Climate Change and Ecosystem Services: A Participatory Approach in a Brazilian Mountainous Region

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Abstract

Climate change is present in all sectors of global societies, causing various damages, including to agriculture. In this process, understanding the perception of the most affected population and including them in decision-making is a matter of social justice and a more assertive path. Aiming to obtain subsidies for better adaptation to climate change in family farming, this study established a methodology for evaluating the risks of climate change impacts on ecosystem services, related to water and food security, under the perception of rural actors in the mountainous region of the Rio de Janeiro state, Brazil. The methodology consisted of five steps, including the application of the questionnaire to 29 rural actors and ending with validation of the results in a focus group. The main results obtained were that the interviewees perceive the risks of the impacts of climate change in ES, both related to water and food security. Additionally, 24.14% of interviewees mentioned that their family has a monthly income below the Brazilian minimum wage, which exposes their food insecurity. In relation to water security, the risks classified as Very High were mainly in relation to low per capita investments in adaptation policies and infrastructure for environmental protection, between others. The use of many chemical inputs in agriculture also highlighted as a risk to water and food security. Regarding the methodology, it concluded that it was effective in obtaining the perception of the rural actors interviewed regarding the impacts of climate change on ecosystem services at a local scale.

Keywords: adaptation, impact risk, security, family farming, agriculture, indicators

1. Introduction

Climate change is a growing global threat to biodiversity, ecosystems, and people. Climate change affects individuals and the way they interact, which alters the structure and function of ecosystems and the goods and services that natural systems provide to humanity (Díaz et al., 2019). As the world's climate continues to change, nearly every person on the planet will be impacted by the repercussions. About 85% of the world's population is already being affected by human-driven climate change (Callaghan et al., 2021). Understanding the direction and magnitude of ecological responses allows human communities to better anticipate these changes and adapt as necessary.

Along this path, we must listen to and understand the perception of those affected, including them in decision-making. Stakeholder perceptions can reveal essential support for policymakers (Milcu et al., 2014; Zepharovich et al., 2020). Assessing the perceptions of rural actors related to ecosystem services (ES) can allow us to uncover the reasons for land-use decisions (Córdoba & Zepharovich, 2022).

In Brazil, family farming defined as agriculture developed on rural properties of a size compatible with the management of the property and the labor employed, essentially, from the family nucleus (Brazil, 2006). Family farming is an agricultural sector extremely vulnerable to climate change (IPCC, 2014; Garajeh et al., 2023).

Vulnerability refers to the reduction of sensitivity and adaptive capacity to maintain the essential function, identity and structure of communities, as well as their capacity for transformation (IPCC, 2021). Adaptive capacity refers to a system's ability to adjust to climate change, reducing potential damage or disasters and improving the possibilities of dealing with the consequences (IPCC, 2019). Agricultural production from family farming depends directly on the climate (Tanure et al., 2023) and the quality of ES.

The family farming way of production also related to the provision of various ecosystem services, with emphasis on food and water. In Brazil, the number of rural establishments related to family farming accounts for 76.8%, occupying only 23% of the total area dedicated to agriculture. On the other hand, they are responsible for 30% of the food production that reaches the table of the population as a whole (IBGE, 2020). Even though structural inequalities associated with the Brazilian territorial and social formation process persist, we observe that Brazilian family farming presents a diversity and an economic and social dynamism that still scarcely analyzed by academia and recognized by public policies (Wanderley, 2017).

The definition of ecosystem services (ES) was proposed by authors such as Costanza et al. (1997), De Groot et al. (2002), Millennium Ecosystem Assessment (MEA, 2005) and Haines-Young and Potschin (2018), differing in some aspects, but all agreeing that ES are the benefits that human beings obtain, directly or indirectly, from ecosystems. The concept of ES has become an important tool for the analysis of environmental issues, linking the role of ecosystems and human well-being (Balvanera & Cotler, 2007).

Palomo (2017) when studying the effects of climate change on ecosystem services in high mountain areas pointed that these areas profoundly affected by climate change. Research on this issue has mainly focused on biophysical aspects, rather than social aspects such as impacts on stakeholders. The study showed that, while most research focuses on northern countries, there is an urgent need to increase the number of studies in southern regions, especially in tropical countries, such as Brazil. The diversity and magnitude of the impacts of climate change highlights the need to monitor ecosystem services in high mountain areas and to increase the adaptation options for local communities and tourists. The study area of this paper inserted in this context.

Ecosystems are rapidly changing in response to climate change and other global change drivers, in not only response to temperature changes but also associated changes in precipitation, atmospheric carbon dioxide concentration, water balance, ocean chemistry, and the frequency and magnitude of extreme events (IPCC, 2023). Changes in natural ecosystems threaten biodiversity worldwide and have implications for global food production and security (Malhi et al., 2020).

Therefore, climate change implies low soil fertility, high salinity and an increase in diseases and pests in agricultural crops (IPCC, 2018; World Bank, 2018). Especially extreme climate events (ECEs) can impact water availability and quality, groundwater supply, crop irrigation, heat stress in herds, displacement of plantations, phytosanitary status of crops and pollinators, agricultural land and infrastructure losses, and ecosystem services related to agricultural production (Asmus et al., 2019). This can compromise food and water security.

The efficiency of the adaptation process in response to climate change occurs within a regional context, in which climate impacts have different local effects and have specific and heterogeneous needs. Meeting these needs in local contexts when facing climate impacts depends on the actions of various government levels in the adaptation process and the effectiveness of decision-making in terms of infrastructure, information, and public policies (IPCC, 2021).

The Information and Analysis System on Climate Change Impacts (AdaptaBrasil MCTI Platform) established by the Brazilian Ministry of Science, Technology, and Innovations (MCTI), through Ordinance no. 3,896, of October 16, 2020. It aims to consolidate, integrate and disseminate information that help advance analyzes of the impacts of climate change, observed and projected in the national territory, providing support to the competent authorities for adaptation efforts. On this platform, the risk of climate impacts analyzed based on indices and indicators under a socio-ecological systemic logic (Biggs et al., 2021). It is a concept whose understanding considers that human and natural systems intertwined, in an interconnected and interdependent way, divided into five dimensions: water resources, food security, energy security, port infrastructure and health (AdaptaBrasil MCTI Platform, 2024). The AdaptaBrasil MCTI Platform has a glossary that can be consulted online, which defines several terms related to this research, including Impact risk, which is defined as the result of the interaction between climate threats, the exposure of socio-ecological systems to them and the vulnerability of these systems. Risk concerns the consequences that may occur in a given exposed environment and how uncertain the outcome is. Due to the

multidisciplinary nature of the impacts, the impact risk assessment methodology not only considers climate-related variables, but also the structural deficits that vulnerability itself forms, such as, for example, aspects related to education, health, housing, access public policies, etc.

Aiming to obtain subsidies for better adaptation to climate change in family farming, this study established a methodology for evaluating the impact risks of climate change on ecosystem services, through indicators from the AdaptaBrasil MCTI Platform, related to water and food security, under the perception of rural actors in the mountainous region of the Rio de Janeiro state, Brazil.

