

Resilience and sustainability in the production of *Ullucus tuberosus* under a biocultural approach in Andean communities

Marcela Aceldo Castillo¹, Orlando Meneses Quelal^{1,2*}

¹Posgrado. Universidad Politécnica Estatal del Carchi, Tulcán-Carchi, Ecuador

²Carrera de Medicina Veterinaria. Universidad Politécnica Estatal del Carchi, Tulcán-Carchi, Ecuador

*Corresponding author, e-mail: orlando.meneses@upec.edu.ec

Abstract

This article evaluates the agroecological and biocultural impact of *Ullucus tuberosus* cultivation in the Montúfar canton of Carchi province, Ecuador. Focusing on the "Producampo" Association, made up mostly of women, the research analyzes how they combine traditional and sustainable agricultural practices to ensure productive resilience and preserve biodiversity. Through qualitative methodologies such as interviews and participant observation, it was shown that 87.5% of farmers are women aged 39 to 75 who work more than 56 hours per week on their small plots, most of which are less than one hectare. Agroecological practices include the use of organic fertilizers, crop rotation, and natural methods for pest control. These actions not only minimize the use of chemical inputs but also strengthen sustainability and food security. Furthermore, bioculturalism plays a key role: farmers apply ancestral knowledge such as the lunar calendar and seed exchange, promoting social cohesion and adaptation to climate challenges. Despite limitations such as limited access to land, *Ullucus tuberosus* remains essential to the local economy and food supply. The study concludes by highlighting the need for public policies that support the integration of traditional knowledge with scientific innovations to strengthen agricultural sustainability and the empowerment of rural communities, especially women, within an inclusive development model.

Keywords: agrobiodiversity, agroecological sustainability, bioculturalism, family farming

Introduction

Agrobiodiversity, a product of natural evolution, local adaptation, and human intervention, constitutes an essential foundation for food security and agroecological sustainability (Nieto & Estrella, 2011). However, its accelerated loss represents one of the greatest global concerns, as genetic erosion far exceeds natural extinction rates (Khoury et al., 2022). This phenomenon, exacerbated by the Green Revolution and the expansion of industrial agriculture, has displaced traditional crops, drastically reducing the diversity of local varieties (Montaño et al., 2021).

In Ecuador, the arrival of intensive agriculture in the 1970s marked the beginning of the decline of native species such as *Ullucus tuberosus*, a tuber of high nutritional value and cultural significance for Andean communities (Pérez-Escobar et al., 2022). Low commercial demand and the abandonment of ancestral practices have exacerbated this situation, limiting its contribution to food

security and climate resilience (Mastretta et al., 2019).

The Andean region, recognized as a global center of plant biodiversity, is home to nearly 40% of the world's genetic resources (Rodríguez & Castillo, 2017). In particular, the province of Carchi stands out as a microcenter of Andean tuber diversification, where traditional knowledge persists and has been key to the in situ conservation of this genetic wealth (Andrade & Ayaviri, 2017).

This study aims to assess the conservation status and agroecological practices related to *Ullucus tuberosus* in the province of Carchi, focusing on the 'Producampo' Producers and Marketers Association of the Montúfar canton. It seeks to identify strategies to preserve this genetic resource, address challenges in its commercialization, and propose measures to strengthen its sustainability, thus contributing to food security and local development.

Materials and Methods

Study area

This research was conducted in the Montúfar canton, located in the Carchi province **Figure 1**. With a population of 29,590, it is the second most populated canton in the province and ranks fourth in land area with 3,807.32 km² (INEC, 2023). It belongs to Zone 1 of the country and is located on the high plateau of the Chota Valley basin, within the upper and middle basin of the Apaquí River (PDOT MONTÚFAR, 2023).

The canton is located at altitudes ranging from 2,200 to 3,800 meters above sea level. It borders Tulcán to the north, Bolívar and Sucumbíos to the south, Huaca and Tulcán to the east, and Bolívar and Espejo to the west. Its climate is temperate-cold, with a rainy season and a dry season. According to the climate classification, it has an equatorial mesothermal climate, semi-humid to humid, characteristic of high mountain areas. Annual rainfall ranges between 750 and 1,600 mm/year, depending on the altitudinal zone, while temperatures vary between 4 °C and 16 °C, with a relative humidity of 80% to 95% (PDOT MONTÚFAR, 2023).

