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Spatial distribution of soil organic carbon along topographic gradients in the Ejido Adolfo Ruiz Cortines, Durango, Mexico

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ABSTRACT

Temperate forests are key to regulating climate and biogeochemical cycles. Specifically, forest management in these ecosystems favors the fixation and storage of carbon in the soil, reducing the concentration of atmospheric carbon dioxide (CO_2). The objective of this research was to analyze the distribution of soil organic carbon stored along a slope in different orientations in a temperate forest under management in the Ejido Adolfo Ruiz Cortines de Durango, Mexico. The factor analyzed was the orientation and position of the slopes. For orientation, slopes with North, South, East, and West orientations were selected, the position of each slope was divided into three sections: low, medium, and high slope, and a zenith area. On each slope, humus and leaf litter stocks were measured, and soil samples were collected to determine bulk density (Bd), soil porosity (P), soil moisture content (M), soil organic matter (SOM), and soil organic carbon (SOC). The carbon storage capacity was significantly influenced by slope orientation. In this sense, the SOC had the following trend: South (73.70 Mg ha^{-1}) >North (73.12 Mg ha^{-1}) >East (67.23 Mg ha^{-1}) >West (54.09 Mg ha^{-1}) >Zenith (47.75 Mg ha^{-1}). Regarding the position, the upper part of the slope had the highest content (83.66 Mg ha^{-1}), while the middle and lower parts had the lowest accumulation with 57.31 Mg ha^{-1} and 60.13 Mg ha^{-1}, respectively. The orientation and position directly influenced the SOC reservoirs, being key to the productivity of the ecosystem, benefiting local producers.

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1. INTRODUCTION

Temperate forests are important since they provide multiple goods and services essential for human beings and life on the planet in general; particularly, they are key in the regulation of climate and biogeochemical cycles. Specifically, forest management in these ecosystems favors the fixation and storage of carbon in the soil, reducing the concentration of atmospheric carbon dioxide (CO_2) due to changes in environmental conditions, vegetation structure, and composition (Terrer et al., 2021). The importance of carbon in the soil results in the fact that it improves the availability of nutrients and improves soil fertility and structure, being key to the productivity of forest ecosystems (Gerke, 2022).

Soil stores a greater amount of carbon (1500 pg); Buczko et al. (2023) indicate that one square meter of forest land stores about 15 kg of C. In particular, soil humidity and temperature, leaf litter, root distribution, and soil microbiology can be modified depending on the intensity and the felling or practice carried out on the forest mass (Buraka et al., 2022); which directly impacts soil carbon stocks (Mushinski et al., 2017). However, this sequestration capacity can also vary due to various factors such as climate, precipitation, temperature, and solar energy, as well as species composition and site-specific conditions (Buczko et al., 2023).

Reed et al. (2021) point out that soil can be a sink or a source of carbon; this is a function of perturbation and changes in land use that break the carbon cycle. Therefore, it is important to analyze what factors are responsible for storage, allowing global climate change to be mitigated. In this sense, Lefèvre et al. (2017) point out that the factors that

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control the decomposition of SOM are soil temperature and water content, which significantly influence the storage of C in the soil due to their effect on microbial activity, and in turn the microbiological composition. The amount of SOC stored in the soil depends on the balance between the amount of C entering the soil and leaving the soil as gases. From microbial mineralization, C can also be lost or gained through soil erosion or deposition, leading to the redistribution of C from the soil on a local, landscape, and regional scale.

In Mexico, there is a great variability of climatic, geomorphological, and edaphological conditions, resulting in a wide diversity of habitats and species (Herrera-Romero et al., 2020). The quantity, quality, and distribution of organic carbon in the soil depend on the interaction of climatic, edaphic, topographic, and biological factors. Specifically, topography plays an important role in defining soil properties with respect to temperature and moisture regimes and is considered to be one of the main soil-forming factors since hillside position, slope, and orientation are important factors in soil formation and can affect soil moisture content. plant growth and distribution of SOC (Jakšić et al., 2021; Zhang et al., 2023).

On the slopes, sequences of soils are formed with different characteristics between depth and texture. In the upper part of the slope, shallow soils of coarse texture are formed due to the erosive processes of the surface soil. The low slopes are characterized by the formation of deeper soils with fine textures and differentiated profiles. This is associated with higher concentrations of SOC on lower slopes due to soil deposition from the dragging of dead plant material (branches and leaves) from the upper part. On the other hand, orientation plays an important role on slopes Jakšić et al. (2021) and Maheshwori et al. (2025) point out that north-facing slopes receive less direct sunlight, storing more SOC in the soil, unlike south-facing slopes that are warmer and drier and present more sparse vegetation. and therefore, the accumulation of SOC in minor. However, it has been documented that the East orientation stores a greater amount of SOC compared to the North and West orientations (Niu et al., 2022).