2. Method

2.1 Study area

The rural micro basin of Barracão dos Mendes is located in the municipality of Nova Friburgo, in the mountainous region of Rio de Janeiro, between the geographical coordinates 22º19'45" and 22º23'45" South Latitude and 42º35'05" and 42º40'10" West Longitude (Mata, 2006). The area belongs to the sub-basin of the upper reaches of the Rio Grande watershed, a hydrographic region in which the Rio Dois Rios Watershed Committee operates. Figure 1 shows the location of the communities in the rural micro basin of Barracão dos Mendes in the municipality of Nova Friburgo, mountainous region of the Rio de Janeiro State, Brazil.

The rural micro basin of Barracão dos Mendes was one of the areas intensely affected by the extreme climate event (ECE) that occurred in 2011 in the mountainous region of the state of Rio de Janeiro. The proportion of the disaster was associated with land use and occupation, the high slopes present in the region, as well as previous rainfall and erosion processes. The agricultural sector was one of the most affected, with losses and damage estimated at R$214 million. Around 2,800 hectares of land were degraded in the seven municipalities affected and 2,096 hectares of crops or pastures were affected (World Bank, 2012). In the rural micro basin of Barracão dos Mendes, family farming in the conventional agricultural system is predominant, aimed at producing fruit, agro-industry and olericulture, and is one of the main producers in supplying the state of Rio de Janeiro (SEAPEC, 2011).
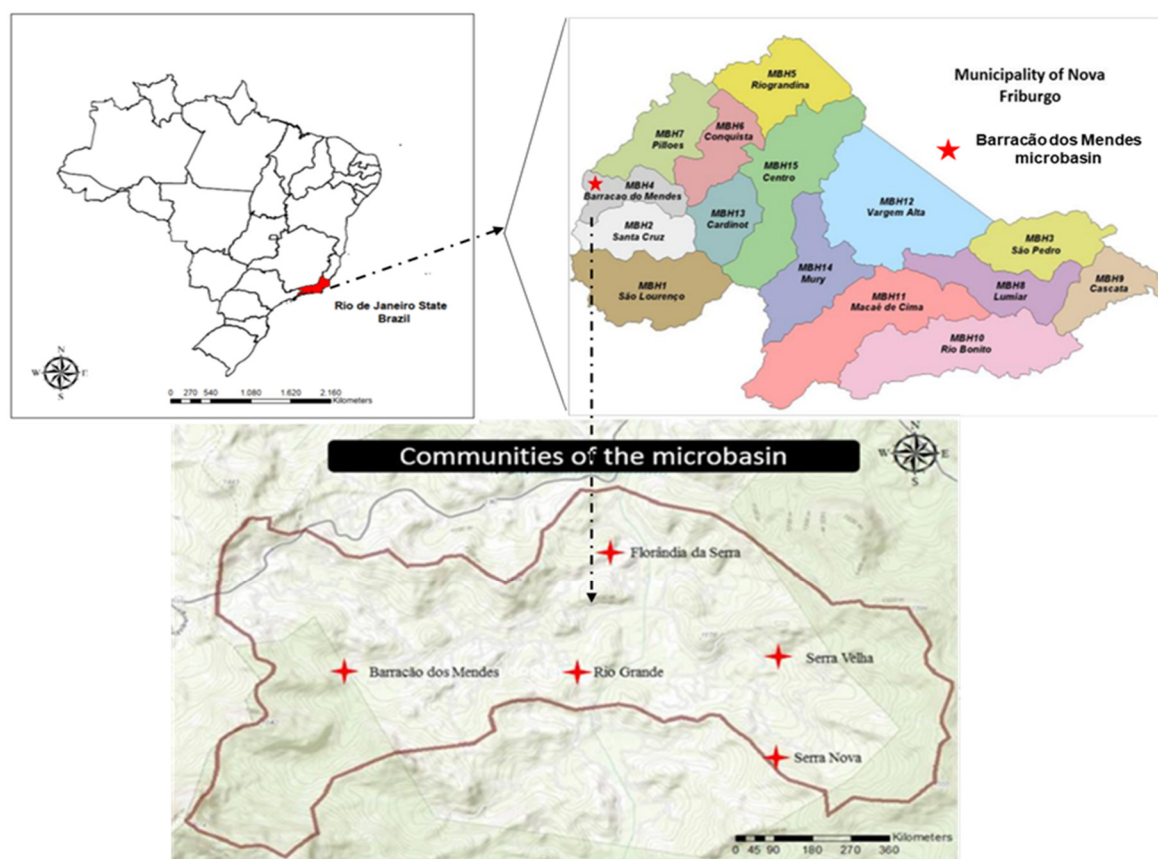

Figure 1. Location of the communities in the rural micro basin of Barracão dos Mendes in the Nova Friburgo municipality, mountainous region of the Rio de Janeiro State, Brazil

Source: Modified from Segovia-Sánchez, 2014.

2.2 Data collection, processing, and analysis

The methodology consisted of five steps, summarized in the Figure 2, with the stages described below.

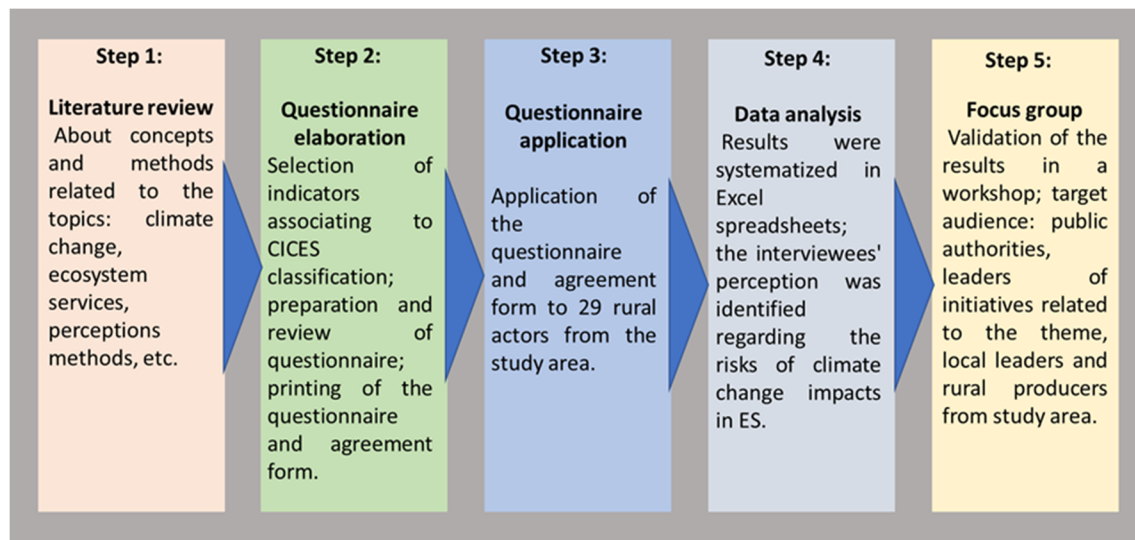| Step 1:	Step 2:	Step 3:	Step 4:	Step 5:
Literature review About concepts and methods related to the topics: climate change, ecosystem services, perceptions methods, etc.	**Questionnaire elaboration** Selection of indicators associating to CICES classification; preparation and review of questionnaire; printing of the questionnaire and agreement form.	**Questionnaire application** Application of the questionnaire and agreement form to 29 rural actors from the study area.	**Data analysis** Results were systematized in Excel spreadsheets; the interviewees' perception was identified regarding the risks of climate change impacts in ES.	**Focus group** Validation of the results in a workshop; target audience: public authorities, leaders of initiatives related to the theme, local leaders and rural producers from study area.

