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TYPIFICATION OF FARMERS IN PARAMO BUFFER ZONES IN LA CRUZ, NARIÑO, COLOMBIA

Tipificación de agricultores en zonas de amortiguamiento de páramos en La Cruz, Nariño, Colombia

Tipificação de agricultores em zonas tampão paramo em La Cruz, Nariño, Colômbia

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ABSTRACT
Typology development is a useful method for condensing the diversity of smallholder farming systems into representative types of operations. The study aimed to typify producers in the buffer zone of the Doña Juana Cascabel National Natural Park, located in the municipality of La Cruz, Nariño, in Colombia, in order to understand agricultural practices in an area facing environmental challenges and to help create more effective, comprehensive, and adaptable approaches for sustainable natural resource management in the region. Ninety-seven surveys were conducted between October and November 2023. The survey covered 110 questions, including sociodemographic, productive and agricultural management, environmental, commercial, economic, and associative aspects. Mixed data factor analysis (FAMD) was used to obtain the most representative variables. Then, using Euclidean distance and the Ward method in Rstudio V. 4.2.2 software, producers were grouped into three typologies: (i) conventional agriculture (52.58% of respondents), (ii) moderate agricultural diversification (41.24%), and (iii) sustainable intensive agriculture (6.19%). This study provides an updated classification of production systems in the buffer zone of the Doña Juana - Cascabel paramo complex, in addition to offering strategies tailored to the needs of the territory, constituting an important input in the decision-making of key actors in the region.

KEYWORDS
Clusters, rural development, sustainable development, rural diagnosis, agricultural practices.

RESUMEN
¿El desarrollo de tipologías es un método útil para condensar la diversidad de los sistemas de agricultura de pequeños productores en tipos representativos. Este estudio tuvo como objetivo tipificar los productores en la zona de amortiguamiento del Parque Nacional Natural Doña Juana Cascabel en La Cruz, Nariño, Colombia, para entender las prácticas agrícolas en una área con desafíos ambientales y crear enfoques efectivos y adaptables para la gestión sostenible de los recursos. Se realizaron 97 encuestas entre octubre y noviembre de 2023, cubriendo 110 preguntas sobre aspectos sociodemográficos, de gestión productiva y agrícola, ambientales, comerciales, económicos y asociativos. El análisis factorial de datos mixtos (AFDM) identificó las variables más representativas. Utilizando la distancia euclidiana y el método de Ward en Rstudio V. 4.2.2, los productores se agruparon en tres tipologías: (i) agricultura convencional (52,58% de los encuestados), (ii) diversificación agrícola moderada (41,24%) y (iii) agricultura intensiva sostenible (6,19%). Este estudio proporciona una clasificación actualizada de los sistemas de producción en la zona de amortiguamiento del complejo páramo Doña Juana Cascabel y ofrece estrategias adaptadas a las necesidades del territorio, sirviendo como un insumo importante para la toma de decisiones por parte de actores clave de la región.

PALABRAS CLAVE
Clústeres, desarrollo rural, desarrollo sostenible, diagnóstico rural, prácticas agrícolas.

RESUMO
O desenvolvimento de tipologias é um método útil para condensar a diversidade dos sistemas agrícolas de pequenos produtores em tipos representativos. Este estudo teve como objetivo tipificar os produtores na zona de amortecimento do Parque Nacional Natural Doña Juana Cascabel em La Cruz, Nariño, Colômbia, para entender as práticas agrícolas em uma área com desafios ambientais e criar abordagens efetivas e adaptáveis para a gestão sustentável dos recursos. Noventa e sete questionários foram realizados entre outubro e novembro de 2023, cobrindo 110 perguntas sobre aspectos sociodemográficos, de gestão produtiva e agrícola, ambientais, comerciais, econômicos e associativos. A análise fatorial de dados mistos (AFDM) identificou as variáveis mais representativas. Utilizando a distância euclidiana e o método de Ward no Rstudio V. 4.2.2, os produtores foram agrupados em três tipologias: 1) agricultura convencional (52,58% dos entrevistados), 2) diversificação agrícola moderada (41,24%) e 3) agricultura intensiva sustentável (6,19%). Este estudo fornece uma classificação atualizada dos sistemas de produção na zona de amortecimento do complexo páramo Doña Juana - Cascabel e oferece estratégias adaptadas às necessidades do território, servindo como um insumo importante para a tomada de decisões por atores chave da região.