Understanding the spatial dynamics of the SOC on a slope is important to identify areas of vulnerability to climate change, which are more prone to erosion and soil degradation due to their relief. Most research assesses slopes as a whole (Buraka et al., 2022; Jakšić et al., 2021; Maheshwori et al., 2025; Niu et al., 2022), however, the dynamics within a slope change in the areas that make it up, for example: the upper areas of the slopes are more vulnerable to losing SOC due to sediment dragging, the lower part is benefited by the accumulation of organic matter, this is very common in agricultural areas, But in a poorly managed forest ecosystem, the dynamics could change by implementing proper management practices. According to Jakšić et al. (2021) and Leal et al. (2023), areas under forest management reduce cover by modifying soil properties depending on the intensity of management practices. Therefore, the objective was to analyze the distribution of soil organic carbon stored along a slope in different orientations in a temperate forest under management in the Ejido Adolfo Ruiz Cortines in Northwest Mexico, belonging to the mountain massif of the Sierra Madre Occidental.

2. MATERIAL AND METHODS

2.1. Description of the study area

The experiment was conducted in May 2025 in an area located southwest of Durango, Mexico, in the Sierra Madre Occidental. Specifically, in the ejido Adolfo Ruiz Cortines, between coordinates 23°44'48.43" N and 105°18'17.03" W, presenting a temperate subhumid and semi-cold subhumid climate, with rainfall in summer and winter (Silva-González et al., 2024). The average temperature oscillates between 13 and 24°C, with an average annual rainfall of 800 to 1200 mm. The dominant soil group in the area is the Regosol type, characterized by poorly developed soils with a thickness of 20 cm, due to its young age and slow soil formation (Schad, 2023).

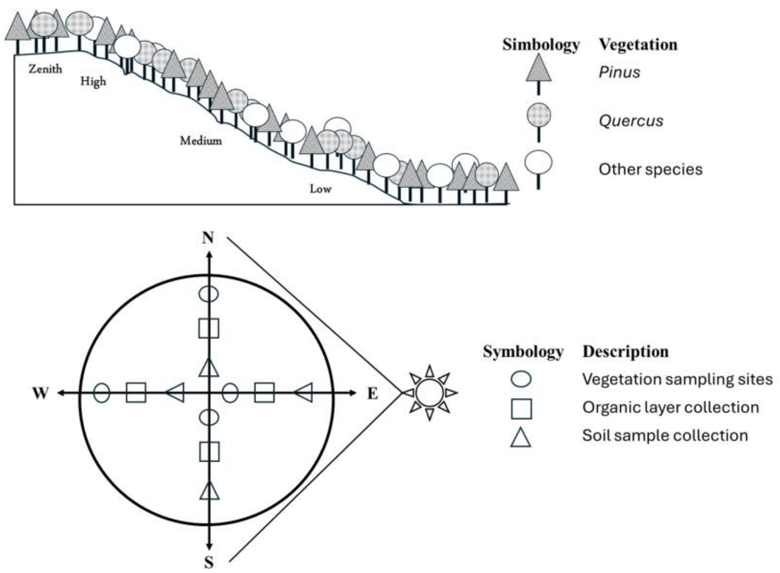

Figure 1. A) Distribution of vegetation across the slope and B) Distribution of sampling units by orientation of the vegetation, organic layer, and soil (Muche et al., 2025).

The orientation and position on the slopes were analyzed. Four slopes were selected with North, South, East and West orientations and each slope was divided into three sections that consisted of low, medium and high slopes and area a zenithal to compare (Fig. 1).

The dasometry of the species present on the slopes was measured, considering their orientation. Sites of 1000 m^{-2} were registered, and diameter was measured at breast height, total height, crown diameter and tree density (trees ha^{-1}) (Silva-González et al., 2024). It should be noted that the areas are under management by the Mexican Method of Irregular Forests (MMOBI).

In each position, four composite samples of soil (500 g) were collected, in total 12 samples were obtained per slope, then dried in the open air and sieved at 2 mm. The samples were transferred to the Soil Science laboratory of the Instituto Tecnológico del Valle del Guadiana for further analysis.

