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Family farmers' environmental perception of ecosystem services in the Brazilian semi-arid region

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Abstract

Rural populations, whose economies are based on agriculture and livestock, depend on ecosystem services. The aim of this study was to assess family farmers' environmental perception of ecosystem services and their importance. The study was conducted in two communities in the semi-arid region of Piauí, Northeastern Brazil. Data were collected through nonparticipant observation and semi-structured interviews and analyzed using word clouds, Likert scales, and semantic networks. Farmers have a broad perception of ecosystem service categories, recognizing and valuing provisioning and cultural services above all. Nature is seen as playing a fundamental role in the activities of these communities, which depend on natural resources for their livelihoods and leisure.

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Keywords
semi-arid region, family farming, Caatinga biome, provisioning services, cultural services

Introduction

Rural populations with agriculture- and livestock-based economies depend on ecosystem services: their activities are often related to and dependent on the surrounding landscapes (Fagerholm et al., 2012). Ecosystem services (ES) represent the benefits that people obtain from ecosystems, both directly and indirectly, and are classified into four categories: support, which includes soil formation processes, nutrient cycling, and water cycling; regulation, which involves maintaining air quality, climate, and water regulation; provision, which covers food, fiber, fuel, and fresh water; and culture, which concerns cultural diversity, ecotourism, recreation, and aesthetic values (Millennium Ecosystem Assessment [MA], 2005). ES are fundamental to supporting human well-being and are considered an important component of sustainability (Summers & Smith, 2014; Wang et al., 2017).

Agriculture, for example, benefits directly from ES such as pollination, biological pest control, shade, and shelter (Stallman, 2011; Zhang et al., 2007). However, the loss of natural habitats damages ecosystem processes and their functioning, reducing nature's ability to provide ES (Díaz et al., 2019). Extensive agriculture and agricultural intensification are the main drivers of biodiversity loss and biotic homogenization worldwide (Kehoe et al., 2017). They not only jeopardize global conservation goals but also undermine the provision of many ES on which farming communities, especially family farms, and society in general depend (Bommarco et al., 2013). Furthermore, this rapid conversion of natural systems into agricultural land results in a significant loss of ES, including loss of biodiversity, increase in CO_2 emissions, soil erosion, air pollution, water pollution, and climate change (Fang et al., 2024).

This reality is particularly worrying in the Brazilian semi-arid region, already one of the most vulnerable regions in the world due to a combination of factors that include irregular rainfall, rising temperatures, soil degradation, and desertification (Marengo et al., 2017). These conditions mainly affect farmers, who depend on rainfall for rainfed crops (Marengo et al., 2011).

Landscapes composed of agricultural and forest lands are essential for providing a complete ES package for a population (Martín-López et al., 2012). However, the management of these landscapes should be focused on agriculture that establishes lower-impact management practices, such as polyculture and the cultivation of species in association that can increase the diversity of an agroecosystem (Gliessman, 2001). Studies carried out in the Caatinga, a seasonally dry tropical forest in Brazil, concluded that it is necessary to include ES in ecological restoration areas, taking into account the vulnerable human population in dry regions and their demand for natural resources (Costa et al., 2021).

Despite a growing base of studies related to ES, there is a lack of understanding of farmers' perceptions of ES and how this is associated with natural environment management (Teixeira et al., 2018). Awareness of these perceptions contributes to drawing up sustainable development strategies (Giansanti, 1998) and formulating public policies (Dominati et al., 2010).

For example, studies carried out in Colombia highlight the need to consider local perceptions when assessing which perceptions ES farmers value, in order to guide policy decisions with concrete data (Leroy & Barrasa García, 2021). These perceptions can vary widely depending on the context and environmental conditions, as evidenced by research in Indonesia (Muhamad et al., 2014), Germany (Küchen et al., 2023), Kenya (Miller et al., 2021), and Brazil (Osório de Sousa et al., 2024a). These differences are based on cognitive aspects of the perception of visual stimuli and people's experiences of nature and the surrounding environment (Arias-Arévalo et al., 2018), as well as social factors such as educational level (Maas et al., 2021). For example, living in a semi-arid region can influence farmers' perceptions, as observed in farmers in Nigeria and Ghana, where food production is highly dependent on rainwater (Aniah et al., 2024a).