PALAVRAS-CHAVE
Clusters, desenvolvimento rural, desenvolvimento sustentável, diagnóstico rural, práticas agrícolas.

Introduction

Inhabited volcanic territories are not limited to physical and spatial distribution but are also constructed from social relationships that are transmitted from generation to generation. These relationships constitute them as complex socio-ecological systems (Pardo et al., 2021), which require a comprehensive approach to understand the type of socio-ecological interactions that converge in the territory.

In this sense, it is necessary to design public policies that contribute to the design of plans that improve the sustainability of this type of territory. This implies understanding the limitations and possibilities of the different productive systems present in the buffer zone, as well as the needs of the farmers. Additionally, it is necessary to understand the development dynamics to formulate, manage, and execute projects in a timely manner, according to the identified characteristics (Rodríguez et al., 2021).

The present study was developed in the Doña Juana Cascabel National Natural Park zone, which hosts one of Colombia's paramo ecosystems. This ecosystem has great biodiversity and plays an essential role in regulating and supplying water to the rural and urban populations surrounding it (Montenegro-Muñoz et al., 2019). However, it faces various problems, such as deforestation, soil degradation, and loss of biodiversity caused by human activity (Rodríguez et al., 2021). The expansion of the agricultural frontier and unsustainable practices are generating significant impacts on these ecosystems, compromising their ability to provide essential ecosystem services.

In territories characterized by the heterogeneity of physical, socioeconomic, and technical aspects of production systems, as well as farms or farmers, it is necessary to group agricultural exploitations (Santos et al., 2014).

Even though these may not be organized identically, they share similar characteristics and properties in some aspects (Rodríguez et al., 2021). This similarity facilitates their grouping and allows addressing the complexity of reality through analysis methods that organize diverse objects but belong to the same type (Rodríguez et al., 2022).

In this scenario, the typification of agricultural producers emerges as a tool that allows understanding the diversity of agricultural systems that exist around the Doña Juana Cascabel National Natural Park. Not only does typification allow characterizing and classifying farmers according to their practices and resources, but it also provides crucial information for the design of sustainable management strategies and the promotion of resilient agricultural practices (Olivares et al., 2016).

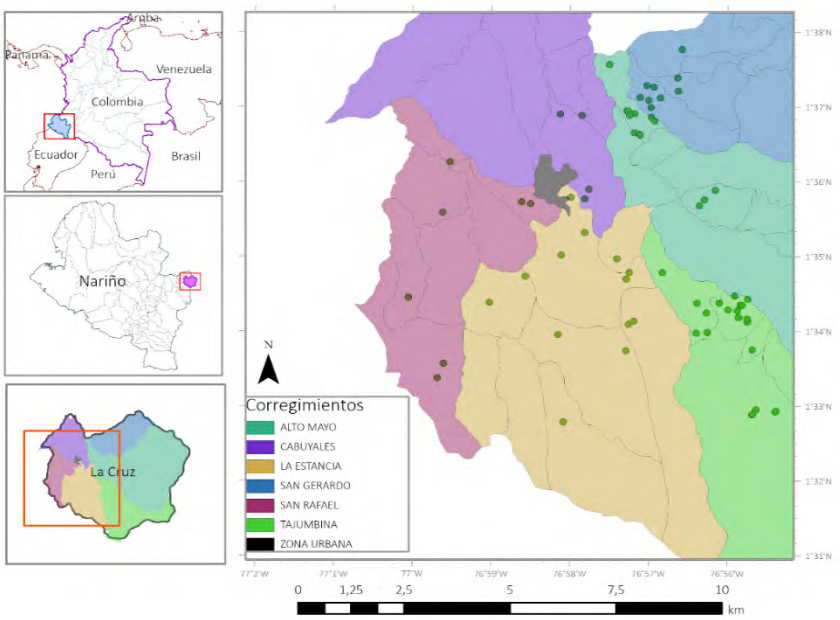
This project aimed to characterize and classify producers in the buffer zone of the Doña Juana Cascabel National Natural Park according to the variation in the productive systems in which they carry out their activities. The results of this research will serve as a basis for the design of strategies and policies that encourage sustainable and resilient agriculture in the protected area of the park.