The canton's mountainous geography includes two mountain range systems, the western and eastern, separated by the Inter-Andean Depression. Areas below 3,200 meters above sea level have mountainous terrain, while areas above this altitude are dominated by the high, cold Sierra, with vegetation typical of the Andean promo and high-altitude scrub. The Inter-Andean Basin is

key to agricultural activities (PDOT CARCHI, 2023).

In economic terms, agriculture and livestock farming predominate, accounting for 47% of the economically active population. These sectors, along with the dairy agroindustry, represent approximately 60% of economic activity. 58.6% of the territory is dedicated to agricultural and livestock production, highlighting the canton's agricultural vocation (GAD MONTÚFAR, 2016).

The canton's history is linked to the Pasto culture, which inhabited the region during the Piartal, Tuza, and Capulí periods. During this period, the cultivation of *Ullucus tuberosus* was the economic foundation, and its biocultural knowledge has been passed down from generation to generation (López, 2012). Today, many families combine traditional practices with modern agroecological techniques. The "Producampo" Association of Producers and Marketers, formed in 2010 and composed mostly of women, is a prominent example of conservation and sustainability in local production systems (MAG, 2010).

Focus and type of research

comprehensively explore the agroecological and biocultural assessment of the *Ullucus tuberosus* crop. This approach is well-suited to understanding complex phenomena in their specific context, integrating the perceptions and experiences of the actors involved, in this case, the farmers (Gallardo et al., 2017).

Given the limited agroecological and biocultural

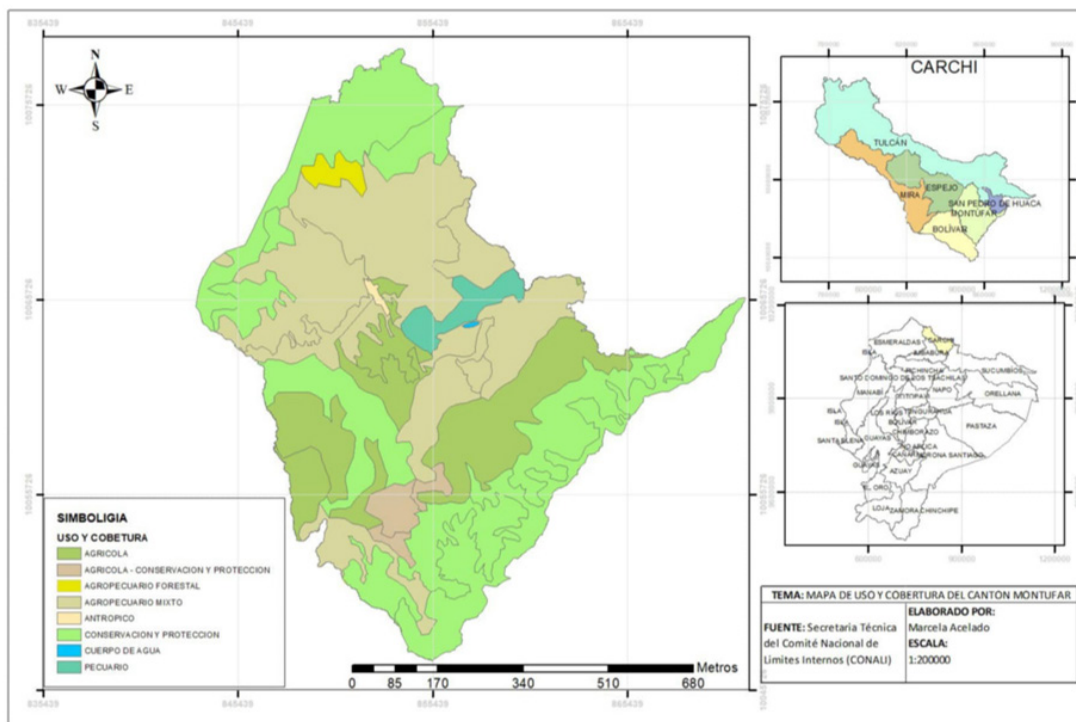


Figure 1. Location and map of land use and land cover of the Montúfar canton

knowledge available on *Ullucus tuberosus*, an exploratory research design was chosen. This design provided a first insight into the topic, providing initial information on the practices and knowledge associated with the crop (Bernal, 2014). Furthermore, a descriptive approach was used to document the phenomenon as it occurs in its natural context, providing a detailed analysis of the factors involved in cultivation practices (Guevara et al., 2020).