This study aimed to analyze how family farmers in two communities in the Brazilian

semi-arid region perceive ES. We hypothesized that the family farmers in our sample would prioritize provisioning ES, especially those associated with the use of rainwater, due to their relevance to agricultural production in this semi-arid region.

Methodology

The study was conducted in the communities of Fornos and Pau D'Arco, located on Chapada do Mucambo, in the municipality of Picos, in the Southeast Piauí state, Northeastern Brazil. According to information obtained directly from the records of the Association of Small Rural Producers of Fornos and Pau D'Arco during field visits, these communities have a total of 212 inhabitants. The region is located 307 km (191 miles) from the state capital Teresina and has a predominantly dry and semi-arid climate, with rainfall concentrated in the months of December, January, and February (Mainar de Medeiros et al., 2012).

Our study area is part of the Caatinga, a seasonal Brazilian forest (Pennington et al., 2009) in the Northeast region with an area of 912,529 square km or 352,329 square miles (da Silva et al., 2018). It has a rich and varied biodiversity, with a high number of endemic species (Prado, 2003; Rito et al., 2017). The soils in this region come from the alteration of sandstones, siltstones, and conglomerates; they are lithic, alkalic, and dystrophic soils, with a medium texture, poorly developed, shallow to very shallow, and with a stony phase (Jacomine, 1986).

The Fornos and Pau D'Arco communities employ rainfed family farming as a source of income and food, especially corn, cassava, beans, and backyard production for human consumption (Viva o Semiarid Project, IFAD, 2020). Backyard production includes a wide diversity of food species that are grown all year round and contribute to household consumption (de Sousa et al., 2025). The community uses well water and water stored in cisterns and has no public water supply. In order to define a representative group of farmers in the region, the research was carried out with farmers from the Association of Small Rural Producers of Fornos and Pau D'Arco. Of the 35 members, 29 took part in the survey.

Sample Design and Analysis Methods

During visits to the communities, it was found that the farmers were organized into a local association made up of 35 members (N=35). For this research, 29 farmers who maintained backyard production and family-based vegetable gardens were selected, a criterion in line with the study's objective of understanding farmers' perceptions of ecosystem services. All participants were informed of the research objectives and voluntarily agreed to take part by signing an informed consent form, in accordance with the ethical principles applicable to research with communities. Our data collection combined nonparticipant observation, which allowed for a contextual understanding of local agricultural practices, and semi-structured interviews, which were used to explore in greater depth the participants' experiences, values, and perceptions in relation to provisioning, regulating, cultural, and supporting ecosystem services.

The interview form contained 42 questions focusing on the four categories of ES: provision, regulation, support, and culture. One part of the questionnaire contained open questions so that interviewees could develop their thoughts or cite examples, and another part contained questions with answers organized according to the Likert scale. This scale has rating categories, and its main objective is to obtain from interviewees how much they agree or disagree with certain statements (Allen & Seaman, 2007). In this study, the Likert scale was adapted to analyze the degree to which farmers perceived the importance of ES, with five possible answers: 1 (*very bad*), 2 (*bad*), 3 (*fair*), 4 (*good*), and 5 (*very good*).

To analyze farmers' perceptions of ES, a word cloud and a semantic network were constructed. The word cloud is an analysis that lists the most important words in a category and where the size of the words highlights their citation frequency. For a more refined qualitative analysis, we created a semantic network, an analysis that demonstrates the perceived connections between different elements. Areas that are more densely connected may indicate greater interdependence or a more significant impact between elements on farmers' perceptions. The data collected in the interviews were analyzed in the R Studio 4.2.1 program using the

following packages: quanteda, textplots, ggalluvial, ggplot, and igraph (Benoit et al., 2018; Brunson, 2020; Csárdi, 2020; Wickham, 2016).

This research was submitted to and approved by the Ethics Committee of the Federal University of Paraíba, Protocol no. 5.432.561 (CE/CCS/UFPB), through Plataforma Brasil CAAE n. 58670122.5.0000.5188.

