Characterization of bovine production system typologies on indigenous reservations (Etnia-Pijao) at Natagaima-Tolima, Colombia

Caracterización de tipologías del sistema de producción bovina en los resguardos indígenas (Etnia-Pijao) de Natagaima-Tolima, Colombia

Caracterização de tipologias de sistemas de produção bovina em reservas indígenas (Etnia-Pijao) no Natagaima-Tolima, Colômbia

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Rev. Fac. Agron. (LUZ). 2025, 42(3): e254233
ISSN 2477-9407
DOI: https://doi.org/10.47280/RevFacAgron(LUZ).v42.n3.IV

Received: 13-03-2025
Accepted: 06-06-2025
Published: 07-07-2025

Socioeconomics
Associate editor: Dra. Fátima Urdaneta
University of Zulia, Faculty of Agronomy
Bolivarian Republic of Venezuela

Keywords:
Livestock
Typologies
Multivariate analysis
Agroecosystem

Abstract

In southern Tolima, Colombia, the Indigenous Reservations (IR) of the Pijao ethnic group depend on cattle ranching, but their productive dynamics are poorly understood, making it difficult to design sustainable models. The objective of this study was to characterize the emerging typologies of the bovine production system of these IR by considering the sociocultural, techno-economic, and environmental processes. In 2023, a semi-structured interview was conducted in fifteen production units (PU) of the twenty-nine existing in the area. Indicators from each dimension (techno-economic, sociocultural, and environmental) were analyzed through multivariate analysis, identifying three typologies: G1 (46.6 %), composed by small IRs whith technology low level, showing a small-scale production; G2 (26.7 %), also grouped small IRs with small-scale production but moderately technified; and G3 (26.7 %) was integrated by large IRs, moderately technified and with a medium scale production. G3 stood out for some indicators of the techno-economic dimension. Although, all groups showed a low level of technological adoption, which resulted in poor productive and reproductive performance. The differences in G3's better economic outcomes are due to its larger scale of production. In the social sphere, female leadership stood out, especially in groups with the highest proportion of trained people (G2 and G3). Overall, the PUs showed soils with poor organic matter content, low fertility level, little forest coverage and a moderate degree of erosion, indicating some alterations of the agroecosystem.

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Resumen

En el sur del Tolima, Colombia, los Resguardos Indígenas (RI) de la etnia Pijao dependen de la ganadería, pero sus dinámicas productivas son poco conocidas, lo que dificulta el diseño de modelos sostenibles. El objetivo de este estudio fue caracterizar las tipologías emergentes del sistema de producción bovina de estos RI considerando los procesos socioculturales, tecnoeconómicos y ambientales. En 2023, se realizó una entrevista semiestructurada en quince unidades de producción (UP) de las veintinueve existentes en la zona. Los indicadores de cada dimensión (tecnoeconómica, sociocultural y ambiental) fueron analizados mediante análisis multivariado, identificando tres tipologías: El G1 (46,6 %), compuesto por RI pequeños, con bajo nivel tecnológico y producción a pequeña escala; el G2 (26,7 %), agrupó también a RI pequeños con producción a pequeña escala, pero moderadamente tecnificados; y el G3 (26,7 %) estaba integrado por RI grandes, moderadamente tecnificados y con una producción a mediana escala. El G3 se destacó en algunos indicadores de la dimensión tecnoeconómica. Sin embargo, todos los grupos mostraron un bajo nivel de adopción tecnológica, lo que resultó en un pobre desempeño productivo y reproductivo. Las diferencias en los mejores resultados económicos del G3 se deben a su mayor escala de producción. En el ámbito social, se destacó el liderazgo femenino, especialmente en los grupos con mayor proporción de personas formadas (G2 y G3). En general, las UPs mostraron suelos con pobre contenido de materia orgánica, bajo nivel de fertilidad, escasa cobertura forestal y un moderado grado de erosión, indicando algunas alteraciones del agroecosistema.

Palabras clave: ganadería, tipologías, análisis multivariado, agroecosistema.

