Revista de CIENCIAS AGRÍCOLAS

e-ISSN Online 2256-2273

Received: June 14 2024 Accepted: February 18 2025 Published: April 28 2025

Research article: Soil science

Evaluation of the physical and chemical properties of andisol order soils under different production systems

Evaluación de las propiedades físicas y químicas en suelos del orden andisol en diferentes sistemas de producción

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Cite: Lazo-Bravo, S.A.; Mora-Tisoy J.V.; Guerra-Acosta, A.; Coral-Narvaez E.V.; Solarte-Benavides Y.E. (2025). Evaluation of the physical and chemical properties of andisol order soils under different production systems. Revista de Ciencias Agrícolas. 42(1): e1255.

ABSTRACT

Analyzing the chemical and physical properties of the soil is essential to understanding its fertility and structure, which allows for improving the availability of nutrients and optimizing soil management, contributing to agricultural sustainability. This study was conducted in the Cascajo area of Santiago Putumayo. The objective was to determine the behavior of the chemical properties (cation exchange capacity - CEC, organic matter - OM, organic carbon - CO, pH, and nitrogen - N) and physical properties (apparent density, porosity, gravimetric humidity, and hydraulic conductivity) of andisol soils under different production systems. Three systems were evaluated: T1 - Secondary Forest system, T2 - Livestock system, and T3 - Agricultural system with blackberry cultivation (*Rubus glaucus* Benth). A completely randomized design (CRD) was employed, and soil sampling for chemical variables was done at a depth of 0 - 15 cm; however, they were done at depths of 0 - 15 and 15 - 30 cm for physical properties. The results indicate that the secondary forest system showed the most behavior in chemical variables CEC, MO, CO, and N with values of 10.02, 12.71, 7.42, and 0.64, as well as the highest values in the variables of gravimetric humidity with 250.14, porosity with 77.49, and hydraulic conductivity with 1.57. These findings highlight the importance of forests as systems capable of conserving soil properties more effectively that other production systems, due to their organic matter content, biological diversity, and minimal anthropic disturbance.

Keywords: bulk density; cation exchange capacity; hydraulic conductivity; organic carbon; organic matter; porosity

RESUMEN

Analizar el comportamiento de las propiedades químicas y físicas del suelo es esencial para entender su fertilidad y estructura, puesto que, permite mejorar la disponibilidad de nutrientes y optimizar el manejo del suelo en beneficio de la sostenibilidad agrícola. Este estudio se realizó en la vereda Cascajo de Santiago Putumayo, el objetivo fue determinar el comportamiento de las propiedades químicas (capacidad de intercambio catiónico - CIC, materia orgánica - MO, carbono orgánico – CO, pH y nitrógeno - N) y físicas (densidad aparente, porosidad, humedad gravimétrica, conductividad hidráulica) de suelos andisoles en diferentes sistemas de producción. Para ello se evaluaron tres sistemas: T1- Sistema de bosque secundario, T2 - Sistema ganadero y T3 - Sistema agrícola con cultivo de mora (*Rubus glaucus benth*). Se realizó un diseño completamente aleatorizado (DCA) y el muestreo de suelo de las variables químicas se hizo a una profundidad de 0 – 15 cm; sin embargo, para las propiedades físicas se hicieron a profundidades de 0 – 15 y 15 – 30 cm. Los resultados obtenidos indican que el sistema de bosque secundario presentó el mejor comportamiento en variables químicas CIC, MO, CO y N con valores de 10,02, 12,71, 7,42 y 0,64, al igual que mayores valores en las variables de humedad gravimétrica con 250,14, porosidad con 77,49 y conductividad hidráulica con 1,57. Finalmente, se resalta la importancia de los bosques como sistemas capaces de conservar las propiedades del suelo en comparación con otros sistemas de producción, debido a su contenido de materia orgánica, diversidad biológica y baja intervención antrópica.