Results

Of those interviewed, 85.7% were female and 14.3% male, with an average age of 49.5 years. With regard to participants' level of schooling, 78.3% had incomplete primary education. The farmers mentioned services in all four ES categories: provision, support, regulation, and culture. The most cited category was provisioning, accounting for 56% of the total, followed by cultural with 20%. Regulatory services received 17% of the responses, while supporting was the least cited, with 7% of mentions.

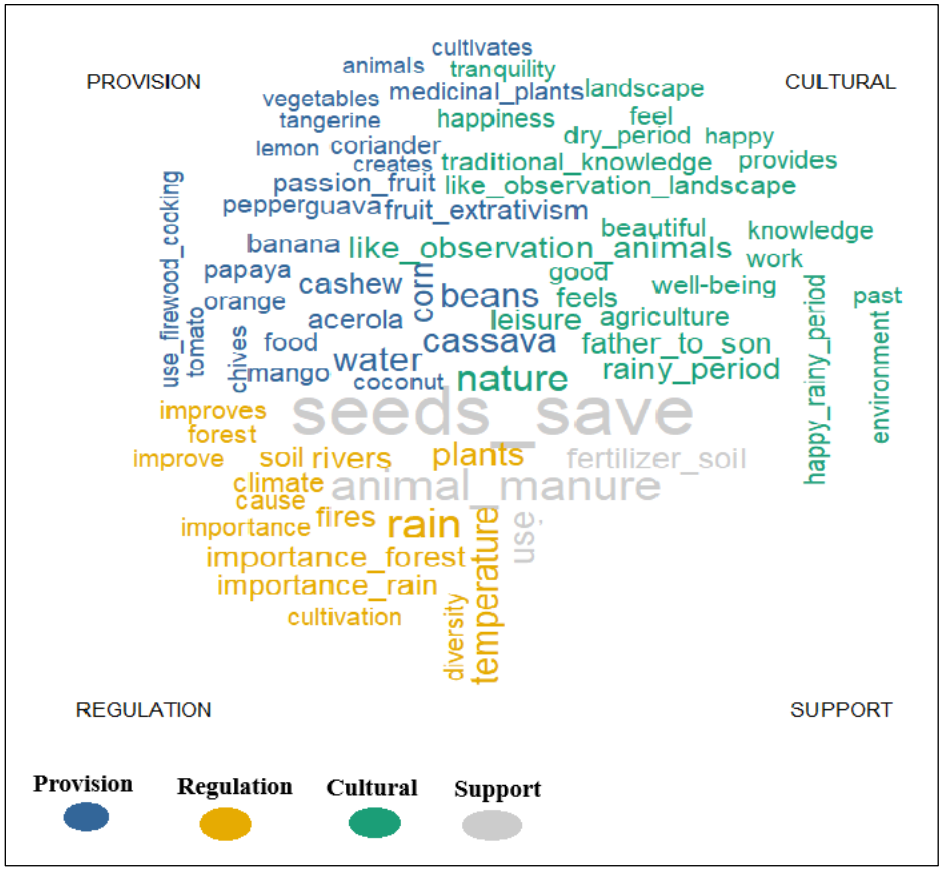
The main services cited for the provision category are directly related to agriculture, with the production of corn, beans, and cassava, and the use of water being the most visible services (Figure 1). These are the main crops planted by farmers, and water stands out due to its essential role in growing these foods.

Various services were mentioned in the cultural category; however, they all seem to have the same degree of importance since there is little difference in the size of the words, with no specific emphasis. Farmers value moments of leisure in direct contact with nature, the only word with a subtle emphasis in this cloud (Figure 1). The regulation category shows that farmers perceive the forest as regulating water maintenance in the environment and, less clearly, the soil (Figure 1). The services mentioned are more directly related to the water cycle and indicate that farmers are aware of climate change.

The support category received the fewest mentions, but the practice of saving seeds was perceived as very important. Farmers keep the best seeds from the harvest in plastic bottles. The seeds, mainly corn, beans, and pumpkin, are stored in a house set aside in the community as a "seed bank." Two other elements in the support category, soil fertilization and animal manure, also appeared with some prominence, demonstrating the significance of these practices for sustainability and agricultural productivity in the region.