Figure 2. Summary of the methodological steps

In the first step, a literature review carried out, looking for similar studies that could feed into this study, both in conceptual and methodological terms.

The second step consisted of drawing up the questionnaire used in the semi-structured interviews, based on the methods of Panigassi (2005), Rangel and Nauditt (2017), with the aim of identifying the perception of rural actors about the risks of climate change impacts on ecosystem services (ES), in a mountain region of the state of Rio de Janeiro - Brazil. The format of the questionnaire can be found in Supplementary Material - SM1. The questions in the questionnaire related to the water and food security indicators at level 6 (indicators at municipal level) of the semi-arid and 1.0 versions of the AdaptaBrasil MCTI Platform (2022).

The questions in the questionnaire related to the water and food security indicators at level 6 (indicators at municipal level) of the semi-arid and 1.0 versions of the AdaptaBrasil MCTI Platform (2022).

For the methodology developed, we first selected the climate change impact risk indicators from the AdaptaBrasil MCTI Platform (2022) related to water and food security.

Once the indicators had been selected, they were associated with the ecosystem services (ES) groups in the Common International Classification of Ecosystem Services (CICES) table, version 5.1 (Haines-Young & Potschin, 2018). Leaving only those indicators which could be associated with ES groups, these implemented in the questionnaire.

Also at this stage, an agreement to participate in the survey drawn up, as well as an acknowledgement that the data would be processed and published in aggregate form, without identifying the respondents. The interviewees signed this form before the interviews.

In the third stage, before the questionnaire applied, a survey of potential actors to answer the questionnaire, including rural producers and local leaders in the areas of agriculture and the environment, carried out. The questionnaire administered between March 21 and 25, 2022, to local actors in the rural micro basin of Barracão dos Mendes, located in the mountain region of Rio de Janeiro, in the municipality of Nova Friburgo. A total of 29 producers of varying ages were interviewed. The questionnaires administered by the project team, which comprises a multidisciplinary team with members from research institutions, rural extension and civil society.

In the fourth stage, the results of the questionnaires systematized in Excel spreadsheets to identify the interviewees' perceptions of the risks of climate change impacts on ES, with an emphasis on water and food security. According to the Food and Agriculture Organization of the United Nations (FAO, 2022), food security is understood as the nutritional quality and quantity of individuals and the maintenance of food production in a permanent and sustainable manner. The accepted definition of water security is that of the United Nations Organization/United Nations Development Program (UN & UNDP, 2014). Water security is the ability of the population to have access to water in adequate quantity and quality, enabling human well-being and the maintenance of life, guaranteeing

the development of economic activities, protection against water-borne diseases and hydrological disasters, and the preservation of ecosystems.

The analysis of the results grouped by water and food security. For the analysis of the interviewees' responses, we considered the percentage of frequency of responses (among the multiple options offered for each question) (Brazil, 2018) in relation to the questions previously associated with the AdaptaBrasil MCTI Platform (2021) indicators. This done in order to generate the perception in general terms of the indicator, considering the negative impact of risk (Silva, 2018). The same classification and colors of the AdaptaBrasil MCTI Platform (2024) used to assess the impact risks for each indicator analyzed, according to the perception of the interviewees: *Very Low*, *Low*, *Medium*, *High* and *Very High* and Not Perceived (which applied to questions unanswered by most respondents) (Figure 2). Some questions in the questionnaire analyzed together, making the classification of indicators more precise.

| Very Low (0 to 10%) |
| Low (11 to 30%) |
| Medium (31 to 50%) |
| High (51 to 70%) |
| Very High (71 to 100%) |
| Not perceived |

Figure 3. Classification of the perception of impact risk according to the methodology of the AdaptaBrasil MCTI Platform (2024), of respondents' answers

The last and fifth stage consisted of validating the results in a focus group that took place at the 1st Sustainable Cities Project - CNPq Workshop, held in Nova Friburgo on June 14, 2022. The target audience were representatives of public authorities, leaders of initiatives related to the project's theme, and local leaders and rural producers from the Barracão dos Mendes micro basin. With the feedback on the results provided to the decision-makers and the rural interviewees, the results validated and suggestions on how to present them incorporated into the study, summarized in Figure 3 and described below.

3. Results

3.1 Interviewee Profilet

The profile of the rural actors interviewed can be seen in Table 1.

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3.2 Association of the AdaptaBrasil MCTI Indicators with the Groups of ES of the International Classification of Ecosystem Services (CICES) and the Perception of Impact Risk of the People Interviewed in the Barracão Dos Mendes Micro Basin

Based on the indices and indicators of the Semi-Arid version and version 1.0 of the Adapta Brasil-MCTI Platform, 14 indicators for water security associated with the Ecosystem Services (ES) groups of the Common International Classification of Ecosystem Services (CICES) selected. Table 2 shows the result of the association of the water security indicators selected and the result of the perception of the risk of impact of the people interviewed in the rural micro basin of Barracão dos Mendes.

Based on the indices and indicators of the Semi-Arid version and version 1.0 of the Adapta Brasil-MCTI Platform, 21 indicators selected for food security associated with the Ecosystem Services (ES) groups of the Common International Classification of Ecosystem Services (CICES). Table 3 shows the result of the association of the food security indicators selected and the result of the perception of the risk of impact of the people interviewed in the rural micro basin of Barracão dos Mendes.