The study also adopted an ethnographic approach, selected for its ability to delve deeper into traditional practices and adaptations made by farmers. This method allowed for capturing the interaction between cultural beliefs, ancestral knowledge, and agricultural activities surrounding *Ullucus tuberosus* (Hoke & Schell, 2020). Through participant observation and semi-structured interviews, both agricultural techniques and associated cultural meanings were documented, generating a contextualized and enriching analysis.

Data collection

Data collection was conducted using primary sources, with field trips as the primary tool, complemented by semi-structured interviews with producers from the "Producampo" Association of Producers and Marketers. The methodological design was a case study with purposive non-probability sampling, selecting producers who cultivated *Ullucus tuberosus* and applied agroecological practices.

The recorded and transcribed interviews were validated by experts in statistics, agroecology, and bioculturalism, who reviewed the quality and focus of the questions to ensure their technical and cultural relevance (Robles & Rojas, 2015). In addition, a pilot interview was conducted with association members, adjusting the questions to improve their clarity (Mora, 2023).

Data analysis was carried out using thematic analysis, which allowed for the identification and correlation of narrative patterns, providing a comprehensive view of the agroecological and biocultural dimensions of *Ullucus tuberosus* cultivation (Braun & Clarke, 2006). This approach also captured symbolic meanings and respected local narratives (Vaismoradi et al., 2013). To ensure validity and reliability, data triangulation was applied, combining interviews, participant observation, and literature review (Bernard, 2006).

The target population included members of Producampo, but the final sample was limited to eight producers who met the established criteria. This size was adequate, as data saturation was reached, as evidenced by the lack of new relevant information during the interviews (Martínez, 2012).

Bioethical Considerations

The study was previously shared with Producampo members, and authorization was obtained through informed consent signed by the association's legal representative. Each interviewee authorized the use of the information provided exclusively for academic purposes, guaranteeing the privacy and confidentiality of the data.

Results and Discussion

Sociodemographic and family characterization of the producers

The data obtained from the interviews show that the producers are from the Montúfar canton, Carchi province, and are geographically distributed across the parishes of Fernández Salvador (El Tambo community), Piartal (San Pedro community), Cristóbal Colón, and San José (El Chamizo community). This distribution, represented in **Figure 2**, shows the producers' location using coordinates and coincides with official records that highlight the predominance of agricultural activities in these rural areas (PDOT MONTÚFAR, 2023).

The analysis shows that 87.5% of producers are women and 12.5% are men, confirming the high female participation in Family and Peasant Agriculture (FFA) in Ecuador, as indicated by the (MAG, 2023). In terms of age, producers are between 39 and 75 years old, with 75% concentrated in the 45 to 64 age range, a common trend in the Sierra region (Martínez, 2013).

Regarding education, 62.5% have primary education and 37.5% secondary education, in line with national data (INEC, 2024) reflecting a predominance of basic education among farmers. Furthermore, 87.5% of producers identify as mestizo and 12.5% as indigenous, results that coincide with national patterns of ethnic distribution in the agricultural sector (INEC, 2008; INEC, 2022).

In terms of geographic mobility, all interviewees were born and reside primarily in the Montúfar canton, except for one case of temporary migration for work reasons. This territorial stability highlights the importance of biocultural interactions in the preservation of traditional agroecological knowledge (Toledo & Barrera, 2009).

Producer families consist of, on average, 3.8 people, higher than the national average of 3.2 members per household (INEC, 2022). This pattern can be attributed to dynamics specific to rural areas, where households tend to be larger (Castro, 2012).

In the SIPA (Integral Agroecological Production System), all household members participate in agricultural work, although the primary role falls on women, who are highly involved in these activities, as noted by (MAG,