In addition to perceiving provisioning and cultural services very well (Figure 1), farmers highly

Figure 1. Word Cloud of Farmers' Perceptions of Ecosystem Services in Communities in the Semi-Arid State of Piauí, Northeastern Brazil



value these services (Figure 2). These categories received the highest ratings on the Likert scale, suggesting that farmers strongly depend on nature for both resources and leisure.Soil quality and the availability of water resources, both directly related to farming, are also seen as significant services (Figure 2).

In contrast, insects and hunting received the lowest scores, reflecting a negative perception of the role of insects in agriculture and the environment as a whole. Insects were cited as synonymous with agricultural pests, disregarding their crucial roles in pollination, biological control, and other services. Additionally, responses indicated disapproval of animal hunting (Figure 2). Other ES that also proved to be important were plants, both in terms of diversity and medicinal use (Figure 2). Animal watching and interest in native animals were likewise highly rated, as were outdoor activities, fruit picking, and nature walks, thus indicating a strong interest in interacting with nature.

Semantic network analyses revealed that the three major groups of ES perceived by farmers are directly related to the term "nature," indicating that farmers consider nature to be a vital element in their daily lives (Figure 3). Provisioning ES such as cassava, beans, corn, medicinal plants, and fruit extraction are highly interconnected. Also in this category are animal services and collecting firewood for cooking. These connections indicate that farmers consider these elements significant for their livelihoods (Figure 3).

Cultural ES well-being, happiness, leisure, father-to-son, and traditional agriculture are clearly interconnected with nature, which demonstrates its importance in promoting well-being, happiness, and leisure, as well as the transmission of traditional knowledge and practices passed down from father to son (Figure 3).

Another interesting association with nature is the happy rainy period, because being a semi-arid region, farmers identify this period with happiness and increased production due to the abundance of water. The relationship between these terms sug-

Figure 2. Degree of Importance on the Likert Scale that Farmers Attribute to Some Ecosystem Services in Communities in the Semi-Arid State of Piauí, Northeastern Brazil