Palabras clave: capacidad de intercambio catiónico; conductividad hidráulica; carbono orgánico; densidad aparente; materia orgánica; porosidad

INTRODUCTION

The evaluation of the chemical and physical properties of soil is essential for understanding soil quality in agricultural and livestock production systems, where factors such as compaction, erosion, and loss of organic matter directly impact productivity and sustainability (González-Sánchez, 2008; Calderón-Medina *et al.,* 2018). Soil erosion is one of the ten major threats identified in a 2015 report on the global status of soil resources. Although this phenomenon can occur naturally across various climates and continents, it is exacerbated by unsustainable human practices such as intensive agriculture, deforestation, overgrazing, and land-use changes. These practices degrade soil productivity and threaten food security (Organización de las Naciones Unidas para la Alimentación y la Agricultura, 2025).

Similarly, Castelán *et al.,* (2017) state that soil erosion is one of the world's leading environmental issues, causing a progressive loss of soil and its essential nutrients, and ultimately reducing the soil's biological potential for production. Gómez-Calderón *et al.,* (2018) assert that soil compaction is one of the most significant degradation processes caused by agricultural activities. It affects water infiltration and retention capacity, decreases nutrient availability, reduces effective soil depth, lowers organic matter content, and consequently diminishes productivity.

In Colombia, several studies have shown that intensive land use and the introduction of mechanical and chemical practices alter ecosystems and reduce the soil's capacity to nourish and sustain crops, thereby affecting biodiversity and the quality of ecosystem services (Dutta *et al.,* 2017; Mora-Marín *et al.,* 2017). In addition, Martínez *et al.,* (2008) highlight how agricultural activities impact carbon storage and the balance of essential nutrients, such as carbon and nitrogen, thereby influencing the decomposition of organic matter and soil health. One of the most significant issues in soil degradation is continuous cropping combined with irrigation, fertilization, and mechanization. These practices lead to the loss of soil organic carbon (SOC), alter physical properties, such as the destruction of microaggregates, disruption of the soil's original structure, increased dispersion factor, and contribute to soil compaction (Hernández *et al.,* 2022).

Soil quality is affected by factors such as increased bulk density resulting from compaction and erosion. Additionally, livestock farming is associated with ecosystem degradation due to its impact on the soil and the pressure it exerts on forests as a result of deforestation for pasture establishment (Calderón-Medina *et al.,* 2018).

In this context, the study of these properties in different productive systems—such as agriculture, livestock, and forestry—is essential to formulate management strategies that preserve soil resources. In the Cascajo area, located in Santiago

Putumayo, the continuous use of agrochemicals and poor management of organic matter have considerably altered these properties, reducing the soil capacity to sustain valuable ecosystem services. Therefore, understanding how land use practices influence the physicochemical properties of soil is key to promoting sustainable agricultural practices and preventing soil degradation (Luna, 2017).

This research aimed to evaluate the behavior of the chemical and physical properties of soil under different production systems.

MATERIALS AND METHODS

Location

The research was carried out in the Cascajo area of the municipality of Santiago, Putumayo, located at 1° 08'13.2 "LN 77° 01'16.1" LO, with an altitude of 2150 masl, average annual rainfall of 2500 mm, temperature of 16 °C and a relative humidity of 76%. The soils are within the Andisols order. According to Medina-Castellanos *et al.,* (2017), the Andisols mountain or hillside soils are derived from volcanic ash with very fine textures; they are deep and, in some sectors, limited by coarse rock fragments. It is located within the Low Montane Humid Forest life zone (bh-MB) (Holdrige, 2000).