Resumo

No sul de Tolima, Colômbia, as Reservas Indígenas (RI) da etnia Pijao dependem da criação de gado, mas suas dinâmicas produtivas são pouco conhecidas, dificultando o desenho de modelos sustentáveis. O objetivo deste estudo foi caraterizar as tipologias emergentes do sistema de produção bovina dessas RI, considerando os processos socioculturais, tecnoeconômicos e ambientais. Em 2023, foi realizada uma entrevista semi-estruturada em quinze unidades de produção (UP) das vinte e nove existentes na área. Os indicadores de cada dimensão (tecnoeconômica, sociocultural e ambiental) foram analisados por meio de análise multivariada, identificando três tipologias: O G1 (46,6 %), composto por pequenas RI, com baixos níveis de tecnologia e produção em pequena escala; o G2 (26,7 %), também agrupava pequenas EIs com produção em pequena escala, mas moderadamente tecnificadas; e o G3 (26,7 %) era integrado por grandes RI, moderadamente tecnificadas e com produção em média escala. O G3 destacou-se em alguns indicadores da dimensão tecno-económica. No entanto, todos os grupos apresentaram um baixo nível de adoção tecnológica, o que resultou num fraco desempenho produtivo e reprodutivo. As diferenças nos melhores resultados económicos do G3 devem-se à sua maior escala de produção. Na esfera social, a liderança feminina destacou-se, sobretudo nos grupos com maior proporção de pessoas formadas (G2 e G3). No geral, as UPs apresentaram solos com baixo teor de matéria orgânica, baixo nível de fertilidade, pouca cobertura florestal e um grau moderado de erosão, indicando algumas alterações do agroecossistema.

Palavras-chave: pecuária, tipologias, análise multivariada, agroecossistema.

Introducción

There are about 476 million indigenous peoples worldwide, representing 6.2 % of the world's population. Their territories cover 28 % of the planet's surface and account for 11 % of the world's forests (Food and Agriculture Organization of the United Nations [FAO], 2024). The ways of life and subsistence of these ethnic groups integrate elements that allow food production in harmony with nature. This is related to local ecological knowledge, forest conservation, native crops and agricultural practices that are resilient to climate change (FAO, 2024). These production models are considered to have the potential to feed the world based on the structuring of sustainable agrifood systems in the world.

There are 1.9 million indigenous people in Colombia, of whom 62,836 live in the department of Tolima and 6,845 in the Natagaima-Tolima municipality. (Departamento Administrativo de Estadística de Colombia [DANE], 2018). Most of this population belongs to the Pijao ethnic group, native peoples of Tolima, who live and develop their activities in rural areas, based on the interrelationship of spirits, gods and mother earth; they are mostly organized as Indigenous Reservations (IR) and use a large part of their territory for cattle ranching, becoming one of their main economic activities (Organización Nacional Indígena de Colombia [ONIC], 2024). However, there is very scarce information that allows a more precise understanding of the dynamics and interrelationship of the socio-cultural, technical-economic and environmental processes of these productive units (UP), which is of utmost importance for planning the care of these communities.

Some published references on the socioeconomic dynamics of these livestock systems showed its realtionship to a low technological adoption, production backwardness, limited development of the value chain and low competitiveness (Arrieta-González *et al*., 2022). These conditions are closely related to the conventional dual-purpose bovine system (SDPBC) in Colombia, where more than 60 % of the UPs develop forms of production focused on an animal feeding model based on grazing, stocking rate of 0.5 $AU.ha^{-1}$, in pastures with predominantly gramineae cover, mostly overgrazed (Parodi *et al*., 2022; González-Quintero et *al*., 2020). This management, leads to a soil degradation and water contamination, and also favors indirectly deforestation processes (Parodi *et al*., 2022). Finally, these conditions are expressed in a poor agribusiness technical-economic performance since they can barely produce 44.5 kg of $meat.cow^{-1}.year^{-1}$, 483.3 L of $milk.cow^{-1}.year^{-1}$ and the profitability is below 14 % (Ortiz-Valdes *et al*. 2023). In the same way, it is likely that IRs are immersed in a production model far removed from their cultural identity, contributing to the progressive degradation of their agroecosystems and the deterioration of the quality of life of these ethnic groups.