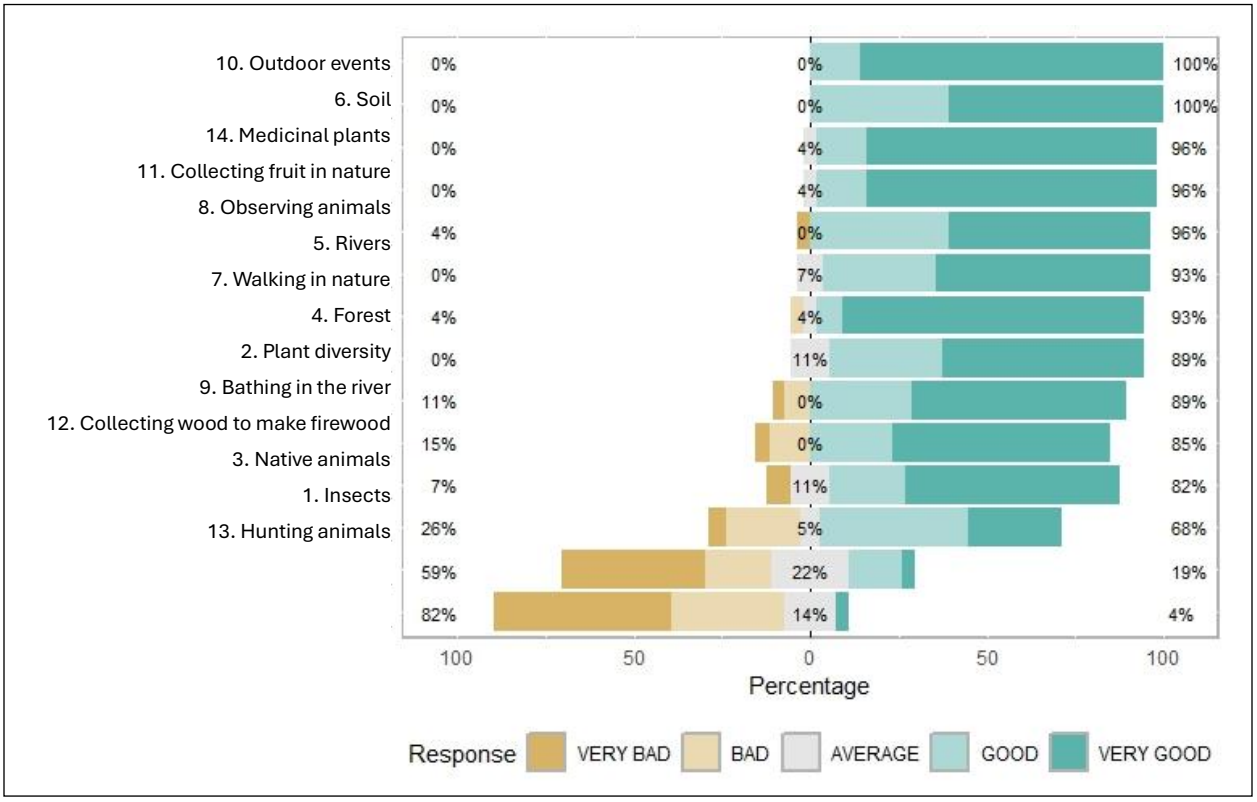
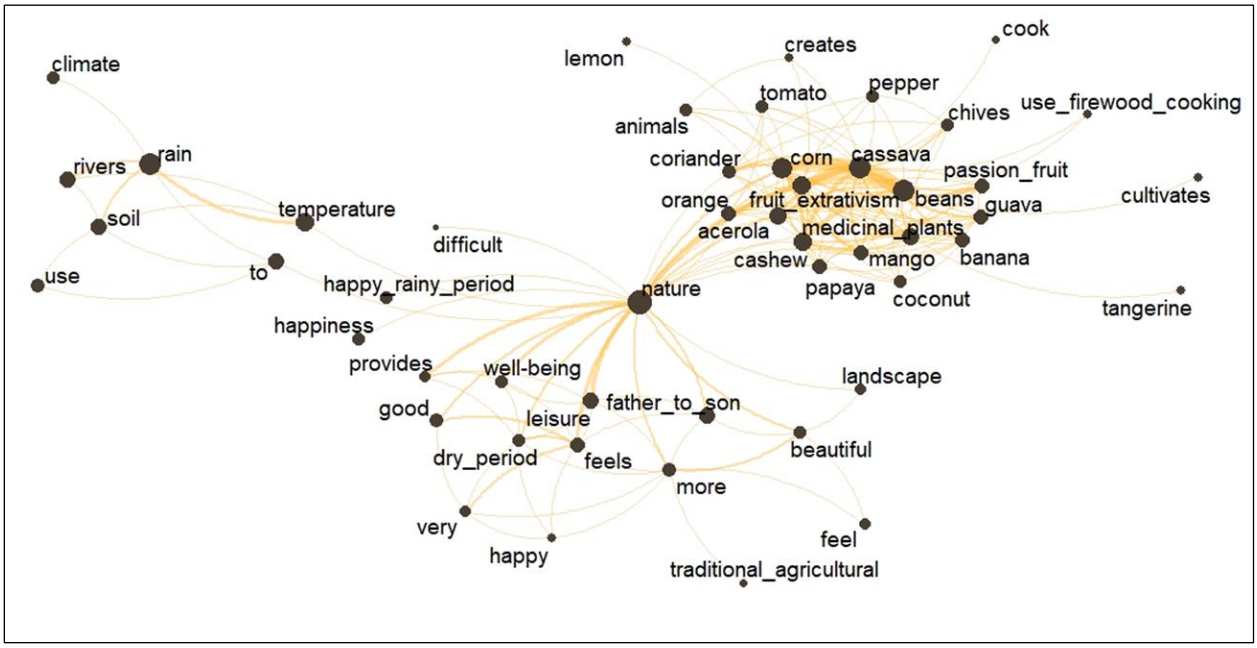


Figure 3. Semantic Network of Farmers' Perceptions of Ecosystem Services in Communities in the Semi-Arid State of Piauí, Northeastern Brazil



gests that farmers value nature not only for the resources it provides but also for its cultural and emotional benefits. Regulatory ES such as climate, rain, temperature, soil, and rivers are related to the idea of environmental regulation (Figure 3).