Description of the different production systems

Three production systems were selected, which are described below (Table 1):

Table 1. *Description of soil uses for the determination of physical and chemical properties at two depths of 0-15 cm and 15-30 cm*

Land use	Species	Age	Planting distance	Planting density
Secondary forest	Chilca (*Baccharis latifolia*), May tree (*Turdus ignobilis*), Motilón (*Hieronyma colombiana*), Yarumo (*Cecropias* spp.), spoonbill (*Rapanea guianensis*), cedar (*cedrela montana*), myrtle (*Myrcianthes rhopaloides*), cauchillo (*Sapium* sp.)	40-50 years	2 × 3 m	>10,000 trees/ha
Cattle raising	Kikuyu (*Pennisetum clandestinum*)	20-25 years	Randomly	Indeterminate
Agricultural	Blackberry (*Rubus glaucus*)	3-4 years	2.5 × 2.5 m	2,000 plants/ha

Experimental design

A completely randomized design (CRD) was used to assess the chemical and physical properties of the soil across three production systems. Three treatments were considered: T1 – secondary forest, T2 – livestock, and T3 – blackberry cultivation. Each treatment was replicated four times for a total of 12 experimental units. Soil samples for chemical variables was carried out at a depth of 0 – 15 cm; however, for the physical properties, two depths were used: 0 – 15 and 15 – 30 cm. The physical soil samples were analyzed at the laboratory of the Technological Institute of Putumayo, while the chemical samples were analyzed at the specialized laboratories of AGROSAVIA.

Determination of the chemical and physical properties of the soil

The properties evaluated were (Table 2):

Table 2. *Physical and chemical properties and determination method*

Physical and chemical properties	Method of determination	Unit of measurement
Apparent density (ρa)	Cylinder of known volume	g cm^{-3}
Actual density (ρr)	Pycnometer	g cm^{-3}
Porosity	1-(Da/ Dr) ×100	%
Gravimetric humidity	Stove at 105 °C	%
Hydraulic conductivity	Constant head permeameter	cm/hour
Organic matter	Walkley and black, hydrogen peroxide	%
Cation exchange capacity	Ammonium acetate 1N pH 7 colorimeter	cmol kg^{-1}
Total nitrogen	Based on organic matter	%
Organic carbon	Walkley and black, colorimeter	%
pH	Potentiometric	pH scale

Statistical analysis

An analysis of variance was performed between the different systems, and Fisher's LSD tests were also performed, where significant differences were found. For this purpose, the statistical software InfoStat version 2020 was used.

RESULTS AND DISCUSSION

Behavior of the chemical properties of the soil

The analysis of variance indicated that there were no significant statistical differences between treatments for the chemical properties of organic matter (OM), organic carbon (OC), and nitrogen (N) with $p > 0.05$. However, statistical differences were presented for pH and cation exchange capacity (CEC).

Below are evaluated the results of the soil chemical properties in the three production systems (Table 3).

Table 3. *Chemical properties and behavior in the three production systems*

Systems	Chemical variables				
	pH	CIC	MO	CO	N
Secondary forest	5.56 A	10.02 A	12.71 A	7.42 A	0.64 A
Pastures	5.75 A	3.20 B	11.42 A	6.63 A	0.57 A
Blackberry crops	5.17 B	4.94 AB	12.31 A	7.30 A	0.62 A

*Different letters indicate significant differences ($p \leq 0.05$).

Analysis of variables

Below is the analysis of the chemical properties based on the comparison of means between the three systems evaluated:

pH. The pH showed significant statistical differences among the production systems. Both the livestock system, with a pH of 5.75, and the forest system, with a pH of 5.56, are classified as moderately acidic. In contrast, the blackberry crop had a pH of 5.17, is considered strongly acidic, suggesting greater acidity and a possible reduction in the availability of essential plant nutrients.

Ma *et al.* (2022) state that livestock systems usually have a moderately acidic pH due to the high biological activity and the constant contribution of organic matter, favoring the availability of essential nutrients and microbial activity in the soil.