Characterization and typification processes are important as mechanisms to identify limitations and opportunities in order to promote changes in the socio-cultural, technical-economic and environmental components of UPs (Cuevas-Reyes and Rosales-Nieto, 2018). This favors the approach of viable production alternatives to improve technical-economic performance, considering a reduction in environmental impact and a better linkage with local ecological knowledge (Arrieta-González et al., 2022). The objective of this paper was to characterize the typologies of productive units considering the socio-cultural, technical-economic and environmental processes of the RI cattle production system (Pijao ethnic group) at Natagaima-Tolima municipality, Colombia.

Materials y methods

Study area

This study was carried out in the bovine productive units of the indigenous reservations (Pijao ethnic group), Municipality of Natagaima-Tolima, Colombia, located at coordinates 3°37'18.0 "N 75°05'36.2 "W. This region corresponds to the tropical dry forest life zone, between 0-1000 masl, with an average temperature of 32 °C. It is also characterized by precipitation between 1,000 and 1,500 mm per year, with a bimodal climatic regime, with two dry seasons (December-March and July-September) and two rainy seasons between April-June and October-December (Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM, 2024).

Sampling thecnique and sample size

A non-probabilistic convenience sampling was used (Otzen and Manterola, 2017), given the need to have the voluntary participation of the communities, the legally constituted indigenous reserves were selected and they expressed their voluntary willingness to participate in the research. The study included fifteen IRs out of the twenty-nine existing in the area (Ministerio de Tecnologías de la Información y las Comunicaciones de Colombia, 2024).

Data collection and related variables.

The fieldwork was carried out in the first half of 2023. Previously, an informed consent form was signed explaining the objectives and scope of the study. Data were obtained through semi-structured interviews with the indigenous leaders (governors) of each community, using a guide designed by three expert researchers, which addressed socio-cultural, technical-economic and environmental aspects (Table 1). In addition, data were verified through field visits and a review of production records.

The Animal Unit measure was considered as established by González-Quintero et al (2020). The index of machinery (IMAQ) and infrastructure (INFRA) was calculated using an adjustment of the methodology proposed by Cuevas-Reyes and Rosales-Nieto (2018). The analysis of fifteen implements (plow, tractor, cooling tank, harrow, mill, chopper machine, water pump, scale, straw thermo-storage, mechanical milking machine, rennet vats, back pump, pickup truck, trailer and scythe) and fifteen facilities (animal handling pen, milking parlor, administrative area, maternity paddock, feeding troughs, drinking area, salting area, electric fences, input storage, calf grazing paddocks, pharmacy, house, calf grazing paddock, manure management area). The indexes were calculated by dividing the amount of equipment or facilities found in the UPs by 15 x 100.

The technological adoption index (TAI) was estimated by adjusting the methodology proposed by Valdovinos *et al.* (2015), integrating twenty-one technological components (technical and economic records, water harvesting, deworming and vaccination, genetic selection and improvement, integrated management of ectoparasites, disease diagnosis, good milking practices, animal load adjustment, pasture rotation, electric fences, forage conservation, supplementation with balanced diets, silvopastoral systems, fertilization of grazing areas, irrigation systems, forage banks, mineral supplementation, artificial insemination, gestation diagnosis and reproductive evaluation of the breeding male. In the calculation of this index, a value of 0 was considered if the producer does not apply the technology, 0.5 if it applies it deficiently and 1 if it applies it adequately, the total value of the index being the arithmetic sum of what was found.

The birth rate was valued considering the number of calves born per year. The PEC and PEL and the economic performance indicators were determined by means of the methodology used by Ortiz-Valdes *et al.* (2023). The environmental variables were evaluated by analyzing geospatial information in ArcGIS Desktop version 10.8 (Environmental Systems Research Institute (Esri, 2020). For this purpose, the Shape type file corresponding to the Map of marine and coastal continental ecosystems of Colombia-2017 (Ministerio de Ambiente y Desarrollo Sostenible de Colombia (Minambiente, 2024) was used.

Table 1. Description of the dimensions and indicators studied in the cattle production systems of Pijao indigenous communities of Natagaima-Tolima, Colombia.