Physical and chemical properties were determined, as follows: Bulk density (Bd): it was determined by the thermogravimetric method (Luna Robles et al., 2023). The bulk density was determined with Equation 1. Soil porosity (P): assuming that the density of soil porosity is 2.65 g cm^{-3} (Robinson et al., 2022), was determined from Equation 2. Soil moisture content (M): it was determined by the thermogravimetric method (Kashyap & Kumar, 2021). The M is determined by Equation 3.

$$Bd\ (g\ cm^3) = \frac{\text{Dry weight of the sample (g)}}{\text{Volume of the cylinder } (cm^3)} \quad [1]$$

$$P\ (\%) = 1 - \frac{\text{Bulk density } (g\ cm^3)}{\text{Particle density } (g\ cm^3)} * 100 \quad [2]$$

$$M\ (\%) = \frac{m_{wet} - m_{dry}}{m_{dry}} * 100 \quad [3]$$

where m_{wet} is the mass of the wet soil sample (fresh soil sample), m_{dry} is the mass of the dried soil sample.

2.2. Estimation of organic matter and organic carbon

The organic matter of the soil was determined by the Walkley and Black method, this method consists of wet combustion, then the organic carbon content is determined by multiplying by the Van Bemmelen correction factor (Gerenfes et al., 2022).

The estimation of SOC (Mg ha^{-1}) was estimated with the equation described by Luna Robles et al. (2024) and Khalid et al. (2025). The SOC is determined by Equation 4.

$$SOC = \%C * Bd * D \quad [4]$$

Where SOC is the organic carbon of the soil expressed in Mg ha^{-1}, %C percentage of carbon, Bd is the bulk density (g cm^{-3}) and D is the depth of the sample (cm).

Table 1. Dasometric characteristics of slopes by orientation

Orientation	Species	DBH (cm)	h (m)	ACD (m)	Trees ha^{-1}
North	*Quercus sideroxyla* Humb. & Bonpl	16.41	10.11	1.75	370
	Quercus rugosa Neé	15.50	9.75	1.74	40
	Pinus durangensis Martínez	16.74	10.23	1.69	390
	Juniperus deppeana Steud	14.67	7.33	1.60	30
	Average	15.83a	9.36a	1.70a	207.50c
South	*Arbutus bicolor* L.	11.78	5.60	4.42	50
	Juniperus deppeana Steud	32.00	10.00	4.75	10
	Pinus durangensis Martínez	17.80	11.92	5.12	220
	Quercus rugosa Neé	17.50	6.00	4.41	10
	Quercus sideroxyla Humb. & Bonpl	25.42	14.33	6.50	90
	Average	20.90b	9.57a	5.04c	76.00a
East	*Juniperus deppeana* Steud	8.15	4.5	2.5	20
	Pinus durangensis Martínez	24.6	16.7	4.6	120
	Quercus rugosa Neé	24.8	13.6	6.3	200
	Quercus sideroxyla Humb. & Bonpl	24.3	14.4	4.8	150
	Average	20.47b	12.29b	4.56b	122.50b
West	*Juniperus deppeana* Steud	11.10	8.33	3.08	30
	Pinus durangensis Martínez	15.53	11.43	3.02	610
	Quercus rugosa Neé	12.6	8.00	2.85	10
	Average	13.08a	9.26a	2.98b	216.67c
Zenith	*Juniperus deppeana* Steud	16.81	6.33	2.33	260
	Pinus durangensis Martínez	10.00	5.00	1.95	10
	Pinus teocote Schiede ex Schltdl.	16.70	9.41	1.85	370
	Quercus rugosa Neé	24.60	8.42	3.36	50
	Quercus sideroxyla Humb. & Bonpl	50.00	13.00	9.75	10
	Average	23.62b	8.43a	3.85b	140.00b

Notes: DBH: diameter breast height, h: height, ACD: average crown diameter and Trees/ha: Trees per hectare. Different letters indicate significant differences between groups (*Tukey* $p < 0.05$)

2.3. Soil organic layer sampling

The procedure consisted of measuring the thickness and weight of the leaf litter (L) and humus (H) with the help of a 100 x 100 cm grid. The sample was collected separately, taken to the laboratory, and dried in a TERLAB brand forced air stove at a temperature of 65°C for 72 hours (Tapia-Coronado et al., 2022).

2.4. Statistical analysis

The SOC complied with the assumptions of normality (Kolmogorov-Smirnov) and homogeneity of variances (Levene), so an analysis of variance (ANOVA) was carried out to determine the effect of orientation and position on the slope. A Tukey mean comparison test was then performed ($p \leq 0.05$). To determine the relationship between soil physical properties and SOC content, a Pearson correlation test was performed (Roni & Djajadikerta, 2021).