Zhang *et al.,* (2020) indicated that livestock soils tend to maintain a moderately acidic pH due to the constant contribution of organic matter and high biological activity, which is consistent with the pH of 5.75 observed in this study. According to Li *et al.,* (2019), this pH range between 5.6 and 6.0 is optimal for microbial activity and nutrient retention. On the other hand, soils under intensive cultivation, such as blackberry, tend to acidify rapidly due to the leaching of basic cations and the application of acidic fertilizers, as reported by Ma *et al.,* (2022). This coincides with the lowest pH (5.17) recorded in these soils, which can negatively affect the availability of certain nutrients if not managed properly.

Cation Exchange Capacity (CEC). The Cation Exchange Capacity (CEC) showed significant statistical differences between the three systems evaluated. The forestry system presented the highest value, with 10.02 cmol kg^{-1}, indicating a medium CEC, favorable for the retention of essential nutrients. In contrast, the agricultural system showed a value of 4.94 cmol kg^{-1}, while the livestock system registered the lowest value, with 3.20 cmol kg^{-1}, which is classified as a very low CEC, being in the range below 5. These results reflect a lower cation retention capacity in agricultural and livestock soils, which can affect fertility and the supply of nutrients to plants (Table 3).

According to Pérez-Rosales *et al.* (2017), forests have a higher CEC due to their high organic matter content, which improves nutrient retention and exchange, favors water infiltration, optimizes soil structure, and reduces erosion losses. In contrast, Olveín-Cruz *et al.,* (2021) point out that agricultural and livestock soils have a very low CEC since they depend on the application of fertilizers due to the scarcity of organic matter, which limits their natural fertility. This is consistent with the results of the present study, where the soils evaluated showed a medium CEC in forests and a very low CEC in agricultural and livestock systems, probably due to differences in organic matter content, since these variables are closely correlated.

Organic matter (OM). This variable did not show significant statistical differences. The highest percentage of organic matter was observed in the forest system, with 12.71%, followed by the agricultural system, with 12.31%, and the livestock system with the lowest value, 11.42% (Table 3). Despite these differences, all three systems exhibited a high accumulation of organic matter, as values exceeded 10% in every case.

Pérez-Hernández *et al.* (2023) state that the highest levels of soil organic matter (SOM) are found in forests, while agricultural areas usually register lower contents, classifying them with a medium content. This decrease in organic matter can be attributed to agricultural practices that accelerate the decomposition and loss of SOM. Izquierdo-Bautista & Arévalo-Hernández (2021) highlight that organic matter is a key indicator of soil quality, as it is related to its physical, chemical, and biological properties. Therefore, its measurement is essential to determine the type and amount of amendments necessary to improve soils with low organic matter content.

Organic carbon (OC). This variable did not present significant statistical differences. The forest system recorded the highest value of organic carbon, with 7.42%, followed by the agricultural system with 7.30%. Both values are considered high, since they exceed 6.63%. The livestock system, with 6.63%, is also within an ideal range for these soils, classified between 5.8% and 7%. These results indicate that all systems maintain adequate levels of organic carbon.

Organic carbon values were high in the soils of this area because agricultural and livestock production is relatively recent (3-5 years). In addition, the presence of organic matter, derived from crop pruning and livestock excrement, has contributed to increasing this property. These results coincide with those indicated by Gómez-Balanta & Ramírez-Nader (2022), who state that forest soils, having greater vegetation cover, store more carbon in the mulch, while in grasslands, the carbon is deposited in the soil in less quantity. Somovilla-Lumbreras *et al.,* (2019) mention that the storage of organic carbon in the soil (SOC) affects multiple ecosystem functions, such as nutrient provision, water storage, and climate regulation. Likewise, Pérez-Iglesias *et al.* (2021) highlight that SOC is a key indicator of soil quality, since it participates in biochemical and physical processes and acts as an important carbon reservoir in terrestrial ecosystems.

Nitrogen (N). This variable did not show significant statistical differences. The forest system had the highest value, with 0.64%, followed by the agricultural system with 0.62%, while the livestock system registered the lowest value, with 0.57%. These results indicate that, despite slight variations, the levels of this variable are relatively similar in the three systems.