Sub dimension	Indicators by dimension
Socio-cultural dimension	
1) Social and cultural	Number of families (NF), persons (NP) and persons per family (NPF) that make up the community, time of experience in community cattle production (TE), sex of the indigenous leader (male, female), personnel trained in cattle management (yes, no).
Técnico-económico dimension	
2) Production unit management	Livestock management area (GA), number of paddocks (NP), stocking rate (CA), number of total cows (NVT) and milking cows (NVO), milk production (PL), technology adoption index (IAT), infrastructure index (IINFRA and machinery (IMAQ).
3) Productive performance	Milk production per day (PLD), milk production per cow (PLV), calf weight (PD) and age at weaning (ETD), calf weight gain/day (GPD), milk production per lactation (PLL), and effective milk (PEL) and meat (PEC) production.
4) Reproductive performance	Age at first calving (EPP), cow days open (DA), calving interval (IEP) and birth rate (TN).
5) Economic performance	Total gross income per year (IB), production cows per year (CPA), net income per year (BN) and per family (BNF), return on cost.
Ambiental dimension	
6) Environmental	Land cover and land use (dense forest, fragmented forest, gallery forest, crops and pastures). Soil characteristics; depth (deep or shallow), pH (alkaline, acid and neutral), organic matter (high, medium and low) and fertility (high, medium and low), soil erosion (light, moderate and severe).

Statistical analysis

To group the IRs, a principal component analysis (PCA) was performed, considering only quantitative variables, which represented more than 75 % of the variables linked to the study. The PCA was applied by blocks of subdimensions, to reduce the dimensionality of the information and multicollinearity between variables, maintain the conceptual coherence of the indicators, and thus improve the robustness of the analyses in view of the available sample size (n=15).

A hierarchical cluster analysis (Ward's algorithm) was then performed, integrating the components of each subdimension that explained the greatest variance in the model (cut-off point greater than 70 %). Basic statistics (means and frequency tables) were used to characterize the groups. In addition, the effect of the groups found on the quantitative variables was evaluated by analysis of variance (ANOVA), considering the typologies as a fixed effect, within a general linear model. The analysis was complemented with Tukey's multiple comparison tests (α=0.10). All analyses were performed by SAS Enterprise Guide 8.3 software (SAS Institute Inc., 2020).

Results and discussion

Principal Component Analysis

The principal component analysis made it possible to select the following components: in subdimension 1 (social and cultural), the first 3 PCs were selected, which explained 99.9 % of the variability; in subdimension 2 (management of the productive unit), the first 3 PCs were chosen which explained 74.7 % of the variability; in subdimension 3 (productive performance), were selected the first 2 PCs, with 80.0 %; and for dimensions 4 (reproductive performance) and 5 (economic performance), the first 2 PCs were selected, with 88.4 % and 98.0 %, respectively (Table 2).

PCA did not imply a large reduction in the number of variables. However, it allowed grouping redundant information into latent components by subdimension block, improving the robustness of the cluster analysis, compared to the sample size (n=15) available.

Ethnic agroecosystems Typology

Based on the CPs selected in the five thematic areas, the IRs were classified into three groups or types of UPs, according to the following characteristics:

Group 1 (G1): small reservations, with reduced availability of infrastructure and small production scale (n=7; 46.6 %); group (G2): small reservations, with moderate availability of infrastructure and small scale of production (n: 4; 26.7 %) and group 3 (G3): Large reservations, with moderate availability of infrastructure and medium scale of production (n=4; 26.7 %).

Characteristics of the production unit groups

The mean comparison test between groups showed statistically significant differences (α=0.10) to the variables: number of families, number of people, number of animals, number of milking cows, infrastructure index, milk production per day, calving interval, birth rate, effective milk production, gross income, production costs, net income, income per family, and profitability (Table 3).

Groups 1 (G1) y 2 (G2)

These two groups of UP have similarities in most of the studied characteristics. However, G2 has 15.83 more families per community, 8.67 more infrastructure index and 69.61 more days of cows calving interval than G1 (**α**=0.10). In these groups, women participate in community leadership. G1 carries out productive activities in an empirical way, while G2 has trained personnel.