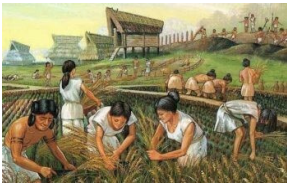Table 1. Profile of the interviewed rural actors

Characteristic		Class	Percentage
Gender		Female	51.72%
		Male	44.83%
		No answer	3.45%
Age group		20 to 30	24.14%
		31 to 40	20.69%
		41 to 50	20.69%
		51 to 60	10.34%
		More than 60	24.14%
Years of farming act		1 to 10	10.35%
		11 to 20	10.34%
		21 to 30	17.24%
		More than 30	58.62%
		No answer	3.45%
Type os agricultural system		Conventional	96.55%
		Conventional to agroecological transition	3.45%
Land situation		Owner	75.86%
		Renter	10.34%
		Settlement	10.34%
		Lending	3.45%
		Others	4.5%
Family income in minimum wages		0 to 1/2	17.24%
		1/2 to 1	6.9%
		2 to 3	62.07%
		4 to 5	10.34%
		No answer	3.45%

Table 2. AdaptaBrasil MCTI indices and indicators associated with the international classification of ecosystem services (CICES) and perception of impact risk obtained from interviewees in Barracão dos Mendes micro basin in percentage (%) – water safety

Indices	Indicators	Ecosystem Services Group	Very Low	Low	Medium	High	Very High	Not perceived
Sensitivity Index	Water unavailability	Surface water used for nutrition, materials or energy		20.0%				
	Population not served by water supply system	Surface water used for nutrition, materials or energy					96.0%	
	Occurrence of diseases related to inadequate environmental sanitation	Pest and disease control		27.5%				
	Water quality for multiple uses	Water conditions	3.4%					
Adaptive Capacity Index	Level of involvement in basin committees	Surface water used for nutrition, materials or energy			37.9%			
	Level of implementation and articulation of the municipal basic sanitation plan	Surface water used for nutrition, materials or energy					100.0%	
	Per capita investment in adaptation policies and infrastructure for environmental protection	Regulation of baseline flows and extreme events					93.0%	
	Alternatives to water supply	Surface water used for nutrition, materials or energy	4.0%					
	Storing and reserving water	Surface water used for nutrition, materials or energy				51.7%		
	Water resource management plans	Surface water used for nutrition, materials or energy					76.0%	
Exposure Index	Vegetation Cover in Permanent Preservation Areas	Regulation of baseline flows and extreme events		13.7%				
	Areas with steep slopes, no cover	Regulation of baseline flows and extreme events		21.0%				
Climate Threat Index	Consecutive dry days	Regulation of baseline flows and extreme events			45.0%			
	Consecutive days of rain	Regulation of baseline flows and extreme events			41.3%			

Table 3. AdaptaBrasil MCTI indices and indicators associate with the international classification of ecosystem services (CICES) and perception of impact risk obtained from interviewees in Barracão dos Mendes micro basin in percentage (%) – food security

Indices	Food security impact indicators		Impact Risk Perception					
	Indicators	Ecosystem Services Group	Very Low	Low	Medium	High	Very High	Not perceived
Sensitivity Index	Low production of basic foods	Cultivated terrestrial plants for nutrition, materials or energy					86.0%	
	No diversification of local production	Cultivated terrestrial plants for nutrition, materials or energy/ Reared animals for nutrition, materials or energy					100.0%	
	Agriculture without sustainable farming practices	Regulation of soil quality	3.4%					
	Dependence on large-scale irrigation	Surface water used for nutrition, materials or energy					96.1%	
	Level of food and nutritional insecurity	Cultivated terrestrial plants for nutrition, materials or energy		31.0%				
	Use of agrotoxics	Cultivated terrestrial plants for nutrition, materials or energy					75.8%	
	Livestock stocking rate	Regulation of soil quality						100.0%
Adaptive Capacity Index	Population accessibility	Cultivated terrestrial plants for nutrition, materials or energy / Reared animals for nutrition, materials or energy		20.0%				
	Food safety planning and management tools	Cultivated terrestrial plants for nutrition, materials or energy		20.0%				
	Per capita investment in adaptation policies and infrastructure for environmental protection	Regulation of baseline flows and extreme events					93.0%	
	Scope of the National School Feeding Programme	Cultivated terrestrial plants for nutrition, materials or energy / Reared animals for nutrition, materials or energy				65.5%		
	Scope and diversity of the National Programme to Strengthen Family Farming	Cultivated terrestrial plants for nutrition, materials or energy / Reared animals for nutrition, materials or energy				68.6%		
	Level of service to the population of the units receiving the Food Acquisition Programme	Cultivated terrestrial plants for nutrition, materials or energy / Reared animals for nutrition, materials or energy				65.5%		
	Agricultural productivity for staple foods	Cultivated terrestrial plants for nutrition, materials or energy				69.0%		
	Level of technical guidance	Cultivated terrestrial plants for nutrition, materials or energy / Reared animals for nutrition, materials or energy		13.8%				

Exposure Index	Agriculture and livestock farming in degraded pastures	Regulation of soil quality		100.0%
	Agricultural and livestock areas with low agricultural potential	Cultivated terrestrial plants for nutrition, materials or energy	24.0%	
	Bioclimatic risk zones for food crops	Cultivated terrestrial plants for nutrition, materials or energy		55.0%
	Vegetation Cover in Permanent Preservation Areas	Regulation of baseline flows and extreme events	13.7%	
Climate Threat Index	Consecutive dry days	Regulation of baseline flows and extreme events		45.0%
	Consecutive days of rain	Regulation of baseline flows and extreme events		41.3%

3.3 Risk Indicators for the Impact of Climate Change on Ecosystem Services as Perceived by the Interviewees

3.3.1 Water Security - Rural Micro Basin of Barracão dos Mendes

When assessing the risk of negative impacts related to climate change from the point of view of rural actors in Barracão dos Mendes, based on the indicators of the AdaptaBrasil MCTI Platform, in relation to water security, the most perceived indicator was 'Population not served by water supply system'. Therefore, the ES with the greatest risk of negative impacts from climate change in the perception of the interviewees are "Surface water used for nutrition, materials or energy", which refers to the ES section of water supply conferred by the hydrological cycles arising from the geophysical processes of the ecosystem (Haines-Young & Potschin-Young, 2018).

The indicator least perceived by respondents in relation to the negative risk impacts of climate change was 'Water quality for multiple uses', associated with the SE section on regulating the chemical, physical and biological conditions of water resources by ecosystem processes that influence water quality (Haines-Young & Potschin-Young, 2018).

3.3.2 Food Security - Rural Micro Basin of Barracão dos Mendes

The impact of risks related to climate change on the perception of rural actors in Barraco dos Mendes based on indicators from the AdaptaBrasil MCTI Platform. The perception of risks and the groups of ecosystem services (CICES) for food security identified. The indicator most perceived by the interviewees was 'No diversification of local production'. The indicator associated with the grouping of ES "Cultivated terrestrial plants for nutrition, materials or energy/ Reared animals for nutrition, materials or energy" is incorporated into the section on supply ES. It is understood as an ES provided by the quality of the ecosystem, in edaphic, biological and hydrological processes, and by the human contribution necessary for agricultural and livestock production, which is a complementary and inextricable relationship (Haines-Young & Potschin-Young, 2018).

The indicator least perceived by respondents in relation to the risk of negative impacts from climate change was 'Agriculture without sustainable farming practices', associated with the SE group "Regulation of soil quality" in the regulation section. It refers to the soil's capacity for food production, which depends on its physical, chemical and biological conditions (Haines-Young & Potschin-Young, 2018).

The indicators 'Low production of basic foods' and 'Agricultural productivity for staple foods' refer to basic foods that are agricultural crops such as rice, beans, cassava, wheat and milk, considering their presence in the basic diet in Brazil.

4. Discussion

4.1 Profile of Those Interviewed in the Barracão dos Mendes Rural Micro Basin

In the profile of the interviewees, the difference, the non-significant difference between men and women, demonstrates an increase in the participation of women in agricultural production in Nova Friburgo municipality. According to data from the Brazilian Agricultural Census, there has been an increase in the participation of women in the agricultural sector nationwide (IBGE, 2017).