Materials and methods

Study area

The municipality of La Cruz is located in the subregion of the Mayo River, in the northeastern part of the department of Nariño (Colombia), with coordinates 1°35'14.99'N; 76°58718.31'W. The study area was situated between 2,240 and 3,122 m.a.s.l., encompassing the rural districts of Alto Mayo, Cabuyales, La Estancia, San Gerardo, San Rafael, and Tajumbina (Figure 1).

Figure 1. Location of surveyed producer households in the municipality of La Cruz, Nariño, in the buffer zone of the Doña Juana Cascabel paramo complex, 2023
Figura 1. Ubicación de los hogares productores encuestados en el municipio de La Cruz, Nariño, en la zona de amortiguación del complejo de páramos Doña Juana Cascabel, 2023



Source: own elaboration. Fuente: elaboración propia.

Survey design

Data collection took place between September and November 2023, through the implementation of surveys to farmers and ranchers located in the influence zone of the Doña Juana Cascabel National Natural Park. The instrument consisted of 110 questions, organized into six sections: i) general sociodemographic identification, ii) productivity and agricultural management, iii) environmental aspects, iv) marketing, v) economic aspects, and vi) associativity. To ensure its effectiveness and validity, it was previously consulted with experts regarding the main characteristics of the area.

Additionally, a pilot test was conducted with representatives of local organizations to assess the clarity of the questions, execution time, and comprehension of the instrument, following Mora's methodology (Mora, 2023).

Statistical design

The sampling frame was constructed from unified databases provided by the Municipal Agricultural Secretary of La Cruz, Nariño, and the office of National Natural Parks of Colombia. A population universe of 129 producers was identified. However, due to factors such as the presence of armed conflict in the study area, time constraints, and resource limitations, it was not possible to conduct a complete census. Therefore, it was decided to carry out a probabilistic sampling following the methodologies proposed by Mucha and Lora (2021). To do this, equation (1) was used, which describes the finite and known population, and allowed determining the representative and stratified sample corresponding to 97 farmers.

$$n = Z_{\propto}^{2}.N.p.q/i^{2}\,(N-1) + Z_{\propto}^{2}\,.p.q \qquad (1)$$

Where:

n: sample size; **N:** population size; **Z:** value corresponding to the Gaussian distribution $Z_{\alpha=0.05}$ = 1.96 y $Z_{\alpha=0.01}$ = 2.58; **p:** expected prevalence of the parameter under evaluation, if unknown (p = 0.5), making the sample size larger **q:** 1 – p; **i:** error expected to be committed, if it's 5%, i = 0.5.

Data analysis

The criterion for selecting quantitative variables was a minimum coefficient of variation (CV) of 70%; the selection of qualitative variables was based on a minimum qualitative variability index (QVI) of 0.70 (Rodríguez et al., 2021). In this way, variables with greater discriminative capacity were selected to ensure statistical analysis. This selection was based on technical knowledge of the study area, which reaffirmed the relevance of each variable.

The classification of producers was carried out by selecting nine highly discriminative variables out of the initially formulated 110: (i) livestock ownership (QVI: 0.99); (ii) cultivation of achira crop (QVI: 0.94); (iii) membership in associative groups (QVI: 0.85); (iv) livestock technification (QVI: 0.81); (v) sustainable livestock management (QVI: 0.80); (vi) agricultural technification (QVI: 0.71); (vii) total area of the main crop (CV: 189%); (viii) total number of animals (CV: 163%), and (ix) total number of productive systems (CV: 72%).

Subsequently, statistical processing was carried out using a multivariate analysis technique called Mixed Data Factor Analysis (FAMD). This methodology combines the approach of Principal Component Analysis for continuous variables and Multiple Correspondence Analysis for categorical variables (Rodríguez et al., 2021).