Table 2. Principal components retained by thematic subdimension, variance explained and higher factor weights variables.

Sub dimension	CP	Explained variance (%)	Variable	Factorial weight
Social and cultural	1	43.85	Number of persons	0.73
			Number of persons per family	0.61
	2	31.93	Number of families	0.84
	3	24.07	Time of experience	0.97
Production unit management	1	38.26	Number of paddocks	0.41
			Number of milking cows	0.39
			Number of animals	0.33
			Infrastructure index	0.40
	2	23.06	Area dedicated to livestock	0.59
			Animal load	-0.44
	3	13.35	Technology adoption index	0.68
			Machinery index	0.54
Productive performance	1	51.14	Milk production per day	0.42
			Milk production cow day	0.45
			Milk production per lactation	0.51
			Effective milk production	0.51
	2	28.78	Final calf weight	0.66
			Effective meat production	0.66
Reproductive performance	1	56.69	Age at firts birth	0.69
	2	31.78	Interval between births	-0.44
Economic performance	1	81,53	Net income per family	0,45
			Gross income	0,46
			Net income	0,49
	2	16,51	Production cost	-0,52
			Return on cost	0,67

PC: principal components

Cattle raising activity is carried out in areas with a medium sized surface area, also with medium sized herds with scarce availability of milking cows (Table 3). These groups reflect a small technological adoption rate (<5.85 rated from 1 to 21). Animal feeding is mainly based on grazing, with *Bothriochloa pertusa* forages, using a rotational system with low stocking rate (<0.87 AU.ha^{-1}). Nutritional supplementation is based on the supply of mineralized salt and little amounts of corn silage that were used during the dry season (mainly for milking cows) in some UPs. G1 and G2 showed basic infrastructure for the management of the production system. However, the G2 infrastructure index is higher compared to G1 (α=0.10), since there are approximately 20 and 25 % more UP that have a pharmacy area and maternity paddocks in G2.

These groups are characterized by an average milk production less than 51.37 L.day^{-1} and an individual production per cow lower than 3.21 L. day^{-1}, reaching a lactation anual volume less than 730.95 L. At the same time, they showed an annual birth rate less than 0.57 calves.cow^{-1} and an effective annual production that did not exceed 98 kg.cow^{-1} of meat and 414.64 L.cow^{-1} of milk. These groups are statistically similar in most of the economic indicators, except for net income per family, which is $32.4 USD higher in G1 compared to G2.

Table 3. Socio-economic characteristics by typology of bovine agrosystems on indigenous reservations.

Indicator	G1 (n=7)	G2 (n=4)	G3 (n=4)
Social and cultural			
Number of families	30.42 a	46.25 b	47.25 b
Number of persons	255.43 a	284.75 a	536.50 b
Number of persons per family	9.00 ab	6.06 a	11.5 b
Time of experience (years)	21 .71 a	23.50 a	20.75 a
Productive unit management			
Livestock management area (ha)	136.3 a	73.25 a	12 .5 a
Stocking rate (AU.ha^{-1})	0.63 a	0.87 a	0.88 a
Number of total cows	66.85 a	85.25 a	153.75 b
Number of cows in milking	14.57 a	16.50 a	33.50 b
Technology adoption index (0-21)	5.85 a	4.25 a	7.25 a
Infrastructure index (0-100)	52.04 a	60.71 b	62.50 b
Machinery index (0-100)	21.9 a	28.33 a	30.00 a
Productive performance			
Milk production per lactation (L)	730.95 a	709.48 a	1,108.03 b
Milk production (L.day^{-1})	39.1 a	51.37 a	133.12 a
Milk production per cow (L.day^{-1})	2.70 a	3.21 a	3.91 a
Weaning weight (kg)	172.8 a	163.75 a	176.5 a
Weight gain (kg.day^{-1})	0.54 a	0.63 a	0.52 a
Effective milk production ***	414.64 ab	362.73 a	607.17 b
Effective meat production ****	98.27 a	84.03 a	95.9 a
Reproductive performance			
Age at first birth (months)	36.80 a	37. 5 a	35.70 a
Birth interval (days)	643.19 a	712.80 b	674.41 ab
Birth rate	0.57 b	0.51 a	0.54 ab
Economic performance			
Gross income (USD*)	11,973.55 a	11,241.90 a	25,364.46 b
Production costs (USD*)	10,263.70 a	10,139 .87 a	20,217.72 b
Net income (USD*)	1.709.85 a	1,102.03 a	5,146.74 b
Net income per family (USD*)	56.20 b	23.80 a	109.04 c
Return on cost (%)	16.0 ab	10.00 a	25.00 b