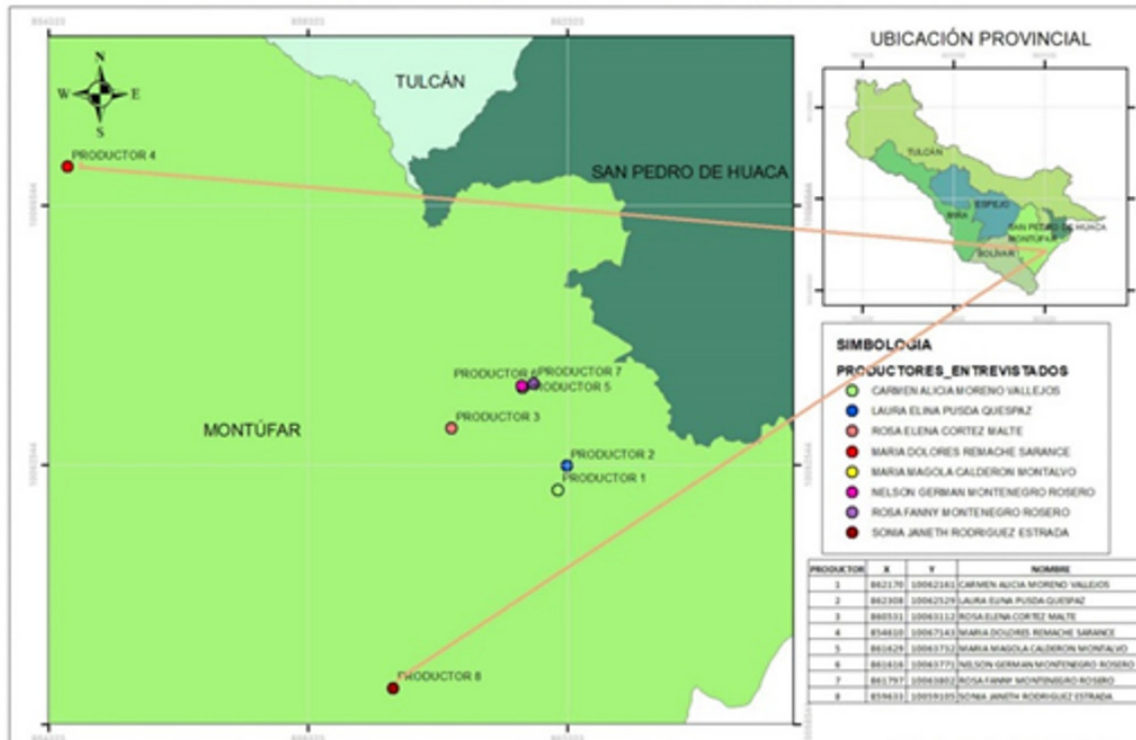


Figure 2. Geographic distribution within the Montúfar canton in coordinates of the *Ullucus tuberosus* producers of the "Producampo" association.

2023). On average, each household dedicates 56.8 hours per week to these tasks, exceeding both the ordinary working day in Ecuador and the national average of hours worked in the agricultural sector (INEC, 2024 ; Monesterolo, 2013).

These findings underscore the central role of family organization in the sustainability of agroecological production, highlighting the contribution of women and collective work in the rural communities of the Montúfar canton.

Characteristics and Structure of Agroecological Production Units (SIPA)

Agricultural Production Units (UPA) and Integrated Agroecological Production Systems (SIPA) are key concepts in this study. According to the INEC (2013), a UPA is an economic unit dedicated partially or entirely to agricultural production, with a minimum area of 500 m², although it also includes smaller areas that market agricultural products. The term SIPA, adopted by the association "Producampo," describes the productive units of its members using an agroecological approach.

Regarding the size of the interviewed producers' SIPAs, these range from 200 m² to 5,000 m², with one exceptional case being 2 hectares. This range illustrates the inequalities in access to land in Ecuador, where the Gini coefficient is 0.81, one of the highest in the region (León & Rivera, 2020). While corporate agriculture controls 80% of the land with only 15% of the UPAs, family farming,

which represents 84.5% of the UPAs, manages barely 20% of the land (FAO, 2025). This is reflected in the fact that 87.5% of those interviewed own less than one hectare, and only one owns a larger area, which is partially leased.

Regarding land tenure, 75% of producers are owners, 12.5% work borrowed land, and another 12.5% combine ownership and renting. These figures are consistent with the III Censo Nacional Agropecuario (2000), which reports that 68.5% of land in Ecuador is owned, while 15.9% is rented, reflecting historical limitations in access to land for small farmers.

In the structure of the SIPAs, it is observed that 50% of producers allocate areas to forests, 37.5% to pastures, and 75% to animal husbandry. All interviewees dedicate at least half of their land to crops, managing an average of 25 different species, including vegetables, tubers, legumes, fruit trees, medicinal plants, and shrubs. This pattern coincides with previous research, such as that of (Chamba et al., 2019), which shows a greater presence of short-cycle crops, occupying 51% of the land, while 40% is used for pastures.