The hierarchical cluster analysis used the Ward algorithm (Peña, 2002), and the information was represented through a factorial map. The optimal number of clusters was determined using the elbow method, analyzing the relationship between explained variance and the number of clusters to identify the inflection point in the curve (Varada et al., 2019). The analysis was conducted using R 4.2.2® software (The R Project, 2025).

To validate the identified clusters in a statistical fashion, the following methods were used: Gower distance matrix to evaluate the quality and stability of the clusters, average silhouette coefficient and silhouette plot to analyze the accuracy of the clustering, and the Hopkins

statistic to determine the natural clustering tendency of the data (clusibility) (Varada et al., 2019). Additionally, the results of the typification were validated with expert stakeholders from the municipality. This allowed for the confirmation of findings and adaptation to the specific characteristics of the territory, thus enriching the interpretation and applicability of the identified clusters.

Results

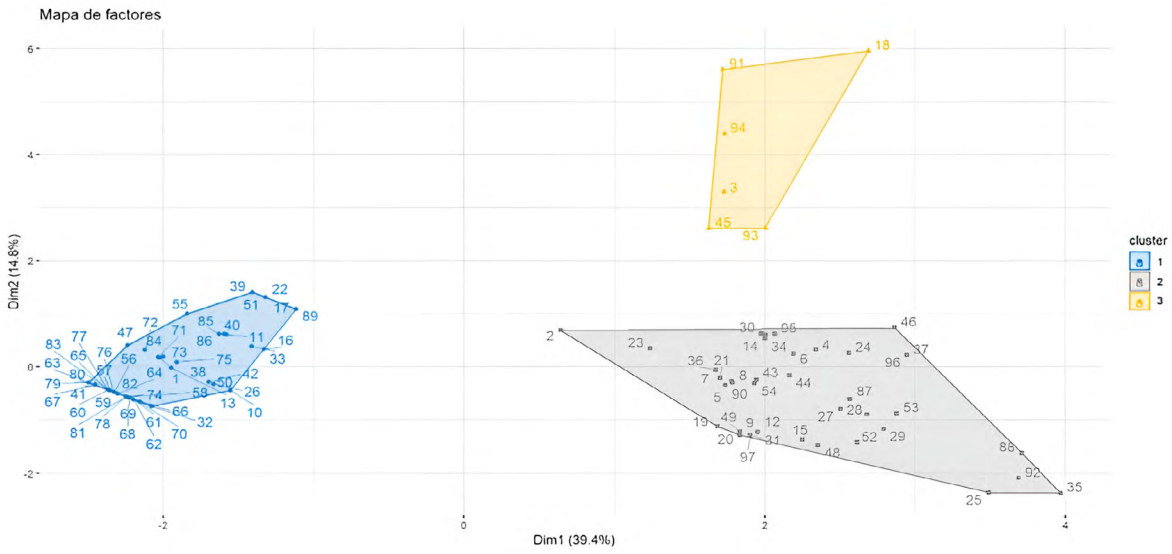
Typology of surveyed producers

Cluster analysis identified three clusters using a Euclidean distance cutoff of 0.87. Validation of the quality and stability of the clusters, using the Gower distance, indicated adequate cohesion and separation between the groups, with an average silhouette of 0.28. In turn, the silhouette plot showed good separation between the groups and appropriate assignment of observations to their respective clusters. Additionally, the data clustering capability represented by a Hopkins indicator value of 0.79 suggests that the data have a significant tendency to cluster, making them suitable for clustering techniques.

The first group, which was the largest, comprised 52.58% of the participants (51 producers). The second cluster consisted of 40 producers (41.24%). Meanwhile, the third cluster was the smallest, gathering 6 producers (6.19%).

Figure 2. Factor map of individuals according to cluster grouping for the typification of surveyed producers in the municipality of La Cruz, Nariño, in the buffer zone of the Doña Juana Cascabel paramo complex, 2023

Figura 2. Mapa factorial de individuos según agrupación clúster para la tipificación de productores encuestados en el municipio de La Cruz, Nariño, en la zona de amortiguamiento del complejo de páramo Doña Juana Cascabel, 2023



Source: own elaboration. Fuente: elaboración propia.

