.1, PERCP.1, IMPCP.1 and LIMCP2 (Table 4). They stood out for adopting sustainable practices, such as service crops, planting flowers to stimulate pollination, plant-animal consortia, and diversification. They perceived changes in rainfall amounts 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 respondents had farming experience on the property ranging from one to nine years (Tables 5 and 6).

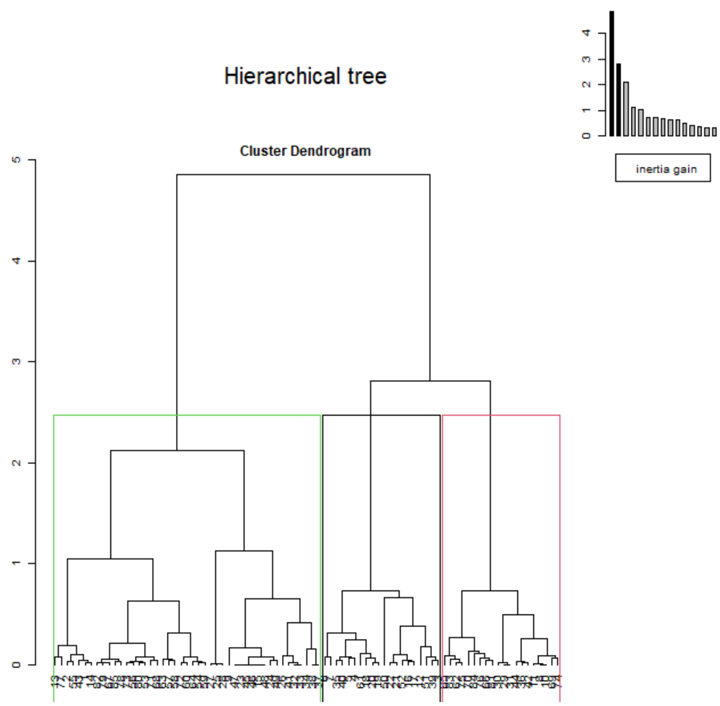


**Figure 5 – Representation of the hierarchical tree by means of a dendrogram.**

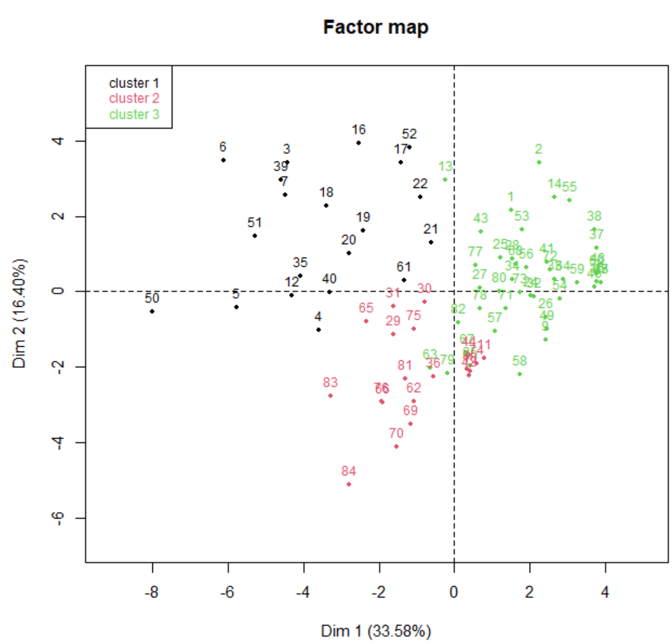


**Figure 6 – Representation of the formation of three clusters by ascending hierarchical classification of individuals.**

**Table 4 – 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 | -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 |

**Table 5 – Results of V-test analysis on the influence of the qualitative variables of the groups, resulting from Cluster 1, 2, and 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 6 – 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 | 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 |

## Discussion

Farmers in the western Paraná region perceived a wide range of climatic variations, including increased temperatures and shifts in dry and rainy seasons over the last five years, which can be associated with CC (Nicholls and Altieri, 2019; Cheval et al., 2022). The impacts of CC were felt in both the short and long term; for example, rising temperatures led to more frequent and intense heat waves, which directly affected agricultural production and food security (Fourment et al., 2020). Although farmers recognized the effects of CC, their decisions to adopt sustainable agricultural practices were limited by a lack of economic resources, financial support, and 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. These limitations are consistent with recent studies conducted in Brazil, which emphasize that family farmers often face institutional and socioeconomic barriers that reduce their adaptive capacity and increase vulnerability to CC. The lack of integration between public policies, rural extension services, and local adaptation demands remains a major challenge for strengthening climate resilience in family farming systems (Garcia and Buainain, 2024; Gonzalez et al., 2024).