The distribution by age group of the producers interviewed was uniform, with a slight predominance in the 20 to 30 and over 60 age groups. It is worth noting that the Instituto Bélgica - Nova Friburgo (IBELGA) adopts the pedagogy of alternation for teaching and technical training in agriculture for the sons and daughters of producers related to family farming. On the other hand, older people in rural areas observed throughout Brazil. Data from

the 2017 Agricultural Census shows a higher concentration of family farmers aged over 55 (IBGE, 2017).

In terms of land ownership, most of the producers interviewed own their land and farm using the conventional system, with extensive use of inputs such as fertilizers, pesticides and fertilizers (Table 1). The results reinforce the scenario of family farmers in Brazil, where 81.0% own their land (IBGE, 2017). According to Araújo et al. (2007), with regard to the type of production system, the intensive use of inputs in conventional systems in the Mountain region of Rio de Janeiro has generally compromised ecosystem services.

With regard to the interviewees' family income, the majority reported an income of one or a few minimum wages (Table 1). The average salary for formal workers in Nova Friburgo is 1.8 minimum wages, or R$2,160.40 (IBGE, 2021). However, the most alarming thing was that 24.14% of the interviewees mentioned that their family had a monthly income of less than the minimum wage. This information further highlights the risk associated with these people's food security, mainly due to limited resources to invest in diversified foods with high nutritional quality.

4.2 Classification of Interviewees' Perception of the Risk of Climate Change Impacting on Ecosystem Services (Water and Food Security)

4.2.1 Water Security Indicators

Regarding water security, the indicators considered by the interviewees to be a *Very High* impact risk generally concern the lack of public policies aimed at adaptation and infrastructure in the face of climate change, as well as the lack of basic sanitation in the communities. The interviewees indicated an absence of actions related to water resource management in the micro basin to which they belong.

Most of the interviewees reported that their water comes from springs or shallow wells, and that its distribution is a private solution rather than a supply from a public supply network. This indicates the precariousness of the water infrastructure supplying rural producers. Pfeil (2014) identified that there was no public water supply in this rural micro basin, with the population supplied by springs and tube wells, corroborating the results of this research.

The only indicator associated with the *High* class was "Water storage and reservoir". This result may be associated with the high demand for water for irrigation, which widely used in the region and based on inefficient systems, such as sprinkling, used by 70% of respondents, related to the ES group "Surface water used for nutrition, materials or energy". The study by Antonio (2022) presents results that corroborate the results found here.

The indicators "Level of involvement in basin committees" related to the ES group "Surface water used for nutrition, materials or energy" were classified as *Medium* risk (Table 2). Representatives of the Rio Dois Rios Basin Committee selected the Barracão dos Mendes micro basin to implement the Mananciais project, which provides for an investment program in Environmental Services for the Conservation and Recovery of Watersheds. In this way, local farmers identified the main demands of the Barracão dos Mendes micro basin, which include, of particular note, the implementation of the Production Zone (micro-sprinkler or drip irrigation, as well as Agroforestry Systems (SAF) in production zones) and Permanent Preservation Areas (APPs) in Riparian Zones (fencing of springs and total planting of riparian forest). The study by Zabala et al. (2021) presents results that corroborate the results found here.

"Consecutive rainy days; Consecutive dry days", were related to the ecosystem services groups of and "Regulation of baseline flows and extreme events". The interviewees related these indicators to the impact of risk *Medium* demonstrates that these have perceived climate change, in the Nova Friburgo municipality in the rural micro basin of Barracão dos Mendes.

In the *Low* risk class, the interviewees associated the indicators "Areas with steep slopes, without cover" and "Vegetation cover in Permanent Preservation Areas (PPAs)", related to the physiographic condition of the landscape such as slope, land use and cover, and type of soils that reflect on water resources. This indicates their lack of understanding of the risks associated with the landscape in which they inserted, on a broader scale. Both indicators then related to the ES group "Regulation of baseline flows and extreme events".

Another indicator associated with a *Low* risk of impact is "Occurrence of diseases related to inadequate environmental sanitation", the only one that is related to the "Pest and disease control" ES group. This result is noteworthy because the rural micro basin of Barracão dos Mendes is a region poorly served by sanitary sewage systems, where the use of rudimentary pits predominates (Pfeil, 2014). However, the occurrence of diseases linked to problems with poor sanitation not perceived by the interviewees and may indicate the efficiency of the cesspits implemented and maintained by rural producers. The Mananciais Project intends to improve this mechanism.

Despite the interviewees' identification of deficiencies related to basic sanitation and contamination of water by chemical residues from conventional agriculture, as detected in the studie by Gasparini and Freitas (2013), they

classify the indicator "Water quality for multiple uses" as *Very Low*. This related to ES group "Water conditions". The study by Pfeil (2014) presents results that corroborate the results found here.

Another indicator related to the *Very Low* impact risk is "Alternatives for water supply", in which the interviewees presented more than one alternative for collecting water, from rivers, lakes, reservoirs, wells and springs. Related to the ES group "Surface water used for nutrition, materials or energy". The study by Diaz et al. (2019) and Manes et al. (2022) presents results that corroborate the results found here.

4.2.2 Indicadores de Segurança Alimentar Food Security Indicators

The indicators related to the risk of climate change impacting the ecosystem services responsible for food security were classified as "*Very High*" in the perception of the rural producers interviewed. Families in rural communities generally related them to the low production and diversity of basic foodstuffs for consumption. This situation makes them dependent on products that need to be purchased in supermarkets, which are often industrialized and expensive.

Very High risk was also associated with the indicators "Dependence on large-scale irrigation" and "Use of pesticides". While the former shows the dependence on irrigation to guarantee food production, the latter highlights the perceived risk in relation to the conventional system of agricultural production, which is dependent on a huge amount of fertilizers and pesticides, especially in the case of olive growing in the mountainous region of Rio de Janeiro. The study by Moreira et al. (2002) presents results that corroborate the results found here.

The indicators related to *High* risk generally related to the population's low access to public policies aimed at food security and adaptation to climate change. With regard to access to public policies, 87.7% of those interviewed said they had some kind of access (Table 2). However, the majority of local rural producers had access to the Program for Sustainable Rural Development in Hydrographic Micro Basins - RIO RURAL, which was part of the Rio de Janeiro State Government's public policies for rural areas Nova Friburgo (Hissa, 2020). Another program that stands out is the National Program for Strengthening Family Farming (PRONAF, the acronym in Portuguese), which provides financing to family farmers and producers.

However, the interviews revealed that a major difficulty in accessing funding is being eligible for the required documentation. In this sense, the support of the town hall, trade unions or other government bodies, as well as research, teaching or non-governmental organizations (NGOs), would be very helpful in drawing up projects to access the credits available under public policies. Two indicators related to food programs, such as the National School Feeding Program and the Food Acquisition Program (Camargo et al., 2013).