RIVAR Volumen 12, número 37, 2025: 121-135 • ISSN online 0719-4994
Instituto de Estudios Avanzados, Universidad de Santiago de Chile

Characterization and recommendations for identified clusters

Cluster 1. Producers with conventional agriculture and limited diversification

This cluster consists of small-scale producers (smallholders) with average crop areas of 1.06 ha. They develop their production systems using conventional agriculture techniques such as manual soil preparation and the application of synthetic chemical insecticides, fungicides, and herbicides, without productive diversification or the integration of livestock production.

The main productive system of this group is the achira *(Canna edulis)* with 66.7% of farmers dedicated to the cultivation of this crop, since it adapts well to local conditions and is grown in small farms, providing significant employment during harvest and starch extraction.

Another important system is the strawberry *(Fragaria sp.)* (13.7%), which is characterized by the use of plastic coverings and drip irrigation systems. The Albion and Monterrey varieties are the most common in the region. Following this is the sweet granadilla *(Passiflora ligularis)* (5.9%). Crops planted in smaller proportions include: field pea *(Pisum sativum),* corn *(Zea mays),* Andean raspberry *(Rubus glaucus),* Cape gooseberry *(Physalis peruviana* L), and coriander *(Coriandrum sativum),* which together represent 13.7% of farmers. However, these latter crops play a major role in the food security of the inhabitants of the buffer zone of the Doña Juana Cascabel National Natural Park.

Producers in this cluster work individually; 71.21% of them do not belong to any producer association. Besides, they have limited environmental awareness and prefer the use of chemical fertilizers over organic ones (65.15% chemical fertilization, 31.18% mixed, and 3.03% organic). Furthermore, 55.55% do not usually access bank loans to support their productive activities. These producers are located in the districts of Alto Mayo, La Estancia, San Gerardo, San Rafael, and Tajumbina.

In this context, to improve the competitiveness and sustainability of cluster 1 farmers, it is suggested to implement the selection of more productive materials adapted to the area. It is crucial to establish Integrated Pest and Disease Management (IPDM) programs that integrate the production of high-quality seeds, considering aspects of physical, physiological, genetic, and sanitary quality.

In addition, the implementation of alternative strategies is required, such as biological control through the use of products based on *Trichoderma sp*., for the control of *F. oxysporum* and *F. solani*, as well as the use of entomopathogenic fungi such as *Beauveria bassiana, Metarhizium anisopliae*, *Lecanicillium lecanii*, and the bacterium *Bacillus thuringiensis* for the control of insect pests. The use of bio-rational products such as garlic-chili hydrolates, tobacco and *neem* extracts, sulfocalcic solution, ash broth, Bordeaux mixture, among others, is also recommended. Additionally, ethological pest control through the installation of yellow, blue, and white traps and attractive traps with homemade or commercial baits such as Cebo-fruit®, for monitoring and control, is recommended. Other recommended actions for prevention include shoe disinfection and the use of tools to address soil problems due to pathogens such as *Fusarium sp*. These measures, which should be incorporated into IPDM, offer environmental, human health, and cost advantages over traditional management.

Likewise, it is important to use soil analysis to implement nutritional plans adapted to the soil and crop needs. This, along with the balanced application of solid and liquid organic fertilizers alongside chemical fertilizers, can increase crop yield and profitability by reducing production costs.

Diversifying productive activities is crucial to mitigate economic risk in the face of price volatility of these products. Moreover, promoting associativity can enhance competitiveness in product transformation, optimize transportation and sale of fresh and processed products, meet market requirements, access specialized technical assistance services, and government development projects.

Cluster 2. Producers with conventional mixed agricultural systems

They diversify production mainly with sweet granadilla and cape gooseberry crops, occupying an average area of around 0.77 ha. Nevertheless, both livestock and agricultural production show a low level of technification and environmental awareness. 30% of the producers are dedicated to livestock farming, while the remaining 70% implement two productive systems, combining dual-purpose livestock and fruit crops. On average, they maintain nine heads of cattle in an area of 7.8 ha., using the Holstein breed for breeding, raising, and fattening animals born on the same farm.