3. RESULTS

3.1. Dasometric characterization of the analyzed slopes

Table 1 shows the dasometric data of the vegetation of the evaluated slopes, where it can be observed that the southern and zenithal slopes presented a greater number of tree species, specifically two and three Conifers, and three and two broadleaved, respectively. Besides, the trees with the largest average diameter were present in the zenith zone (23.62 cm) and those with the highest average height in the East orientation (12.29 m), the crowns were higher in the South (5.04 m), and the density of trees was higher in the West (216.67 trees ha^{-1}).

Regarding the test of comparison of means, the DBH, the North and West orientations were similar to each other, but different from the rest of the orientations (South, East, and Zenith), with the zenith zone presenting the largest diameters. As for h, all orientations were similar except for the east, which presented the highest heights. The crown diameter was similar in the East, West, and Zenith orientations, while the North and South orientations were different from each other and from the rest of the orientations. The number of trees per ha^{-1} was statistically similar in the North and West, East and Zenith, and different from the South zone (Table 1).

3.2. Soil characteristics by orientation

Table 2 presents the results of the physical and chemical properties of the topsoil by orientation, where SOM contents ranged from 6.30 to 11.89 %. The moisture content (M) varied from 3.30 to 12.37 %, in terms of porosity and bulk density, the values fluctuated from 72.15 to 81.65 % and from 0.49 to 0.74 g cm^{3}, respectively. In the organic layer of the soil specifically, the litter content (L) ranged from 1.16 to 3.23 Mg ha^{-1}, and the humus (H) ranged from 0.74 to 3.94 Mg ha^{-1}. It is important to note that the East orientation presented the highest values in all the properties analyzed, except for the bulk density, which could be related to the coverage of species present in this area, since Table 1 shows that the dominant species is of the genus Quercus.

Tukey's test showed the presence of significant differences in all the variables analyzed, the SOM was similar in the West and Zenith orientations and different from the rest, the M was similar in the North, South and West zones being statistically similar and different from the rest, the P was similar in the North and West zones and different from the South and Zenithal, the latter being similar to each other, Bd behaved similarly to P. the contents of L were similar in all orientations except for the zenith zone, being the zone of least accumulation, H was similar in the South and Zenith zones, with the lowest accumulations, while the north, East and West were different from each other and the rest of the orientations (Table 2).

Table 2. Mean values ± standard deviation of the physical and chemical properties of the soil analyzed in different orientations (*n*=12)

Orientation	SOM (%)	M (%)	P (%)	Bd (g cm^{-3})	L (Mg ha^{-1})	H (Mg ha^{-1})
North	8.37 ± 1.84b	4.90 ± 0.84ab	72.34 ± 4.64a	0.73 ± 0.12c	2.68 ± 0.96bc	3.30 ± 1.25c
South	10.88 ± 2.33c	5.99 ± 1.07b	77.33 ± 4.00b	0.60 ± 0.10b	2.32 ± 0.90b	1.08 ± 0.44a
East	11.89 ± 2.16d	12.37 ± 3.48c	81.65 ± 4.26c	0.49 ± 0.11a	3.23 ± 0.63c	3.94 ± 3.19d
West	6.30 ± 1.22a	4.46 ± 1.64ab	72.15 ± 3.08a	0.74 ± 0.08c	2.55 ± 0.73bc	1.79 ± 0.40b
Zenith	6.42 ±.0.20a	3.30 ± 0.79a	76.79 ± 5.44b	0.62 ± 0.14b	1.16 ± 0.60a	0.74 ± 0.31a

Notes: SOM = soil organic matter, M = soil moisture, P = soil porosity, Bd = bulk density, L = leaf litter, and H = humus. Different letters indicate significant differences between groups (*Tukey* $p < 0.05$)

Table 3. Analysis of variance of soil properties analyzed by position on the slope

Variable	Sum of squares	df	MS	F	Sig.
SOM (%)	29.48	2	14.74	312.07	<0.001
M (%)	1.85	2	0.93	0.21	0.808
P (%)	184.92	2	92.46	8.295	0.001
Bd (g cm^{-3})	0.13	2	0.07	8.42	0.001
L (Mg ha^{-1})	1.62	2	0.81	1.70	0.196
H (Mg ha^{-1})	32.64	2	16.32	59.61	<0.001

Notes: df = degrees of freedom, MS = Mean square, F = value F, Sig. = significancy, SOM = soil organic matter, M = soil moisture, P = soil porosity, Bd = bulk density, L = leaf litter and H = humus