In this context, it is important to consider that the majority of those interviewed earn between 2 and 3 minimum wages and inflation has caused food prices to rise in recent years, resulting in a loss of purchasing power for basic foodstuffs. These figures are in line with those presented by the FAO (2022), in which the Covid-19 pandemic highlighted the social inequality that exists in Latin America, where the prevalence of hunger in the region increased from 5.8% in 2015 to 8.6% in 2021.

The indicators related with to *Medium* class can represent significant impacts for rural producers such as changes to agricultural calendars, loss of production or in the quantity and quality of production, and the occurrence of extreme climate events (ECEs) that expose the community to severe droughts or extreme rainfall, as has already occurred and predicted. Related to the ES groups of 'Regulation of base flows and extreme events', demonstrating that rural producers are aware of climate change and the risks of impacts on agricultural production.

The indicators related to the *Low* risk of impact class were generally related to the interviewees having a perception of access to adequate nutritional quantity and quality and showing the region's potential for permanent and sustainable family farming. However, we observe that the majority of producers spend between 70 and 100% of their income on food, which puts food security at risk. The high dependence on inputs used in agricultural production is other factor that has increased food insecurity by making agricultural production difficult or unfeasible, which has reduced profits.

The indicators are related to ES groups such as 'Terrestrial plants cultivated for nutrition, materials, or energy', 'Animals raised for nutrition, materials, or energy', and 'Regulation of baseline flows and extreme events'. These ES groups are part of the provision and regulation/maintenance section, focusing on the food production capacity of living systems and the ability of ecosystems to regulate climatic conditions through ecological processes (Haines-Young and Potschin, 2018).

The indicator 'Agriculture without sustainable practices' was associated with the *Very Low* class. When asked about agricultural production practices, all the respondents adopted at least one sustainable management practice, such as spring protection, crop rotation, no-till farming, green manure, among others. Therefore, agriculture in the

region has a significant and growing adoption of sustainable practices, with the development of technologies in the region itself that replace downhill planting with herringbone planting (planting in a diagonally sloping area), the adoption of sustainable agricultural practices in the climate change scenario is important. The study by Garajeh et al. (2023) presents results that corroborate the results found here.

The indicators related to the *Very Low* class related to the 'Regulation of soil quality' group of ES. Improving the quality of ecological processes in natural ecosystems or agrosystems benefits the productivity of small-scale farms, such as family farmers (Guzmán et al, 2022). Therefore, conservation practices in soil management are essential for maintaining this group of ES. Conservation practices in this sense detected in Antonio's study (2022), in the management of rural producers in Nova Friburgo. Also noteworthy is the work of institutions in the municipality of Nova Friburgo that have a regional office, such as the Technical Assistance and Rural Extension Company of the State of Rio de Janeiro (EMATER-RIO), the Agricultural Research Company of the State of Rio de Janeiro (PESAGRO-RIO), the Brazilian Agricultural Research Corporation (EMBRAPA) through the Center for Research and Training for Farmers (NPTA) and the presence of the Belgium Institute - Nova Friburgo (IBELGA)

An important observation is that the only ES group shared between water and food security is 'Regulation of baseline flows and extreme events' which, when perceived by the interviewees, for some indicators presented the risk as Medium, High and *Very High*, These indicators point to actions that should improve and maintain the supply of this group of ES, which is related to the ecosystem's capacity to contribute to resilience in coping with extreme climatic events of hydrological origin (sudden and gradual floods, floods, landslides) (IPCC, 2012).

According to Araújo and Nero (2022, p. 238), 'ecosystem regulation services act to prevent and mitigate hydrological disasters through two main processes: infiltration and water storage', which is relevant for the municipality of Nova Friburgo-RJ in terms of disaster management by decision-makers in order to prevent the impacts of climate change, such as what happened in 2011 in the region, mainly affecting the rural area of Barracão dos Mendes, which was characterized as Brazil's largest hydrological disaster.

5. Conclusions

Regarding the methodology adapted and applied, we conclude that it was effective in obtaining the perceptions of the rural actors interviewed regarding the risks of climate change impacts on ecosystem services related to water and food security on a local scale. Adaptations are necessary in order to improve the interviewees' understanding of what intended to be obtained from their perception, as well as adaptations to the local reality, in the case of its application in other regional contexts.

As for the risk indicators for climate change impacts used from the AdaptaBrasil MCTI Platform, associated with ecosystem services classified according to the CICES classification, we understand that this was an advance in knowledge and methodology, since this platform has been used in different regions of Brazil to assess the risk of climate change impacts on people's daily lives and we can now relate these indicators to the ecosystem services approach.

The most risk indicated for impact climate change on the ES was related to water security in the study area, mostly perceived by the interviewees, but what drew the most attention were the indicators considered to be *Very High*, since all of them depend on interventions by public authorities in order to be improved. This shows that investments have not been sufficient for collective and public solutions aimed at water security. Based on the indicators used, we can also see that the actions related to water resource management in the study area are not being properly perceived by the interviewees, pointing to the need to broaden the dissemination of results and include rural producers in decisions regarding water resources.

Regarding the risk indicators for the impact of climate change on ES related to food security in the study area, the diversification of staple food production, the use of pesticides, the high demand for water for irrigation without the practice of reserving it and the reduced access to public policies aimed at food security were classified as high risk (*Very High* and *High*), indicating that the interviewees perceive the high risks that agricultural production in the region is exposed to, which are increasing and more frequent due to climate change and the ECEs that have occurred. The results of the interviews also show that the costs of agricultural production are rising, as are the costs of the food they do not produce, which leads to impoverishment and vulnerability to the impacts of climate change on food security.

Water resources and food production inextricably linked. Therefore, the adoption of sustainable practices in agricultural production (both on the farm and at the landscape scale) is essential, as it ensures the maintenance and provision of ecosystem services that occur at different temporal and spatial scales.

There is a need for more efficient government action with family farming producers, at the different levels

(municipal, state and federal), with the implementation of effective public policies in the region, aimed at increasing water and food security, which will reduce the risk of climate change impacting on ecosystem services and improve quality of life for all.

References

AdaptaBrasil MCTI Platform. (2021). *Documento teórico-metodológico para avaliação de risco de impacto de mudança climática nos Setores Estratégicos de Recursos Hídricos e Segurança Alimentar da plataforma Adapta Brasil MCTI*. Retrieved from https://adaptabrasil.mcti.gov.br/sobre/metodologia

AdaptaBrasil MCTI Platform. (2022, december 20). *Índices e Indicadores*. Retrieved December 20, 2022, from https://adaptabrasil.mcti.gov.br/sobre/lista-de-indicadores

AdaptaBrasil MCTI Platform. (2024, february 12). Índices e Indicadores de risco de impactos das mudanças climáticas no Brasil, integrados em uma única plataforma: Setores Estratégicos. Retrieved February 12, 2024, from https://adaptabrasil.mcti.gov.br/

Antonio, G. J. Y. (2022). *Tipificação e predição do comportamento agroecológico da agricultura familiar de Nova Friburgo (Rio de Janeiro, Brasil) e de Lavalle, Maipú, Guaymallén e Las Heras (Mendoza, Argentina)* (Unpublished doctoral dissertation). Universidade Federal Rural do Rio de Janeiro, Seropédica, RJ.