*1 USD equals to $ 4,129.5 COP (exchange rate of October 29, 2023). ** (Calves. cow^{-1} by year); *** (L.cow^{-1}.year^{-1}); **** (kg.cow^{-1}.year^{-1}). Different letters between rows indicate significant differences (p<0.10), according to Tukey test.

Table 4. Socio-cultural characteristics by typology in the cattle production system of indigenous reserves.

Variables	Categoría	G1 (n=7, %)	G2 (n=4, %)	G3 (n=4, %)
Indigenous leader sex	Man	5 (71,4)	1 (25,0)	2 (50,0)
	Female	2 (28,6)	3 (75,0)	2 (50,0)
Trained personnel	Yes	0 (0,0)	3 (75,0)	3 (75,0)
	No	7 (100,0)	1 (25,0)	1 (25,0)

The analysis of gross income and production costs of the two groups showed a profit and a return on cost less than $ 1,709.85 USD and 16 %, respectively.

In these UPs, the predominant land use cover is pasture and crop areas, with superficial soils in most of the farmlands. There was also a predominance of soils with poor organic matter content, low fertility, slightly acidic and acidic pH, with a predominantly moderate level of erosion (Table 5). These physicochemical characteristics of the soil are indicative of a degradation process. This condition can be attributed mainly to the low forest cover, which limits water infiltration capacity and causes the soil to be more exposed to the sun. As a result, the soil's internal humidity is deficient and its biological activity is altered. In turn, the scarce forest cover restricts nutrient cycling and favors the minerals washing from the soil by runoff (Parodi *et al*., 2022).

Table 5. Environmental characteristics by typology on indigenous reserves cattle production system.

Variables	Categoría	G1 (n=7, %)	G2 (n=4, %)	G3 (n=4, %)
Land Use Coverage	Pasture and crops	7 (100.0)	4 (100.0)	4 (100.0)
	Gallery forest	1 (14.4)	2 (50.0)	0 (0.00)
	Dense forest	3 (42.8)	2 (50.0)	0 (0.00)
	Fragmented forest	1 (14.4)	0 (0.00)	0 (0.00)
Soil depth	Deep	1 (14.3)	1 (25.0)	2 (50.0)
	Superficial	6 (85.7)	3 (75.0)	2 (50.0)
Soil pH	Alkaline	0 (0.00)	0 (0.00)	2 (50.0)
	Acid	1 (14.4)	2 (50.0)	0 (0.00)
	Neutral	3 (42.8)	0 (0.00)	1 (25.0)
	Slightly acidic	3 (42.8)	2 (50.0)	1 (25.0)
Soil organic matter level	High	0 (0.00)	0 (0.00)	0 (0.00)
	Medium	0 (0.00)	0 (0.00)	0 (0.00)
	Low	7 (100.0)	4 (100)	4 (100.0)
Soil fertility level	High	0 (0.00)	0 (0.00)	0 (0.00)
	Moderate	3 (42.9)	1 (25.0)	4 (100.0)
	Low	4 (57.1)	3 (75.0)	0 (0.00)
Soil erosion level	Slight	0 (0.00)	0 (0.00)	1 (25.0)
	Moderate	2 (28.5)	1 (25.0)	2 (50.0)
	Severe	0 (0.00)	0 (0.00)	0 (0.00)
	Slight to moderate	1 (14.4)	1 (25.0)	1 (25.0)
	Moderate to severe	4 (57.1)	2 (50.0)	0 (0.00)

Grupo 3 (G3)

In this group, women also play a very important role in community leadership processes, since half of the UPs are being guided by women. These UPs are made up of a large population size, with 281.07 and 251.75 more people per community than the G1 and G2 groups (p<0.10), respectively. In addition, the size of the family nuclei of G3 are larger compared to the previous groups. These differences could be due to historical, socio-political, economic factors or settlement strategies, which have influenced the differential growth of the communities (Ortiz-Gordillo *et al*., 2023; Velásquez, 2021).