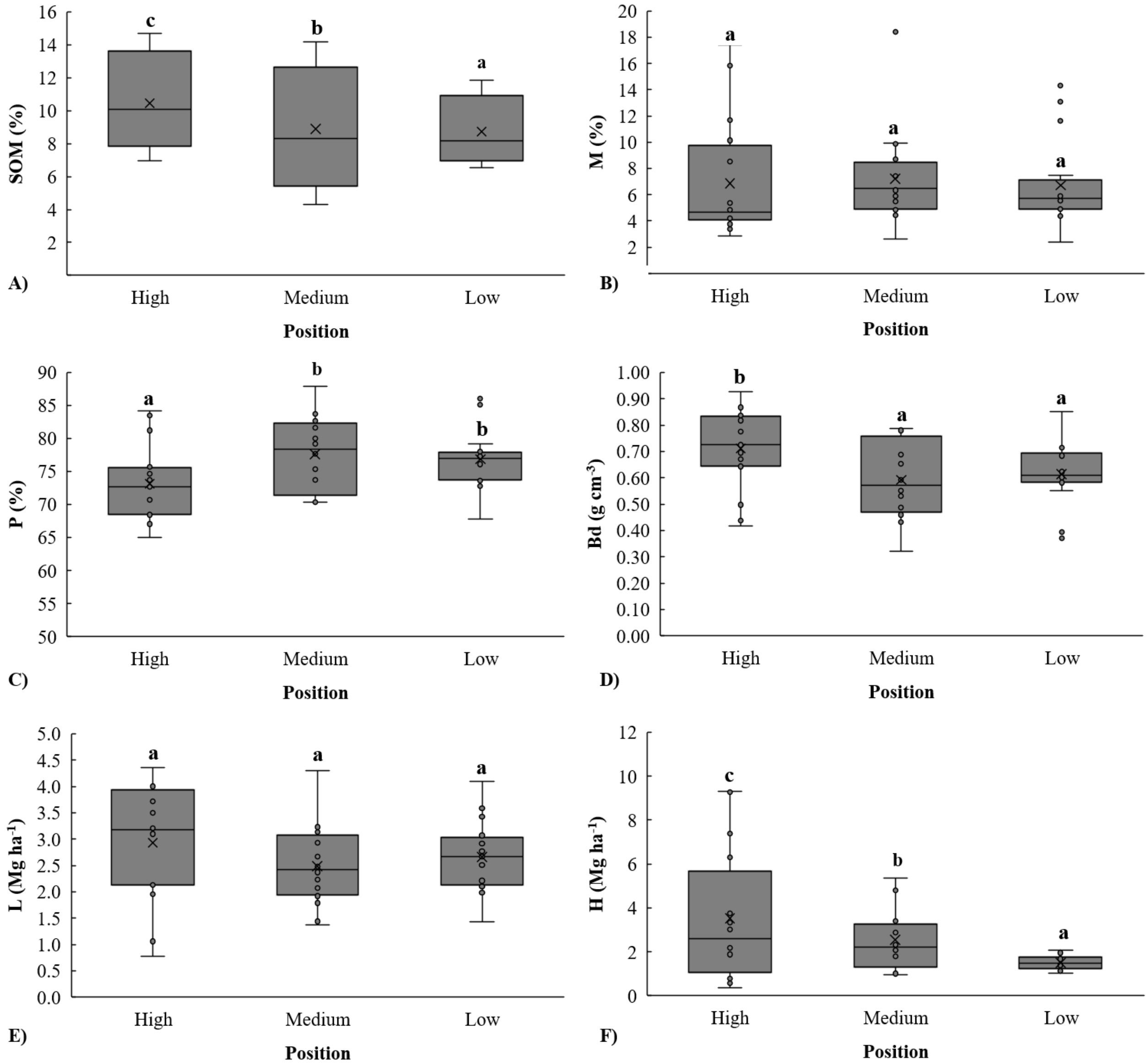

Figure 2. Mean values of soil properties analyzed by slope position, A) soil organic matter, B) soil moisture, C) soil porosity, D) bulk density, E) litter content, and F) humus. Different letters indicate significant differences between groups (*Tukey p < 0.05*)

3.3. Soil characteristics by position in slope

Table 3 presents the ANOVA of the soil properties evaluated by position, which shows the presence of significant differences ($p < 0.001$) in the variables SOM, P, Bd, and H, while M and L did not present differences between the positions of the slopes.

The contents of SOM ranged from 8.72 to 10.46 %, with the upper part being the one with the highest accumulation and presenting significant differences ($p < 0.05$) between the three positions of the slope. The humidity did not vary between positions and was statistically similar. The P fluctuated from 73.13 to 77.64 % and showed significant differences between the upper part of the slope compared to the middle and lower areas. The bulk density, litter content, and humus were higher in the upper part of the slope; however, in the leaf litter contents, the mean comparison test did not show significant differences, while in bulk density, only in the high position and in the humus content, it was different in the three positions (Fig. 2).