Araújo, A. J. D., Lima, J. S. D., Moreira, J. C., Jacob, S. D. C., Soares, M. D. O., Monteiro, M. C. M., ... Markowitz, S. (2007). Exposição múltipla a agrotóxicos e efeitos à saúde: estudo transversal em amostra de 102 trabalhadores rurais, Nova Friburgo, RJ. *Ciência & Saúde Coletiva, 12*(1), 115-130. https://doi.org/10.1590/S1413-81232007000100015

Araújo, A. S., & Nero, M. A. (2022). Levantamento bibliográfico dos mapeamentos de serviços ecossistêmicos para a gestão de riscos de desastres hidrológicos. *Revista Caminhos de Geografia, 23*(90), 273–286. http://doi.org/10.14393/RCG239061318

Asmus, M. L., Nicolodi, J., Anello, L. S., & Gianuca, K. (2019). The risk to lose ecosystem services due to climate change: A South American case. *Ecological Engineering, 130*, 233-241. https://doi.org/10.1016/j.ecoleng.2017.12.030

Balvanera, P., & Cotler, H. (2007). Acercamientos al estudio de los servicios ecosistémicos. *Gaceta ecológica*, (84-85), 8-15. https://doi.org/10.1016/j.ecoleng.2017.12.030

Biggs, R., Clements, H., de Vos, A., Folke, C., Manyani, A., Maciejewski, K., ... Schlüter, M. (2021). *What are social-ecological systems and social-ecological systems research? In The routledge handbook of research methods for social-ecological systems* (pp. 3-26). Routledge.

Brazil. (2006). Law n. 11.326 of July 24, 2006 of the Presidency of the Republic of the Brazil. *Establishes guidelines for the formulation of the National Policy on Family Farming and Rural Family Enterprises*. Retrieved from https://www2.camara.leg.br

Brazil. Tribunal de Contas da União. (2018). *Referencial básico de gestão de riscos*. Brasília: TCU, Secretaria Geral de Controle Externo (Segecex). (Inclui 154 p. : il.). Retrieved from www.tcu.gov.br

Callaghan, M., Schleussner, C. F., Nath, S., Lejeune, Q., Knutson, T. R., Reichstein, M., ... Minx, J. C. (2021). Machine-learning-based evidence and attribution mapping of 100,000 climate impact studies. *Nature climate change, 11*(11), 966-972. https://doi.org/10.1038/s41558-021-01168-6

Camargo, R. D., Baccarin, J. G., & Silva, D. B. P. D. (2013). O papel do Programa de Aquisição de Alimentos (PAA) e do Programa Nacional de Alimentação Escolar (PNAE) no fortalecimento da agricultura familiar e promoção da segurança alimentar. *Temas de Administração Pública, 8*(2), 1-21.

Córdoba, G. S., & Zepharovich, E. (2022). How rural actors relate to nature. Perceptions of ecosystem services in the semi-arid Chaco of northern Argentina. *Land Use Policy, 121*, 106324. https://doi.org/10.1016/j.landusepol.2022.106324

Costanza, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., & Van Den Belt, M. (1997). The value of the world# s ecosystem services and natural capital. *Ecological economics, 25*(1), 3-15. https://doi.org/10.1016/S0921-8009(98)00020-2

De Groot, R. S., Wilson, M. A., & Boumans, R. M. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological economics, 41*(3), 393-408. https://doi.org/10.1016/S0921-8009(02)00089-7

Díaz, S. M., Settele, J., Brondízio, E., Ngo, H., Guèze, M., Agard, J., ... Zayas, C. (2019). *The global assessment report on biodiversity and ecosystem services: Summary for policy makers*. Retrieved from www.ri.conicet.gov.ar/handle/11336/116171

FAO (Food and Agriculture Organization of the United Nations). (2022). *The State of Food Security and Nutrition in the World 2022*. Repurposing food and agricultural policies to make healthy diets more affordable. Rome, FAO. https://doi.org/10.4060/cc0639en

Garajeh, M. K., Salmani, B., Naghadehi, S. Z., Valipoori, H. G., & Khasraei, A. (2023). An integrated approach of remote sensing and geospatial analysis for modeling and predicting the impacts of climate change on food security. *Scientific Reports, 13*(1), 1057. https://doi.org/10.1038/s41598-023-28244-5

Gasparini, M. F., & Freitas, C. M. D. (2013). Trabalho rural, saúde e ambiente: as narrativas dos produtores de flor frente aos riscos socioambientais. *Ambiente & Sociedade, 16*, 23-44. https://doi.org/10.1590/S1414-753X2013000300003

Guzmán, G. I., Fernández, D. S., Aguilera, E., Infante-Amate, J., & Molina, M. G. de (2022). The close relationship between biophysical degradation, ecosystem services and family farms decline in Spanish agriculture (1992–2017). *Ecosyst Serv, 56*, 101456. https://doi.org/10.1016/j.ecoser.2022.101456

Haines-Young, R. H, & Potschin, M. B. (2018): *Common International Classification of Ecosystem Services (CICES) V5.1 and Guidance on the Application of the Revised Structure*. Fabis Consulting Ltd., Nottingham [In English].
https://cices.eu/content/uploads/sites/8/2018/01/Guidance-V51-01012018.pdf
Hissa, H. R. (2020). *Políticas Públicas para o Desenvolvimento Rural Sustentável: Estudo de Caso do Programa Rio Rural* (Unpublished doctoral dissertation). Universidade Federal Rural do Rio de Janeiro, Seropédica, Rio de Janeiro, Brazil.

IBGE (Instituto Brasileiro de Geografia e Estatística). (2017). *Censo Agro 2017: população ocupada nos estabelecimentos agropecuários cai 8,8%*. Retrieved from www.agenciadenoticias.ibge.gov.br

IBGE (Instituto Brasileiro de Geografia e Estatística). (2020). Agricultuta Familiar. In: IBGE. *Atlas do espaço rural brasileiro* (2nd ed.). Rio de Janeiro: IBGE. Retrieved from https://www.ibge.gov.br

IBGE (Instituto Brasileiro de Geografia e Estatística). (2021). *Cidades: Nova Friburgo – RJ*. Retrieved from https://cidades.ibge.gov.br/brasil/rj/nova-friburgo/panorama

IPCC (Intergovernmental Panel on Climate Change). (2012). Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. In C. B. Field, V. Barros, T. F. Stocker, D. Qin, D. J. Dokken, K. L. Ebi, M. D. (Eds.), A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (pp. 594).

IPCC (Intergovernmental Panel on Climate Change). (2014). Livelihoods and poverty: Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change. In L. Olsson et al. (Eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects* (pp. 793-832). Cambridge University Press.