The G3 UPs are slightly larger in area, but without statistically significant differences compared to G1 and G2 (p>0.10). The zootechnical characteristics of the G3 herd are similar to those of the G1 and G2 groups. The technological adoption index of the G3

UPs is low (7.5 from 1 to 21), while, the index of infrastructure and machinery are slightly higher than the previous groups. However, the forms of production in these models are related to the characteristics of the SDPBC (González-Quintero *et al*., 2020), where meat and milk are produced in grazing systems, with predominantly Bos Taurus x Bos Indicus animals and technological indexes that do not exceed 10.8 points as reported by Chuquirima *et al.* (2023).

Among the overall herd characteristics, G3 exceeds the number of total animals by 86.9 and 68.5 compared to G1 and G2 UPs respectively (α=0.10). Similarly, G3 UPs have 19 and 17 more milking cows compared to G1 and G2 groups. In this sense, milk availability per day was higher by 94.02 and 81.75 L in contrast to G1 and G2. These characteristics demonstrate a superior production scale of G3 compared to G1 and G2. This condition may be associated with a better availability of technology, machinery, infrastructure and a more organized productive development in G3 (Arrieta-González *et al*., 2022).

The individual productive performance of G3 analyzed by milk production per day (3.91 L), calf weight gain (0.52 kg.day^{-1}), age at first calving (35.7 months), annual calving rate (0.54 calves. cow^{-1}) and effective annual meat production (95.9 kg.cow^{-1}) did not differ statistically from those found in G1 and G2 UPs (α=0.10). In contrast, effective annual milk production in G3 (607.17 L.cow^{-1}) was higher by 192.53 and 105.7 L. cow^{-1} compared to indicators found in G1 and G2, which were statistically different from G2, but equal to G1. The economic performance analysis showed superiority in all G3 indicators compared to G1 and G2, with the exception of return on cost, which was similar to G1 ($p>0.10$). Thus, this group expresses better economic performance and monetary benefit per family compared to the other two groups (Table 3). The superiority in economic performance of G3 compared to G1 and G3 arises mainly from technological superiority and larger scale of production. These factors are associated as important contributors to the advantage in individual and group milk yield, and consequently in gross income.

100 % of the UPs in G3 have only pasture and cropland areas for land use. Fifty percent of the UPs develop their agricultural activities on superficial soils and the rest on deeper soils. The soil pH varies from farm to farm, ranging from alkaline, neutral and slightly acidic (Table 5). The organic matter content is poor in all the UPs. Fertility levels are moderate. The soil has a level of erosion that varies between light, light to moderate, moderate and moderate to severe, with variation between UP. These environmental characteristics, as in G1 and G2, contrast with the worldview of the Pijao people, who conceive of human beings as guardians of the balance between the spiritual and the physical, which represent the resources of Mother Earth (ONIC, 2024). Thus, it can be interpreted that these indigenous communities have not configured their territory according to their cultural principles.

Conclusions

The principal component and cluster analyses identified three types of production units differentiated by population size, infrastructure index and scale of production. G3 stood out due to some of its technical-economic performance indicators. However, all groups present a small degree of technological adoption, a low index of machinery and a reduced stocking rates management in similar áreas size ($\alpha\geq0.10$), obtaining a weak productive and reproductive performance; thus, the differences in the best economic results of G3 are mainly related to a larger scale of production (greater number of milking cows).

In the social sphere, female leadership stood out, particularly in groups G2 and G3, that were also characterized by a higher proportion of trained people, which may favor the adoption of practices oriented towards the care and improvement of the productive process.

The environmental characteristics of the studied Ups, showed predominant pasture and crop cover, with poor organic matter soil content, low fertility, scarce forest coverage and a predominant moderate level of erosion, indicating alterations in the agro-ecosystem.

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