3.4. Effect of slope orientation and position on SOC storage

Table 4 presents the ANOVA of two factors of SOC content, which evidenced the presence of highly significant differences ($p < 0.001$) between the orientations and positions analyzed on the slopes, as well as in their interaction.

Based on the SOC results of the present study, it can be inferred that carbon storage capacity is significantly influenced by slope orientation and position, as well as by the species present on the slopes.

The SOC content by orientation showed the following trend: South (73.70 Mg ha^{-1}) >North (73.12 Mg ha^{-1}) >East (67.23 Mg ha^{-1}) >West (54.09 Mg ha^{-1}) >Zenit (47.75 Mg ha^{-1}).

The mean comparison test showed significant differences ($p < 0.05$) between the two groups. In the first group, the North, South, and East orientations are presented with the highest SOC reservoirs, and in the second, with the lowest, including the West orientation and the zenith zone (Fig. 3).

Table 4. Analysis of two factors of variance for the SOC levels of slope by orientation and position

Variable	Sum of squares	df	MS	F	Sig.
Orientation	2986.53	3	995.51	9.36	<0.001
Position	6698.85	2	3349.42	31.49	<0.001
Orientation * Position	4846.21	6	807.70	7.59	<0.001

Notes: df = degrees of freedom, MS = Mean square, F = value F, Sig. = significance

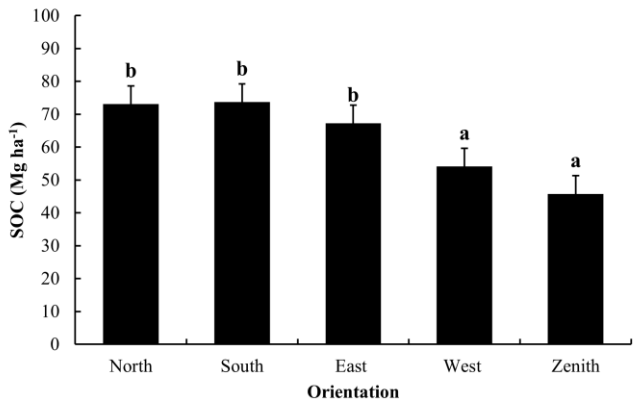

Figure 3. Organic carbon content (Mg ha^{-1}) of the soil in the different slope orientations (n=12). Different letters indicate significant differences between groups (*Tukey p < 0.05*)

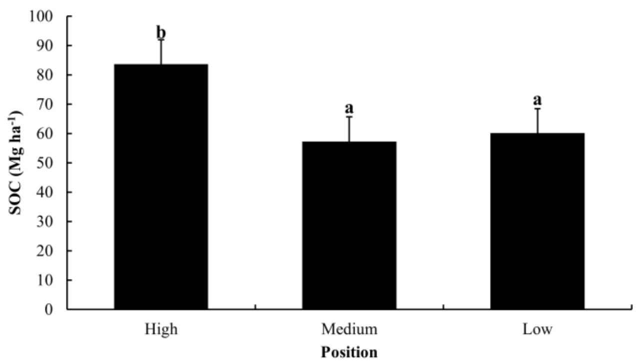

Figure 4. Organic carbon content (Mg ha^{-1}) of the soil in the different slope positions (n=16). Different letters indicate significant differences between groups (*Tukey p < 0.05*)

The positions on the slopes also showed a different dynamic. Specifically, the upper part of the slope was the one with the highest content (83.66 Mg ha^{-1}), while the middle and lower parts had the lowest accumulation, with 57.31 Mg ha^{-1} and 60.13 Mg ha^{-1}, respectively (Fig. 4). Carbon storage by position on the slope behaved as follows: high> low>medium. The results show that there are statistically significant differences ($p < 0.05$) in SOC content between slope positions.

According to the interaction of orientation and position on the slope, SOC storage behaved as follows: the North, East, and West orientations presented the largest stores in the High position with 108.75, 84.31, and 63.97 Mg ha^{-1}, respectively. While in the south, the highest records were found in the middle part of the slope with 78.59 Mg ha^{-1}. Low values (45.74 Mg ha^{-1}) of SOC were present in the zenith zone compared to all interactions (Fig. 5).

3.5. Correlation between Soil Properties

According to Pearson's test, only the variables of soil organic matter (SOM) ($p<0.001$), bulk density ($p<0.01$) and porosity ($p<0.01$) showed a highly significant correlation with the SOC store (Fig. 6). The relationship between SOM contents and the SOC reservoir is high, since the higher the concentration of SOC, the greater the accumulation of SOC. SOM was also positively correlated with soil moisture, and porosity and negatively with bulk density ($p<0.001$).