The effects of CC vary by geographic region, influencing responses and strategies (Marshall et al., 2014). To better understand how family farmers in western Paraná perceive and adapt to CC, 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 CC. While some adaptation strategies were in place, structural constraints, limited access to resources, and vulnerability to extreme weather events were shared challenges. The Diversification and Structural Limitation 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 (Maia et al., 2018; Nicholls and Altieri, 2019).

In turn, the Experience and Concerns about Productivity cluster was primarily affected by the impacts of CC 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 Haruna, 2024), but a lack of access to financial and technological resources limits their ability to respond to extreme weather events (Burney et al., 2014; 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 CC, which in turn would reduce the likelihood of implementing adaptation measures (Hyland et al., 2016; Barokatuminalloh et al., 2021). According to Matos Carlos et al. (2020), there is a positive correlation between the adoption of adaptation practices and the perception of CC.

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 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 a lack of support can increase farmers' vulnerability to CC (Ali, 2015). Consequently, extreme weather events also affected labor availability, making it difficult for farmers to work the land or harvest their crops, which occasionally led them to seek off-farm labor opportunities to increase family income.

Among the support policies that can benefit the groups, 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 and 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, has been shown to increase agricultural productivity and mitigate CC impacts (Khan et al., 2021; Alhassan and Haruna, 2024). Diversification is manifested in various forms, such as integrating crops with animals and trees, and using low-input agroecological systems that minimize chemical fertilizer use and take 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 increased plant and animal diseases, pest problems, and a greater need for fertilizer, 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, including the Cooperativism Law, the COOPERA PARANÁ program, and the Technical Assistance and Rural Extension Law (ATER) (Silva and Patrício, 2022). However, barriers remain due to a lack of integration between public policies and projects designed to foster adaptation to CC (Milanés, 2021). In addition, the current technical assistance, i.e., the advice they receive, does not adequately address climate risk issues, focusing instead on production management. Adaptation strategies should also involve participatory and co-creation processes among farmers, cooperatives, technical assistance services, and local institutions to strengthen the long-term effectiveness of climate adaptation actions.

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 Limitation 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 about Productivity group, 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 Vulnerability to Resources 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 CC should be implemented. In addition, the creation of local seed banks with climate-adapted and disease-resistant varieties, together with economic incentives or market access for farmers who adopt agroecological practices, will significantly contribute to the sustainability and resilience of family farming.

## Conclusion

This work offers a comprehensive view of farmers' perceptions in the municipalities of Foz do Iguaçu, Missal, and Cascavel regarding CC, on-farm impacts, and adopted strategies. Understanding these perceptions is crucial for developing practical adaptive measures. Farmers report multiple responses, yet financial constraints and limited technical assistance strongly shape which sustainable practices are feasible. While innovative agricultural technologies can aid adaptation, they introduce management and sustainability challenges; adequate technical assistance and financial support are therefore pivotal to improve resource use and market access. Implementing sustainable practices, building agricultural systems that withstand extreme weather, and conserving and efficiently using resources are essential to ensure long-term agricultural viability and environmental protection. Our findings inform the design of policies and programs that strengthen climate resilience by promoting the adaptation of agricultural communities—especially in vulnerable regions—to sustainable practices. The results also underscore the need for relevant and substantial investments in agricultural development that consider yield variability, existing constraints, and household capacities to safeguard food security amid the global crisis.

The findings also highlight the importance of strengthening public policies focused on technical assistance, climate education, and financial support for family farmers, especially those with lower educational levels and greater structural vulnerabilities. Expanding access to rural extension services, participatory adaptation strategies, and locally tailored climate policies may contribute to improving the adaptive capacity and long-term resilience of family farming systems in western Paraná.

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