The evaluated systems present a similar amount of nitrogen, which is essential for crop nutrition, since maintaining adequate levels of this element ensures greater soil productivity (Lopez-Choque *et al.,* 2023). In this study, soil organic carbon (SOC), organic matter (OM), and nitrogen (N) did not show significant statistical differences, and these variables are closely related. Gamarra-Lezcano *et al.* (2017) point out that the carbon-nitrogen ratio is crucial to promote the growth of microorganisms that decompose organic matter by providing sufficient carbon as an energy source and nitrogen for protein synthesis, which facilitates nitrogen mineralization and its subsequent use by plants. Furthermore, Cantú Silva & Luna Robles (2022) point out that both carbon and nitrogen are key indicators of the quality of organic matter in the soil; therefore, these elements improve soil structure, nutrient availability, water retention, and microbial activity, with nitrogen being a crucial factor for productivity, as it directly influences plant growth.

Behavior of soil physical properties

The analysis of variance indicated that there were significant statistical differences for the different soil physical variables in the three production systems with $p \leq 0.05$. The results of the physical properties at the system level are shown below (Table 4).

Table 4. *Behavior of physical properties in the three production systems*

Systems	Physical variables			
	From	**Pr**	**HG**	**Kc**
Secondary forest	0.43 C	77.49 A	250.14 A	1.57 A
Cattle raising	0.56 B	69.93 B	159.30 B	0.50 B
Blackberry cultivation	0.65 A	67.53 B	159.88 B	0.57 B

* Different letters indicate significant differences ($p \leq 0.05$).

Analysis of variables. Below is the analysis of the physical properties based on the comparison of means between the three systems evaluated:

Apparent density (Da). The soil from the blackberry cultivation system had the highest apparent density value, with 0.65 g/cm³, followed by the livestock system with 0.56 g/cm³ and the forest system with the lowest value, 0.43 g/cm³ (Table 4). The agricultural and livestock systems, which have experienced more intensive anthropic management, have degraded and compacted the soil, altering its apparent density. In contrast, the forest soil, with a higher organic matter content, has lower apparent density values, which improves its structure and water retention capacity.

Saavedra-Romero *et al.* (2020) mention that the apparent density in forest systems with values less than 1 g/cm³ favors plant development, since it allows an excellent infiltration rate, which facilitates the absorption of nutrients by plants. In contrast, Gómez-Calderón *et al.* (2018) point out that conventional tillage in livestock systems increases soil density, causing compaction, disintegration, and greater susceptibility to erosion, especially when heavy machinery is used in agricultural work. Similarly, Ocampo-Quijano *et al.* (2021) state that, in agricultural systems, high apparent density values limit plant growth, hindering root penetration and nutrient availability.

Porosity (Pr). The soil of the forest system had the highest value, with 77.49%, followed by the agricultural soil with 69.93%, and the livestock soil with the lowest value, 67.53% (Table 4). These results reflect a greater water retention capacity and better structural conditions in the forest soil compared to agricultural and livestock soils, which are more exposed to management practices that can reduce the soil's capacity to maintain moisture.

González Barrios *et al.,* (2012) state that forest soils usually have a very high porosity, since they have not been altered by anthropogenic activities, which allows them to conserve their natural state. This coincides with the results obtained in this study, where the porosity in the forest soil was higher compared to agricultural and livestock systems. However, soil compaction in agricultural and livestock systems significantly decreases porosity and infiltration capacity, as stated by Gregory *et al.,* (2006), who demonstrated that the use of heavy machinery and intensive grazing compact the soil, affecting its structure, which reduces its capacity to retain water and carry out gas exchange, causing the soil to act in a similar way to impermeable surfaces, increasing the risk of runoff and erosion. However, Galvis-Quintero *et al.,* (2016) indicate that, in agricultural and livestock systems, high porosity favors an adequate water regime and a gas exchange that promotes the rapid development of roots and plants, especially when tillage creates an adequate balance between microporosity and macroporosity, allowing the retention and absorption of moisture in the soil.