4. DISCUSSION

The results show that SOC reserves are influenced by the orientation and position of the slope, modifying the behavior of the physical and chemical properties of the soil. Topography is an environmental variable with a direct impact on the dynamics of soil properties (Jakšić et al., 2021). According to Segura-Castruita et al. (2005), temperate forest soils have a high SOC storage capacity of an average of 65.5 Mg ha^{-1}, coinciding with the present study, where on average this ecosystem stores 65.40 Mg ha^{-1}. The characteristics of the soil changed according to orientation. Specifically, the East orientation presented the best conditions with high levels of SOM (11.89 %), higher moisture and porosity content (12.37 and 81.65 %), low bulk density (0.49 g cm^{-3}) and high litter and humus contents (3.23 and 3.94 Mg ha^{-1}) which according to Buraka et al. (2022) a higher SOM content in the surface layer makes soils more porous, reducing Bd, improving hillside productivity by increasing its capacity to store SOC. In contrast to the West, it is evident that there is a loss of SOM as it contains lower reserves of litter and humus (2.55 and 1.79 Mg ha^{-1}, respectively), indicating a decrease in organic matter of 47 % compared to the East (Tapia-Coronado et al., 2022). Egli et al. (2009) point out that this behavior is attributed to the accumulation of labile and poorly degraded organic materials, as well as to low microbial activity, which may be associated with the acidity or low humidity (4.46 %) observed on the slope, unlike the East orientation (12.37 %).

Regarding position, the upper part of the slope stored 83.66 Mg ha^{-1}, while the middle and lower parts showed a decrease in soil organic carbon (SOC) reserves of 31.49% and 28.12%, respectively. This could be attributed to soil conservation practices implemented during forest management on the slopes, such as cortazales residual plant material against the slope, preventing erosion and soil displacement to the lower parts, thus resulting in higher accumulation at the top of the slope (García Gallegos et al., 2023).

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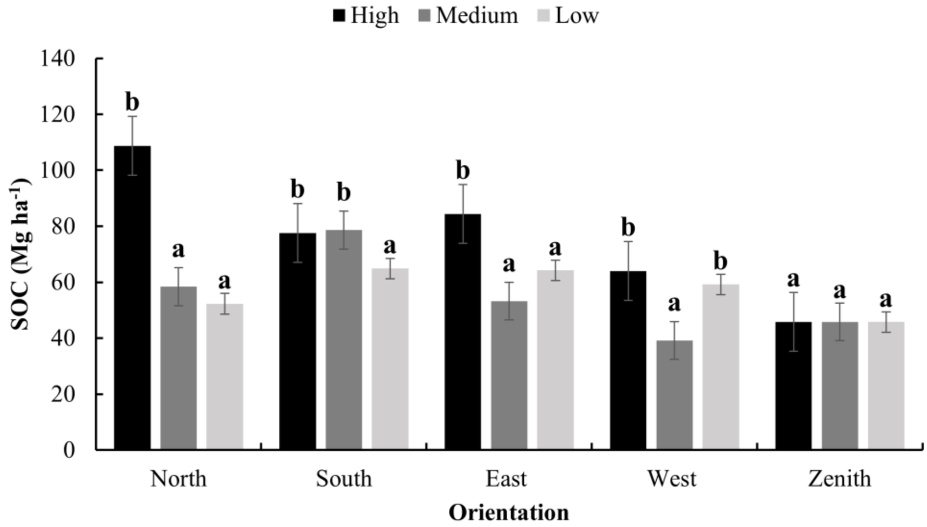

Figure 5. Soil organic carbon content (Mg ha^{-1}) for different slope orientations between slope positions (n=4). Different letters indicate significant differences between groups (*Tukey p < 0.05*)