Discussion

Our results indicate that farmers are aware of, and can identify, the four categories of ES: provision, support, culture, and regulation. However, the most mentioned ES were provision and culture. This is consistent with studies carried out in rural Nigeria in semi-arid savannah and rainforest environments, which found that farmers are collectively aware of a wide range of ES: culture, biofuels, freshwater, species used in natural medicine, and wildlife (Zhang et al., 2016).

Similarly, in the semi-arid regions of Ghana, farmers perceive a wide range of supply and availability of provisioning ES, such as edible wild fruits and vegetables, building materials, fish, game, and medicinal plants. However, these farmers perceive that these ES have decreased significantly over the last decade. This decline in the supply and availability of ES has resulted in increased livelihood insecurity, leading to a deterioration in the well-being of the inhabitants (Aniah et al., 2024b). As in our study, the relevance of nature for food production and the provision of firewood are highly valued services. In poor communities in semi-arid regions, the seasonal variation in water availability shapes crop dynamics and influences environmental perceptions.

In addition to the ES provisioning being the most reported by farmers in the communities studied, they are also the most important. Farmers gave the highest scores to medicinal plants, water use, collecting fruit in the wild (extractivism), observing animals in the wild, and soil, the latter being directly related to food production.

Farmers along a rural gradient in the Iberian Peninsula also attributed greater relevance to provisioning services, besides attributing a higher value of importance compared to the urban population, who ranked regulating services (Martín-López et al., 2012) or cultural services (Fagerholm et al., 2019) as the most significant. This result may also be related to farmers' deep experiential knowledge, motivating them to manage these ES directly and indirectly (Teixeira et al., 2018). In addition, the provisioning services cited and most valued are part of the daily lives of farmers in the communi-

ties studied, being important sources of income and food.

In our study, cultural ES were given much greater relevance by farmers, as they were for farmers in Northeastern Pará in Brazil (Almeida et al., 2023), the Catalan Pyrenees of Northeastern Spain (Calvet-Mir et al., 2012), and the semi-arid Murcia region in Spain (Martínez-Paz et al., 2022), and for urban and rural dwellers in the state of Paraíba, Brazil (Osório de Sousa et al., 2024). Sociocultural factors, gender, level of education, and nature-based hobbies can better explain the variability in the perception of the importance of ES (Kross et al., 2018; Maas et al., 2021). In our study, income and gender seem to be key differentiators in perception of ES.

Socio-economic profile can be an influential factor in the perception of cultural services. Often, contact with nature is the only (or most affordable) leisure option for lower-income populations, as in the case of the communities in this study. Communities with low or very-low incomes tend to make more use of natural and free spaces for leisure and fun. Dryland ecosystems offer a variety of distinctive cultural ES, such as aesthetic values, recreation and tourism, knowledge and education, sense of place, and spiritual and religious values (Palacio-Prieto et al., 2016).

Attributing importance to cultural services may also be directly related to the gender of the farmers, since in our study 86% of the interviewees were women, and women tend to value provisioning services and cultural services more than men (Paudyal et al., 2018; Zoderer, 2016). This aspect is also reflected in the valuation of seeds, as illustrated in Figure 1. Women play a fundamental role in the conservation and storage of seeds, using traditional knowledge that supports food security and the preservation of agrobiodiversity (Ramirez-Santos et al., 2023). It is pertinent to note that cultural services tend to be neglected, while provisioning ES are considered priority services in decision-making by the agencies responsible for development, regulation, defining public policies, and promoting professional restoration (Milcu et al., 2013). However, cultural services should be seen as one of the fundamental services for farmers since they value activities in nature.

Farmers perceived fewer regulatory services and even fewer support services, and also attributed less significance to insects. In Northeastern Pará, Brazil, farmers also attributed little importance to insects (Almeida et al., 2023), while those in semi-arid regions and tropical forests in Nigeria were largely unaware of the beneficial services provided by insects, such as pollinators and natural enemies, due to their low level of education (Zhang et al., 2016).