Only 10% conduct soil analysis to justify fertilization, while the remaining 90% rely on their own experience or recommendations from neighbors for fertilizer use, without considering specific soil analyses. Fertilization is distributed between organic (7.5%), chemical (27.5%), and mixed (37.5%), with the remaining 27.5% not using any type of fertilization. Weed and pest control are carried out chemically.

In livestock production, feeding is based on naturalized pastures such as kikuyu grass *(Cenchrus clandestinus)* and clovers *(Trifolium sp.),* with 80% of producers using continuous and alternate grazing, supplemented with mineralized salt, white salt, and occasionally, energy or protein concentrate. This results in an average production of five liters of milk per animal per day, with an interval between calvings of 1.21 years and 4.2 animals destined for annual sale.

The focus on commercial crops in cold climates and the high dependence on agrochemicals and irrigation characterize crop development by this group. The adoption of sustainable practices, such as silvopastoral systems, is low, with 67.5% of producers not engaging in these activities. Unlike Cluster 1, they tend to be organized into associations and regularly access credit lines. They are located in the rural areas of El Aposento, Loma Larga, and Tajumbina.

According to the above, it is crucial for producers to increase technification to enhance the productivity and profitability of their agricultural operations. It is suggested to implement minimum or vertical tillage practices to loosen the soil, break kikuyu stolons, and sow seeds of alternative grasses adapted to local climatic conditions. Similarly, it is essential to conduct soil analyses to apply amendments and fertilizers properly, thereby improving the availability and quality of pastures for animal feeding.

RIVAR Volumen 12, número 37, 2025: 121-135 • ISSN online 0719-4994
Instituto de Estudios Avanzados, Universidad de Santiago de Chile

On the other hand, implementing rotational grazing systems is required to reduce the time animals spend in the pasture, decreasing soil compaction and allowing pasture recovery. This also enables better grazing control by preventing animals from selecting certain pastures. Additionally, an inclusion strategy of silvopastoral system designs will enhance the previous actions by improving water resource utilization, maintaining soil moisture, optimizing nutrient use, and increasing biodiversity in the area.

Cluster 3. Producers with sustainable mixed agricultural systems

They distribute their productive area between pasture cultivation for cattle breeding (dairy or dual-purpose cattle) and a wide variety of crops such as potatoes, corn, peas, strawberries, sweet granadilla, blackberries, and cape gooseberries in order to loosen the soil, promote natural regeneration of native forest species, promote food sovereignty, supplement animal feed, and sell surpluses. The average area in agricultural production is 1.08 hectares, and for livestock production, it is an average of 4.94 ha with nine head of cattle. 83.33% of respondents have two productive systems (agricultural or livestock), and 16.67% have only one.

The level of agricultural and livestock technification is moderate. Soil preparation is carried out manually or with animal traction, often planting in furrows against the slope or with degrees of inclination to prevent erosion. Regarding fertilization, producers do not conduct soil analyses and utilize mixed strategies to improve soil chemical conditions such as applications of vermicompost, composted manure, and compound chemical fertilizers.

The use of dual-purpose cattle predominates, with a focus on Holstein and Criollo breeds. Producers emphasize the Holstein breed due to its adaptation to the area and its potential for milk production, in addition to using cull animals for breeding, raising, and fattening. The main forages used are kikuyu grass *(Cenchrus clandestinus),* white clover *(Trifolium repens),* and red clover *(Trifolium repens)*. 33% of producers implement some improved forage alternatives such as forage oats *(Avena sativa sp.),* Purple King Grass *(Pennisetum purpureum * Pennisetum typhoides),* Elephant grass *(Cenchrus purpureus),* and some varieties of ryegrass *(Lolium sp.).* Of these, 66.6% use naturalized species (*kikuyu, clovers*) and their mixtures *(ryegrass, oats)* through rotational grazing systems (45 days), while the remaining 33.4% use continuous grazing.

Additionally, they strategically supplement with commercial concentrates such as protein or energy types, mineralized salts, and regionally sourced by-products such as ground corn, molasses, arracacha, and potatoes. Supplementation with harvest by-products is not continuous, as it is limited by the availability of these raw materials locally. Furthermore, 100% of producers integrate silvopastoral systems into the production unit, in designs such as living fences and conservation forests, which include species such as alder *(Alnus acuminata),* elderberry *(Sambucus nigra),* motilón *(Hieronyma macrocarpa),* wax laurel *(Morella pubescens),* and walnut *(Juglans regia)*.