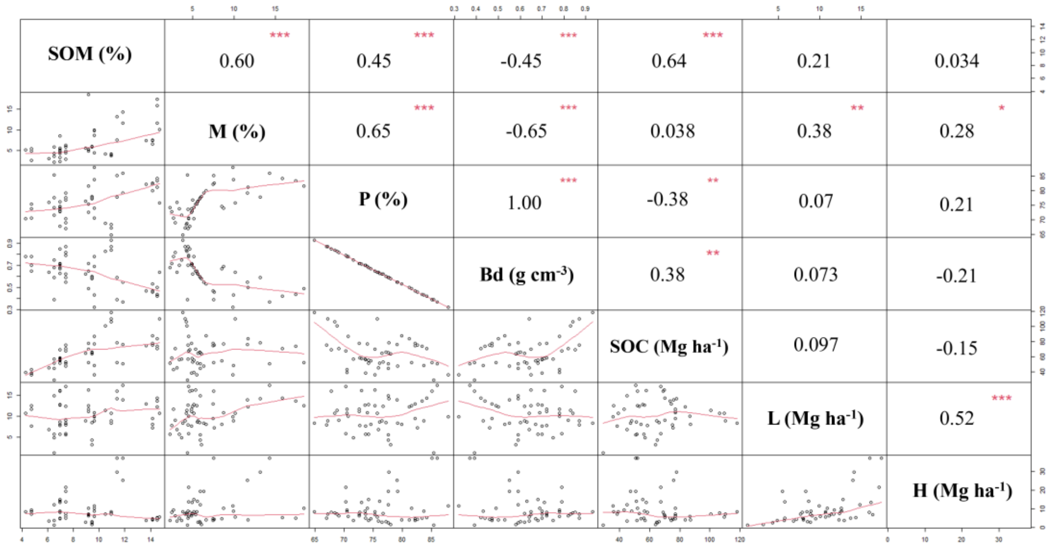

Figure 6. Pearson correlation coefficient matrix (r) between analyzed soil properties. * 0.05 Signification Level, ** 0.01 Signification Level and *** 0.001 Signification Level

The orientation of the slope was key to increasing the amount of SOC accumulated in the soil. Changes in the slope and the amount of solar radiation associated with different slope orientations affect temperature and humidity conditions, increasing the storage capacity of SOC reserves. According to Rawlik et al. (2019), north- and east-facing slopes present more favorable moisture conditions than south- and west-facing slopes. In contrast, in this research, the South orientation presented similar conditions to the North and South facing slopes, which could be associated with the vegetation cover conditions given by the forest management of the area, which generate similar microclimatic conditions in the three orientations and, therefore, a similar SOM decomposition rate (Staszel et al., 2021).

The slopes showed heterogeneity in dasometric characteristics, which influence the quantity and quality of organic material deposited in the soil, which has a direct impact on soil nutrition and carbon reservoirs (Gautam & Shapkota, 2025). Leal et al. (2023) point out that dasometric variables are key in the production and decomposition of SOM; since the opening of the canopy and the change in the composition of the species are modified through forest management, affecting the climatic variables of the place (solar radiation, relative humidity, humidity, and soil temperature, among others). The organic carbon content in the soil by orientation was significantly different, which could be related to the variability of the dasometric characteristics present in the areas. For example, the highest density of vegetation cover was found in the South and East orientation

(5.04 and 4.46 m), in the latter, the largest number of individuals belonging to the genus *Quercus*, which according to Tapia-Coronado et al. (2022) is one of the variables with the greatest influence on SOC contents, considering that it is the main source of organic material to the soil. This coincides with Cano-Flores et al. (2020), who found higher concentrations of SOC in areas dominated by the genus *Quercus*, attributed to the fact that the integration of carbon and nutrients is faster in *Quercus* than in *Pinus*, given by the low contents of lignin and water-soluble compounds.

Various studies attribute that the distribution of SOC responds to multiple complex interactions between the orientation of the slopes (topography), the physical and chemical characteristics of the soil, as well as the contributions of organic material from vegetation (mainly leaves, branches, and fruits) (Buraka et al., 2022; Gerke, 2022; Jakšić et al., 2021; Niu et al., 2022); in particular, the orientation defines the microclimate of the slopes where moisture flows and soil temperature impact the rate of microbial decomposition of organic matter (Pardo-Plaza et al., 2019), for example, in areas with little or no sunlight incidence, biological activity is inhibited, leading to low SOC content (Ameray et al., 2021; Haile et al., 2024; Rawlik et al., 2019). Likewise, a direct incidence of the sun can develop a vegetation cover of species with a lower contribution and quality of organic matter (Hao et al., 2025). Therefore, we can define that vegetation regulates microclimates, creating a suitable point for the accumulation of carbon and stability in the soil, since water and wind erosion on the slopes is reduced, which is reflected in the results of this study.

5. CONCLUSION

Based on the results, it can be defined that topography plays a determining role in the capture of Soil Organic Carbon (SOC). Particularly, on the slopes with North and South exposure, they registered the highest concentrations of carbon in the first 20 cm of the soil. This highlights the importance of the strategic management of plant residues as complementary actions to enhance carbon sequestration in the upper parts of the slopes.

Declaration of Competing Interest

The authors declare that no competing financial or personal interests may appear to influence the work reported in this paper.

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