Animal husbandry is a cross-cutting activity in the SIPAs, aligning with what was noted by Díaz y Valencia (2014), who estimate that 60% of rural families in Ecuador integrate livestock activities into their production systems. In this study, producers raise small animals such as guinea pigs, pigs, chickens, and cattle. This mixed production, which combines agricultural and livestock activities, is common in Latin America and is key to family food

security (Trespacios, 2023).

In short, SIPAs stand out for their productive diversity and integration of agricultural activities, reflecting the structural challenges in access to land and the resilience of small producers in rural contexts.

Agroecological Practices

Fertilization

The analysis of fertilization in Integrated Agricultural Production Systems (IAPS) reveals a marked agroecological approach. All producers use organic fertilizers, especially humus, compost, bocashi, and bioslurry. Of these, 87.5% produce these inputs from organic waste generated on their own farms, while 12.5% use purchased fertilizers. These practices promote sustainability, self-sufficiency, and food sovereignty (Bullor et al., 2023).

The low use of chemical fertilizers (75% do not use them and 25% use them in a limited manner) reinforces the transition toward sustainable agricultural systems, reducing costs and environmental impacts, as highlighted by Sarmiento et al., (2019). This reflects the commitment of Producampo producers to agroecology and the rural peasant economy.

Tillage

Producers use hand tools such as hoes and shovels, avoiding machinery. This minimalist approach, classified as conservation tillage, minimizes soil loss and preserves soil fertility (Altieri et al., 2012; Bezboruah et al., 2024).

100% of those interviewed practice crop rotation and intercropping, key strategies for preserving soil fertility. These practices, such as combining grass with legumes, fixing nitrogen and improve productivity (Montesdeoca et al., 2023).

The presence of earthworms, attributed to the use of organic matter, confirms the health of the soil, an indicator supported by (Momo et al., 2003; Cabrera, 2012; Yáñez et al., 2018).

Irrigation

None of the producer's store water or use irrigation methods, relying exclusively on rainfall. This is explained by the high rainfall in Montúfar, which ranges between 750 and 1,600 mm annually, and the low irrigation coverage in region (PDOT MONTÚFAR, 2023; INEC, 2024).

Pest and Disease Management

Among the most common pests are the slug (*Milax gagates*) and the cutzo (*Barotheus sp.*), while reported diseases include rust, powdery mildew, and

alternaria. However, 62.5% of producers have not observed significant diseases in the crop. These pests and diseases are consistent with reports from previous studies (Aguirre et al., 2012; Jacobsen et al., 2015; Condori et al., 2003).

For control, 50% of producers use organic insecticides based on chili peppers (*Capsicum*), considered the most effective. Other methods include beer traps (25%), sanitary pruning (12.5%), and crop rotation (12.5%). These practices have proven to be effective and sustainable, as noted by (Cabrera et al., 2016; Santacruz et al., 2011; INDAP y FAO, 2018).

The agroecological practices adopted by Producampo producers reflect a commitment to sustainability, environmental conservation, and resilience in the face of current challenges.

Characterization and importance of Ullucus tuberosus cultivation

Ullucus tuberosus, known as melloco, is a crop of great importance to rural communities due to its nutritional, medicinal and economic value. The producers interviewed identified three main varieties based on the shape and color of the tubers: elongated pink, rounded yellow (Quillu melloco) and rounded red (Puca melloco). These local classifications, although based on cultural knowledge, do not always coincide with scientific criteria of Suquilanda (2012) and Barrera et al. (2004). It is worth noting that the varieties "Quillu melloco" and "Puca melloco" were improved and released by INIAP in 1983, with "Puca melloco" being less mucilaginous (Paredes, 2016).

The cultivation area varies between 10 and 60 m², contrasting with previous reports that mention larger areas for Andean combined crops (Aguirre et al., 2012). This reduction reflects the decrease in cultivated area in Ecuador, which fell from 1,070 hectares in 1995 to 800 hectares in 2011 (Bustamante, 2020). In comparison, Peru and Bolivia have significantly larger areas (Lemos & Tello, 2018). Despite this, the cultivated varieties are recognized for their resistance to adverse conditions, pests and diseases, thanks to their hardiness and low input requirements (Mora & Hernández, 2022).

The crop cycle lasts between 7 and 8 months (Suquilanda, 2012). The origin of the seeds varies according to the region: the pink variety comes from Montúfar, and the yellow, from Chimborazo. The exchange of seeds within the association is a common practice, promoted by the Organic Law of Agrobiodiversity (MAG, 2023). Storage is carried out in dry environments, selecting the healthiest tubers, with an optimal time of 2 to 3 months (Cadima et al., 2003). In small plots, *Ullucus tuberosus* is

shown individually, although it is commonly associated with oca or potato, which contributes to the control of pests and diseases (Lemos & Tello, 2018).