Gravimetric humidity (HG). In this variable, the percentages presented values of 250.14% for the forest system, followed by the livestock system with 159.88%, and the agricultural system with 159.30% (Table 4). These results indicate a greater water retention capacity and structure in the forest system compared to the other two systems. This is due to the abundance of organic matter in forests that improves soil structure and facilitates water infiltration and storage. Recent studies by Liu & Zhu (2024) show that forest systems, not being subjected to compaction by heavy machinery or intensive agricultural practices, retain moisture better and maintain a more favorable water balance compared to agricultural and livestock systems, where soil compaction limits water retention capacity.

Hydraulic conductivity (Kc). In this variable, the forest system presented a value of 1.57 cm/hour, which indicates a slow water movement, since it is within the range of 1 to 2 cm/hour. On the other hand, the agricultural system showed a value of 0.57 cm/hour, while the livestock system registered 0.50 cm/hour, which reflects a very slow water movement, since both systems have values lower than 1 cm/hour. These results suggest that the infiltration capacity is considerably lower in the agricultural and livestock systems compared to the forest system.

García-Olmos & García-Olmos (2019) point out that hydraulic conductivity is higher in forest soils due to their high moisture content and the presence of a dense and diverse network of underground roots, typical characteristics of natural forests. These roots facilitate the transit of water, allowing a freer flow in this type of soil. In contrast, agricultural and livestock systems usually have much lower hydraulic conductivity, since the soils in these systems tend to be less porous. Lozano *et al.* (2005) explain that soil compaction caused by livestock trampling and continuous planting of fruit crops reduces the stability of soil aggregates, making it difficult for water to pass through and decreasing infiltration.

Behavior of physical properties between two soil depths (0-15 and 15-30 cm)

Analysis of variance indicated that there were significant statistical differences for the two depths of the soil physical properties with $p \leq 0.05$. The results for the physical properties at the system level are shown below (Table 5).

Table 5. *Behavior of physical properties between the two soil depths (0-15 and 15-30 cm)*

Physical variables	Depths	
	0-15 cm	**15-30 cm**
Apparent density (Da)	0.49 B	0.61 A
Porosity (Pr)	74.10 A	69.21 B
Gravimetric Humidity (HG)	223.59 A	155.97 B
Hydraulic Conductivity (Kc)	0.62 A	1.15 A

* Different letters indicate significant differences ($p \leq 0.05$).

Analysis of variables

Below is the analysis of the physical properties between the two soil depths (0-15 and 15-30 cm):

Apparent density (Da). Apparent density showed significant differences between soil depths. The highest value was recorded at 15 and 30 cm, with 0.61 g/cm³, while the lowest value, 0.49 g/cm³, was observed in the 0-15 cm layer (Table 5). This suggests that the amount of organic matter is greater in the first soil horizons, which contributes to a lower apparent density in these superficial layers. The greater accumulation of organic matter in the upper layers improves the soil structure and reduces its compaction, facilitating water retention and root development.

Martínez-Soto *et al.* (2023) indicate that bulk density tends to increase as soil depth increases, which is due to a lower amount of organic matter in the deeper horizons. Roncallo *et al.* (2013) also highlight that, at depths of 0-30 cm, this increase in bulk density is influenced by animal grazing, especially in the surface layers. Likewise, Ocampo-Quijano *et al.* (2021) explain that an increase in bulk density negatively affects water movement, drainage, and root penetration, limiting plant growth due to soil compaction. These studies reinforce the relationship between bulk density, soil management, and water availability in agricultural and livestock systems.

Porosity (Pr). The highest value was at the depth of 0-15 cm with 74.10%, and the lowest was at the depth of 15-30 cm with a value of 69.21% (Table 5). These results suggest that porosity is higher in the surface layers, where the presence of organic matter and biological activity promote pore formation, compared to deeper layers, where compaction is higher and porosity decreases.