Our results are likely related to the level of education. There is a lack of technical assistance for farmers in the communities, and 78% of the interviewees had not completed primary school. Studies indicate that farmers with higher education tend to attribute significantly greater importance to biodiversity and ES compared to those with only primary education (Maas et al., 2021), and 98% had not received rural technical assistance. The Brazilian Northeast is the region that most lacks technical assistance for family farmers (IBGE/SIDRA, 2019).

Generally speaking, farmers see nature as a valuable element that connects different types of ES. In interviews, the term "nature" is always connected to the services identified and was repeated a large number of times. This is in line with several studies that suggest that smallholder farmers value nature (Burgess et al., 2000; Guillem & Barnes, 2013; Harrison et al., 1998; Stupak et al., 2019).

However, studies in Europe (Estonia, Transylvania, England, Romania, Switzerland, Spain, and Portugal) also show contrasting opinions among farmers about the value of biodiversity and nature. Some view nature as a provider of ES that can be used as a tool to increase productivity and guarantee food security. Others perceive biodiversity as an inherent and universal value of nature, ecosystems, and all living species regardless of their usefulness to humans (Klebl et al., 2024).

Perceptions are varied, and influence by the local reality. In the semi-arid region described in this study, nature is seen as a significant source of resources and a place of well-being. Although farmers perceived a smaller number of regulating ES, terms such as rainfall, temperature, and soil are interconnected.

Farmers seem to identify rainfall as a factor in regulating the temperature and quality of the soil, which can be reflected in the quality of food production. Farmers practicing rainfed agriculture in semi-arid regions of India also identify rainfall as an important element in food production, since without rainfall, food production would be largely impacted by reductions in crop yields, decreased soil fertility and biodiversity, and a high frequency of drought events (Singh et al., 2023).

Farmers in the Fornos and Pau D'Arco communities in the semi-arid region of Piauí identify nature as a provider of essential services; however, they do not see nature only as a path or source for economic gain, but also as a source of well-being and leisure. Many studies state that economic interests are not the only determinants of farmers' behavior (Burton et al., 2008; Hammes et al., 2016; Schenk et al., 2007; Siebert et al., 2006). Thus, a study in Germany suggests that their understanding of nature and its protection is important at all stages of the producer's reasoning about adopting nature protection measures (Stupak et al., 2019). In this sense, knowing how farmers perceive and value services can help define management strategies and public policies for this segment.

Considerations for Community-Based Food Systems Research, Policy, and Practice

Our data showed that farmers have broad perceptions of various ES, recognizing and valuing services in all categories but with a greater emphasis on provision and culture. Understanding these perceptions is fundamental and should be reflected in public policy decisions and/or in the community's own local decision-making, underpinning immediate relief measures with long-term sustainable solutions. In order to improve farmers' understanding of their perception of ES in the region studied, we present three recommendations:

- Implement of effective public policies to improve farmers' quality of life that are based on provisioning and cultural services;
- Carry out research to understand in more detail how farmers deal with regulatory services, which they tend to know less about, and what actions they use to cope with climate change; and
- Provide environmental education on these topics to adults and children to help change perceptions and raise awareness of ES, such as the relevance of insects for agriculture or the importance of forests for climate regulation and water availability.
- Encourage public policies that recognize the conservation of creole seeds a term that refers to traditional, locally adapted seeds saved and exchanged by farmers across generations a common practice among farmers in the region, aligning it with Brazil's Nationally Determined Contributions (NDCs) to strengthen climate resilience and conserve agrobiodiversity.

Conclusion

Our results partially corroborated our hypothesis, which predicted that family farmers would perceive provisioning ES more frequently, viewing rainwater as the main water source for food production and landscape modification.

Although provisioning services were the most frequently mentioned and most important to farmers, it is worth noting the great significance farmers attached to cultural services. Nature was a central element in all food production and leisure activities, demonstrating that they were closely connected to nature. Farmers needed support and more information about the importance of biodiversity in general so that they value the role of insects more and even see other forms of sustainable management, such as the use of insects for biological control. In addition, natural areas can be better cared for and maintained so that they are more accessible leisure areas that the population can use.

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