IPCC (Intergovernmental Panel on Climate Change). (2018). Annex I: Glossary. In R. Van Diemen (Ed.), *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.*

IPCC (Intergovernmental Panel on Climate Change). (2019). Land: An IPCC Special Report on Climate Change. In P. R. Shukla et al. (Eds.), *Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems* (Vol. 41, pp. 43).

IPCC (Intergovernmental Panel on Climate Change). (2021). Summary for Policymakers: Climate Change 2021 – The Physical Science Basis. In V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnøy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, & B. Zhou (Eds.), *Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

IPCC (Intergovernmental Panel on Climate Change). (2023). Summary for Policymakers. In Core Writing Team, H. Lee and J. Romero (Eds.), *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1-34). IPCC, Geneva, Switzerland.

Malhi, Y., Franklin, J., Seddon, N., Solan, M., Turner, M. G., Field, C. B., & Knowlton, N. (2020). Climate change and ecosystems: Threats, opportunities and solutions. *Philosophical Transactions of the Royal Society B, 375*(1794), 20190104. https://doi.org/10.1098/rstb.2019.0104

Manes, S., Vale, M. M., Malecha, A., & Pires, A. P. (2022). Nature-based solutions promote climate change adaptation safeguarding ecosystem services. *Ecosystem Services, 55*, 101439. https://doi.org/10.1016/j.ecoser.2022.101439.

Mata, A. P. (2006). *Legislação ambiental e uso atual do solo: o caso da micro-bacia do Córrego de São Lourenço–Nova Friburgo, RJ* (Unpublished doctoral dissertation). Universidade Federal Fluminense, Rio de Janeiro, RJ.

MEA (Millennium Ecosystem Assessment). (2005). *Millennium Ecosystem Assessment Ecosystems and Human Well-being: Synthesis*. Island Press. Retrieved from https://www.millenniumassessment.org/

Milcu, A. I., Sherren, K., Hanspach, J., Abson, D., & Fischer, J. (2014). Navigating conflicting landscape aspirations: application of a photo-based Q-method in Transylvania (Central Romania). *Land Use Policy, 41*, 408-422. https://doi.org/10.1016/j.landusepol.2014.06.019

Moreira, J. C., Jacob, S. C., Peres, F., Lima, J. S., Meyer, A., Oliveira-Silva, J. J., ... Curi, R. (2002). Avaliação integrada do impacto do uso de agrotóxicos sobre a saúde humana em uma comunidade agrícola de Nova Friburgo, RJ. *Ciência & Saúde Coletiva, 7,* 299-311.

Palomo, I. (2017). Climate change impacts on ecosystem services in high mountain areas: a literature review. *Mountain Research and Development, 37*(2), 179-187. https://doi.org/10.1659/MRD-JOURNAL-D-16-00110.1

Panigassi, G. (2005). Inquérito populacional sobre a percepção da segurança alimentar intrafamiliar no município de Campinas. 2005 (Doctoral dissertation) –Universidade Estadual de Campinas, Campinas, São Paulo, Brazil.

Pfeil, L. E. C. (2014). *Estudo de autodepuração na bacia do rio Grande: Aplicação do modelo Streeter-Phelps ao lançamento de efluentes no córrego do Barracão dos Mendes – Nova Friburgo/RJ.* (Unpublished master's thesis). Universidade Federal Fluminense, Niterói, Rio de Janeiro, Brazil.

Rangel, M. C., & Nauditt, A. (2017). Avaliação dos impactos socioeconômicos e ambientais da seca no meio rural da bacia do rio Muriaé – Zona da Mata de Minas Gerais e Noroeste do Rio de Janeiro - Brasil. In Water JPI. Water Security and Climate Change Conference. Cologne.

SEAPEC (Secretaria de Estado de Agricultura e Pecuária-RJ). (2011). *Projeto Desenvolvimento Rural Sustentável em Microbacias Hidrográficas do Estado do Rio de Janeiro - Rio Rural / BIRD - Plano Executivo da Microbacia de Barracão dos Mendes*. Rio de Janeiro.

Segovia-Sánchez, O. C. (2014). *Environmental cost-benefit analysis of decentralized wastewater and sanitation technologies in the microbasin of Barracão dos Mendes, Brazil* (Doctoral dissertation). Universidad Autónoma de San Luis Potosí, San Luis Potosí, Mexico. And Institute for Technology and Resources Management in the Tropics and Subtropics, Cologne, Germany. 138 p. Retrieved from https://ninive.uaslp.mx

Silva, A. H. S. Da. (2018). *Identificação de riscos em sistema de cria em pecuária de corte*. 2018 (Master's thesis, Universidade Federal do Rio Grande só Sul, Faculdade de Agronomia, Porto Alegre, Rio Grande do Sul) Retrieved from https://www.lume.ufrgs.br/handle/10183/179148

Tanure, T. M. D. P., Domingues, E. P., & Magalhães, A. S. (2023). Regional impacts of climate change on agricultural productivity: evidence on large-scale and family farming in Brazil. Revista de Economia e Sociologia Rural, 62. https://doi.org/10.1590/1806-9479.2022.262515

UN & UNDP (United Nations Organization/United Nations Development Programme). (2014). In Connor, R., & Koncagül, E. (Eds.), *The United Nations world water development report 2014*. UNESCO: United Nations Educational, Scientific and Cultural Organisation. France. Retrieved from https://policycommons.net/artifacts

Wanderley, M. de N. B. (2017). "Franja periférica", "pobres do campo", "camponeses": dilemas da inclusão social dos pequenos agricultores familiares. In G. C. Delgado & S. M. P. P. Bergamasco (Eds.), *Agricultura familiar brasileira: desafios e perspectivas de futuro* (pp. 64-83). Brasília, DF, 1, 474.

World Bank. (2012). *Inundações e Deslizamentos na Região Serrana do Rio de Janeiro* - Janeiro de 2011: Avaliação de Perdas e Danos, 1–63. Retrieved from http://www.obt.inpe.br/

World Bank. (2018). The Deep South: Constraints and Opportunities for the Population of Southern Madagascar towards a Sustainable Policy of Effective Responses to Recurring Droughts/Emergencies, C. The World Bank, Washington, DC. Retrieved from https://documents1.worldbank.org

Zabala, J. A., Martínez-Paz, J. M., & Alcon, F. (2021). A comprehensive approach for agroecosystem services and disservices valuation. *Science of the Total Environment, 768*, 144859. https://doi.org/10.1016/j.scitotenv.2020.144859

Zepharovich, E., Ceddia, M. G., & Rist, S. (2020). Perceptions of deforestation in the Argentinean Chaco: Combining Q-method and environmental justice. *Ecological economics, 171*, 106598. https://doi.org/10.1016/j.ecolecon.2020.106598

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Dr. Rachel Bardy Prado and MSc. Samira F. Oliveira were responsible for study design, data collection, interpretation of data and revising. Dr. Elaine C. C. Fidalgo, Ana P. D. Turetta, Joyce M. G. Monteiro and Bernadete da C. C. G. Pedreira were responsible for data collection, interpretation of data and revising. Gerson J. Y. Antonio, Renato L. de Assis and Sandro R. A. Oitaven were responsible for data collection and revising. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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