In terms of importance, producers highlight their fundamental role in nutrition, health, and the economy. Nutritionally, the tuber contains betalains, essential amino acids, minerals, vitamins, and bioactive compounds with antimicrobial and antioxidant properties (Mejía et al., 2018). Furthermore, studies have demonstrated its healing activity, highlighting its potential in the food and pharmaceutical industries (Quispe & Blácido, 2018).

Consumption and marketing follow a dynamic characteristic of family farming, where most of the production is for personal consumption, and surpluses are sold to generate income. During Holy Week, demand for tuber increases significantly (Deaconu et al., 2021).

The experience accumulated by producers is remarkable: 75% have been cultivating *Ullucus tuberosus* for more than 30 years, while 25% have been cultivating it for more than 10 years, with an average of 35 years of experience. This empirical knowledge is key to the sustainability of family farming, promoting biodiversity conservation and strengthening resilience to environmental and social challenges (Betancourt & Pulido, 2006).

Bioculturality

Ullucus tuberosus producers, who apply traditional knowledge that combines agricultural, ecological, and astronomical approaches, fundamental to the sustainability of their production systems. These practices, passed down from generation to generation, include the use of the lunar calendar, crop association and rotation, the use of manure as fertilizer, and natural pest control methods such as ash application (Paspuel, 2020).

The lunar calendar is central to their agricultural practices: producers avoid planting during the full moon or on the first day of the moon, preferring the fifth day to ensure better yields, based on the influence of lunar phases on sap movement. These empirical observations are consistent with studies linking local knowledge to spatial and temporal conditions (Toledo & Barrera, 2009).

The association of *Ullucus tuberosus* with crops such as corn, broad beans, potatoes, and oca, along with the practice of rotation, contributes to conserving soil fertility and naturally controlling pests. Furthermore, farmers identify soil fertility by its color, associating dark soil with greater productivity. However, they acknowledge that climate change has altered traditional patterns, making it difficult to predict rainfall and drought (Lara &

Vides, 2014).

Despite the loss of varieties such as the round pink and greenish *Ullucus tuberosus*, farmers have maintained community practices such as seed exchange and mingas (meal gatherings), strengthening social cohesion and preserving their biocultural heritage. This legacy also includes knowledge of local biodiversity, varietal classification (ethnotaxonomies), and integrated agroecosystem management, which promotes resilience in the face of contemporary challenges (Cuevas et al., 2019).

Producers emphasize that food in the past was healthier, based on crops such as quinoa, barley, wheat, and corn, and free of chemicals. These traditional diets contrast with the current predominance of processed foods, reflecting the importance of biocultural knowledge in food security and sustainability (Clavijo & Pérez, 2014).

Practices such as polycultures, agroforestry systems, and cover crops have been key to conserving agricultural diversity (Altieri, 2002). This biocultural approach not only ensures long-term productivity but also fosters dialogue between peasant and scientific knowledge, enabling progress toward more sustainable agricultural systems (Gepts, 2023). The experience of the producers of the "Producampo" association demonstrates how biocultural memory is an essential pillar for supporting their families and providing safe and healthy food to the population.

Conclusions

The study demonstrates that the cultivation of *Ullucus tuberosus* in Montúfar, Carchi, is a resilient and sustainable system supported by agroecological and biocultural practices. It highlights that 87.5% of producers are women, who dedicate an average of 56.8 hours per week to agricultural activities, exceeding national standards. The majority (87.5%) produce organic fertilizers on their farms, which reduces costs and dependence on external inputs. All of them apply techniques such as crop rotation and minimum tillage, ensuring soil fertility, and 62.5% report a significant absence of crop diseases. In terms of land access, 75% are owners, although 87.5% manage plots smaller than one hectare, reflecting structural inequalities. The crop, associated with corn, broad beans, and potatoes, covers between 10 and 60 m² per producer, with an average of 35 years of experience per farmer. Bioculturalism is evident in the use of the lunar calendar, practiced by 100% of respondents, and in the sharing of seeds, practiced by 87.5%. These strategies integrate ancestral knowledge and modern

techniques, highlighting the role of women in Family Farming and emphasizing the need for public policies that strengthen agrobiodiversity and local sustainability.

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