The productivity indices for this cluster report an annual commercialization of 4.6 animals, an average calving interval of 1.75 years, and milk production of six liters per day per animal with the implementation of good milking practices.

66% implement some sustainable practices such as water source protection, tree planting, and deforestation control. These producers are located in the rural areas of El Placer, El Paramito, Altos de Escandoy, and Loma Larga.

Based on these characteristics, it is recommended to maintain a focus on organic fertilization, which is based on composting animal manure and plant residues. However, it should be considered that direct application to the crop may increase the risk of fungal proliferation and diseases.

On the other hand, soil analysis is necessary to complement the nutrients that organic matter cannot provide to the soil. Moreover, it is important to initiate genetic improvement processes using artificial insemination and genetic selection. These processes should start from a solid genetic base for animals intended for replacement in milk production (20% to 30% of cows in production). As for the rest of the herd, crossbreeding with specialized beef production breeds should be considered to achieve greater weight gain in less time.

Lastly, considering the limited availability of water resources, it's crucial to utilize automated drinkers or materials that allow for controlling the water flow for animal consumption. In doing so, the slope of the soil should be taken into account when choosing the irrigation type, adjusting the frequency and duration of application according to the terrain properties.

Discussion

Agriculture in the buffer zone of the Doña Juana Cascabel National Natural Park is carried out by small-scale producers with limited technological and economic capacities, whose lands are located on steep slopes and affected by high climatic variability, with frequent water deficits, portraying a hostile landscape as described by Monneveux et al. (2013).

In Colombia, a significant portion of agroecosystems is vulnerable to increased aridity, erosion, desertification, and variations in the hydrological system as a result of climate change (Alarcón et al., 2019). For instance, the department of Nariño is projected to experience one of the greatest decreases in precipitation among Andean regions in the future (Ruiz et al., 2023), making it susceptible to the aforementioned biophysical effects.

In general, greater vulnerability is associated with lower capacity to implement adaptation measures (Nicholls and Altieri, 2019); therefore, the typified producer groups in clusters 1 and 2 are more susceptible to the negative effects of climate change and variability (Easterling et al., 2007; Morton, 2007).

Regarding soil, erosion on slopes, subsurface compaction, and loss of structure are the main degradation factors in Colombia due to high-intensity precipitation and anthropogenically induced factors such as indiscriminate tillage and overgrazing attributed to the lack of technical assistance and resources (Colotti, 1999).

On its part, the increase in the incidence of pests and diseases is related to the loss of and access to specialized markets. Among the challenges identified in the municipality is the characterization of viral problems reported for the area, such as Sugarcane mosaic Virus (Betancourth et al., 2020), which cause a decrease in starch yield and the loss of productive units in production plots, which farmers do not recognize as limiting due to their recent entry into the area.

RIVAR Volumen 12, número 37, 2025: 121-135 • ISSN online 0719-4994
Instituto de Estudios Avanzados, Universidad de Santiago de Chile

Although farmers cannot modify climate conditions, some factors can be managed sustainably to reduce the adverse effects of climate change in these areas, such as soil and water management, cultivar selection, and agronomic management practices, especially with agroecological approaches (Cooper et al., 2009; Moradi et al., 2013).

In this regard, FAO promotes conservation agriculture as a technique to aid adaptation and increase profits despite climatic risks, based on principles of crop rotation, the use of vegetative cover, and minimum or zero tillage (FAO, 2022). These described conditions have been identified in the management of productive systems in cluster 3, associated with crop rotation such as corn, potato, peas, and grasses; strategies for sowing or natural regeneration of relic forests within livestock systems, and the implementation of organic fertilization and biofertilization in fruit trees. Additionally, some sustainable practices were identified in cluster 1, such as harvesting and thinning planting of arrowroot, which conserves soil and reduces the harvest cycle, and the use of residual biomass from starch extraction in a few cases.