Stošić *et al.* (2020) explain that soils with higher organic matter have a pore distribution that improves water flow, while in deep layers (15-30 cm), porosity decreases due to compaction, which reduces water retention and gas exchange.

Gravimetric humidity. Gravimetric humidity was higher in the first few centimeters of the soil, with a value of 293.59%, attributable to the greater moisture retention and presence of organic matter in this surface layer. In contrast, at the 15-30 cm depth, the value decreased to 115.97%, suggesting a lower water retention capacity at greater depth (Table 5).

Gravimetric moisture is usually higher in the first few centimeters of soil in forest systems due to the accumulation of organic matter and biological activity in this layer, which favors greater water retention compared to deeper layers. Shaheb *et al.* (2021) highlight that the greater presence of organic matter in the first horizons increases the capacity of the soil to retain moisture and maintain an adequate structural profile. Similarly, Chinilin & Ermolaeva (2022) found that compaction and the lower amount of organic matter in the lower layers limit the water retention capacity, affecting the overall soil health.

Hydraulic conductivity. Hydraulic conductivity was 1.15 cm/hour at the 0-15 cm depth and decreased to 0.62 cm/hour at the 15-30 cm depth, suggesting a reduction in the water movement capacity at greater depth due to possible compaction and lower porosity (Table 5).

Aoki *et al.* (2013) pointed out that water movement in the soil is closely linked to the natural structure and amount of porosity of each horizon, being greater in superficial layers such as 0-15 cm due to the greater presence of porous spaces and organic matter, which favor infiltration. In contrast, at greater depths, the texture and compact structure of the soil can considerably reduce hydraulic conductivity, limiting water flow. Furthermore, Rincón *et al.* (2008) maintain that hydraulic conductivity can vary between moderately slow and fast in the first horizons of the soil, influenced by factors such as mineral and organic composition, the presence of roots, and the distribution of pores in each profile.

CONCLUSIONS

Although the analysis of variance did not show significant differences in the chemical properties of organic matter, organic carbon and nitrogen between treatments, differences were identified in pH and CEC. This suggests that these factors may vary more significantly depending on soil management or environmental characteristics, compared to other chemical properties that remain stable. The CEC in the forest system recorded the highest value at 10.02 cmol kg^{-1}, indicating a greater nutrient retention capacity, favored by the high organic matter content. In contrast, the agricultural and livestock systems showed values of 4.94 cmol kg^{-1} and 3.20 cmol kg^{-1}, respectively, classifying them as having low CEC, limited by the reduction in organic matter content. Therefore, it is confirmed that CEC is closely related to soil management and organic content, with forest soils being the most favorable for nutrient retention. Soil analysis in livestock, forestry, and agricultural production systems shows that forests have higher values in CEC, OM, CO, and N, favored by their higher content of organic matter and biological activity, increasing humidity and organic carbon in their surface layers; on the other hand, agricultural and livestock soils, subjected to intensive practices, reflect a lower capacity for nutrient retention and greater compaction, which can negatively affect their fertility and structure. The forest system shows higher values of gravimetric humidity, porosity, and hydraulic conductivity due to the abundant organic matter and its less compacted structure, which facilitates water retention and air circulation in the soil. However, livestock and agricultural systems have lower water retention capacity and porosity, as a result of intensive management and use of machinery that compacts the soil, negatively affecting its structure and water support capacity. The analysis of the soil physical properties between the 0-15 cm and 15-30 cm depths shows notable differences. In the first 15 cm, lower values of apparent density and higher values of porosity and gravimetric humidity are observed due to a high presence of organic matter that facilitates water retention and improves soil structure. However, at the 15-30 cm depth, apparent density increases while porosity and humidity decrease. That is probably because of the compaction, which affects water movement and root development.

ACKNOWLEDGMENTS

To the Faculty of Environmental Engineering of the Putumayo Technological Institute, Sibundoy headquarters, Colón extension.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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