In line with the above, the study by Volverás et al. (2020) proposes *wachado* furrowing as a sustainable soil conservation practice, which, although primarily applied in rotation systems between potatoes and grasses, its process can be considered as potential for the agri-food systems present in the area. Studies in Ecuador and Nariño (Colombia) demonstrate the benefits of *wachado* planting and maximum furrow slope or contour between 60 and 70%, achieving a 20% increase in tuber yield and forage availability, a 30% increase in livestock load with a cost/benefit ratio of 40% in terms of soil organism diversity over mechanized tillage, as well as a reduction in erosion between 23 and 35%, compaction, and runoff (Volverás et al., 2020; Zapata et al., 2023).

Regarding dairy production, it represents a significant economic sector in the department of Nariño due to the generation of direct and indirect employment (UPRA, 2022). Although it faces multiple challenges due to climate change, lack of innovation, low quality, competitiveness in milk purchasing, and high production costs, the department of Nariño has positioned itself within the national dairy chain with 117,354 milking cows and 990,428 liters of milk per day, being part of one of the four high-altitude tropical dairy basins composed of Antioquia, Cundinamarca, Boyacá, and Nariño (UPRA, 2022).

In the case of La Cruz (Nariño), despite the adverse conditions present in the municipality, such as its steep topography, soil type, limited access to water, low temperatures, and low level of technological advancement in livestock management, cattle production has emerged as one of the main economic activities in the area (PDET, 2020).

This is clearly evidenced in the present study, which highlights the high participation of agricultural producers in this activity, a situation that contrasts with other paramo areas where extensive livestock farming not only impacts economically but also environmentally, causing the deterioration of conservation territories through soil compaction, consumption and deterioration of plant species, erosion, loss of biodiversity, and depletion of water reserves.

Given that the territory faces challenges in achieving sustainable development, it is necessary to develop collective action strategies such as the cultivation of arrowroot, in which the market has imposed the dynamics of selling starch as a raw material for bakery products that

are not produced in the region (Bohórquez et al., 2022). Thus, membership in work networks would facilitate rural entrepreneurship processes, leading to improvements in the social, economic, and environmental performance of agricultural units, as well as transformation ventures (Días and Franco, 2017; Wright and Paul, 2003).

Participation in producer associations can contribute significantly to the establishment of stable and sustainable processes by providing clearly defined work roles and strengthening community mechanisms such as revolving funds and community banks. In the medium term, these dynamic favours the formation of small and medium-sized producers with leadership, capable of promoting development initiatives and reducing dependence on public resources (Ramos Zambrano et al., 2021)

From this point of view, associativity improves the ability of producers to adapt to fluctuations in the economic system, particularly in terms of access to markets, high production costs, productivity levels and the integration of producers of different sizes, including small, medium and large producers (Martínez Pachón et al., 2021).

The sustainability of these work networks, formalized under the figure of agricultural associations, will depend on the heterogeneity in the relationships of each of the actors that make it up, concerning power distribution, management of their needs, and the objectives set at both individual and group levels. Cooperation in the aforementioned aspects is only possible in scenarios of symmetry (Días and Franco, 2017).

Conclusion

The study presents a typification of producers based on their main characteristics, which differentiate them from each other but share difficulties in accessing resources, education, and healthcare. Their ability to adapt to climate change is limited. The research also identified different types of agricultural systems, ranging from highly technological practices to more sustainable ones. These findings highlight the diversity of agricultural realities in the region.

In this sense, this study provides a deeper understanding of the challenges and opportunities faced by farmers in the Doña Juana Cascabel National Natural Park area, in Colombia. In addition to confirming the vulnerability of farmers to climate change and socioeconomic difficulties, sustainable practices and strategies have also been identified that could strengthen the resilience of agricultural systems in the region.

Therefore, prioritizing actions are necessary to strengthen the capacities of farmers and promote sustainable agricultural practices in the buffer zone of the paramo. This would involve the implementation of policies and programs aimed at improving access to resources, education, and health, as well as the promotion of agroecological practices and crop diversification through the construction of work and knowledge networks among farmers.

In summary, this study provides a foundation for the design and implementation of interventions aimed at promoting the sustainability and resilience of agricultural systems in the study area, which could contribute to sustainable development and the well-being of rural communities in Nariño, Colombia.

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