


Arboreal biomass and economic carbon assessment of the Cerro Tres Puntas of Pillasca (Salas-Motupe, Lambayeque, Perú)

Biomasa arbórea y valoración económica de carbono del Cerro Tres Puntas de Pillasca (Salas-Motupe, Lambayeque, Perú)

Biomassa arbórea e valoração econômica do carbono do Cerro Três Pontas de Pillasca (Salas-Motupe, Lambayeque, Perú)

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ABSTRACT

The work was developed in the Cerro Tres Puntas de Pillasca, in the district of Salas-Motupe, Lambayeque region, Perú. The objective of the study was to determine its tree biomass, accumulated carbon and economic valuation. For this purpose, four linear transects were established covering 11.4 ha of the total 2,975 ha of the study area. In each transect were evaluated the height and diameter (1.30 cm above the ground) e" 5.0 cm of all tree individuals. Also, botanical collections were made for their identification. 410 individuals were registered, comprised of 17 species, 17 genera and 10 families. The estimated biomass in the four transects gave an average of 796.62 t ha⁻¹, which transformed into tons of carbon gave 1 460.6 t CO₂ ha⁻¹, meaning an economic valuation of 28 963.70 USD per ha. The families that contribute more biomass to the Cerro Tres Puntas de Pillasca were Moraceae and Lauraceae, with 8 457.95 t ha⁻¹ and 5 738.79 t ha⁻¹ respectively, while in the rest of the families the biomass was less than 1 000 t ha⁻¹. Cerro Tres Puntas de Pillasca proved to be an important forest with high biomass values for the region of Lambayeque.



Keywords: Aerial biomass; Tropical dry forest; Carbon sequestration; Native tree species; Perú.

RESUMEN

El trabajo se desarrolló en el cerro Tres Puntas de Pillasca, en el distrito de Salas-Motupe, región Lambayeque, Perú. El objetivo del estudio fue determinar su biomasa arbórea, el carbono acumulado y la valoración económica. Para ello, se establecieron cuatro transectos lineales que abarcaron 11,4 ha del total de 2 975 ha del área de estudio. En cada transecto fueron evaluados la altura y el diámetro (a 1,30 cm por encima del suelo) $\geq 5,0$ cm de todos los individuos arbóreos. Asimismo, se realizaron colectas botánicas para la identificación de los mismos. Se registraron 410 individuos, comprendidos en 17 especies, 17 géneros y 10 familias. La biomasa estimada en los cuatro transectos arrojó una media de 796,62 t ha⁻¹, la que transformada en toneladas de carbono arrojó 1 460,6 t CO₂ ha⁻¹, significando una valoración económica de 28 963,70 USD por ha. Las familias que aportan mayor biomasa al cerro Tres Puntas de Pillasca fueron Moraceae y Lauraceae, con 8 457,95 t ha⁻¹ y 5 738,79 t ha⁻¹ respectivamente, mientras que en el resto de familias la biomasa fue menor de 1 000 t ha⁻¹. El Cerro Tres Puntas de Pillasca demostró ser un importante bosque con altos valores de biomasa para la región de Lambayeque.

Palabras clave: Biomasa aérea; Bosque tropical estacionalmente seco; Captura de carbono; Especies arbóreas nativas; Perú.

RESUMO

O trabalho desenvolveu-se no Cerro Três Pontas de Pillasca no distrito de Salas-Motupe, região Lambayeque, Perú. O objetivo de estudo foi determinar a sua biomassa arbórea, o carbono aglomerado e a valoração econômica. Com este fim estabeleceram-se quatro transectos lineares que abrangeram 11,4 ha da totalidade de 2 975 há da extensão de estudo. Em cada um dos transectos avaliados, a altura e o diâmetro (a 1,30 cm por acima do terreno) $\geq 5,0$ cm de todos os indivíduos arbóreos. Mesmo assim, realizaram-se coletas botánicas para a identificação dos mesmos. Registraram-se 410 indivíduos, compreendidos em 17 espécies, 17 gêneros e 10 famílias. A biomassa estimada nos quatro transectos resultou uma média de 796,62 t ha⁻¹, que transformada em toneladas de carbono, trouxe como resultante 1 460,6 t CO₂ ha⁻¹, o que significa uma valoração econômica de 28 963,70 USD por há. As famílias que aportaram maior biomassa ao Cerro Três Pontas de Pillasca, foram *Moraceae* e *Lauraceae*, com 8 457,95 t ha⁻¹ e 5 738,79 t ha⁻¹ simultaneamente, mesmo que no resto das famílias, a biomassa foi menor de 1 000 t ha⁻¹. O Cerro Três Pontas de Pillasca demonstrou ser uma importante floresta com altos valores com altos valores de biomassa para a região de Lambayeque.

Palavras chave: Biomassa aérea; Floresta tropical estacionalmente seca; Captura de carbono; Espécies arbóreas nativas; Perú.

INTRODUCTION

The greatest threat of our times that confronts humanity and that involves and compromises all its actors is global warming, verified by the increase of the atmospheric temperature due to the great emissions of Greenhouse Gases (GHG) such as carbon dioxide (CO₂) - the most important due to the amounts that are emitted -, methane (CH₄), nitrogen oxides (NO_x) and chlorofluorocarbons (CFC). In this sense, tropical forests play an indispensable role in the global terrestrial carbon



cycle (Houghton, 2005), having quantitatively significant carbon reservoirs, stored in the form of biomass (Pan *et al.*, 2011; Feldpausch *et al.*, 2012; Pooter *et al.*, 2016). However, such extensions threaten a steady reduction in areas due to intense deforestation, habitat fragmentation and land use changes (Song *et al.*, 2018).

Among terrestrial ecosystems, forest systems are particularly remarkable, since their arboreal articulation retains large amounts of atmospheric carbon, compared to other types of vegetation (Albritton and Dokken, 2001). Therefore, one of the most important processes in the forest balance stands out, the carbon cycle (C), a chemical element and the main formator of biological matter. The carbon cycle consists of several stages, ranging from its absorption by plants to its transformation into biomass (Brown, 1997). It is estimated that tropical trees absorb ~ 72 Pg C from the atmosphere per year (Beer *et al.*, 2010). In addition, it is estimated that the carbon stock of tropical forests exceeds 370 Pg C (Pan *et al.*, 2011). These carbon sinks represent an intense flow of continuous mitigation of one of the most important greenhouse gases. It should be noted that tropical forests are subject to global appreciation for the services they provide to mitigate GHG concentrations. In this sense, the reduction of GHG emissions and the reduction of global temperature are patterns of global interest. However, estimating the size of carbon resources over time is an arduous and almost impossible task, even when considering a set of complex variables and interactions of different elements of an ecosystem (Mitchard, 2018). Other studies on carbon capture and storage have been conducted in various ecological environments in Latin America, although not precisely in seasonally dry tropical forests. Such is the case of a destructive sampling carried out in Granma, in the Sierra Maestra of Cuba (Toirac *et al.*, 2018).

Among Peruvian's impressive biomes is one of the world's most fragile and threatened ecosystems, the Tropical Seasonal Dry Forest (TDS) (Apgaua *et al.*, 2014). In the ecological context of biomass and carbon studies, the seasonally dry tropical forests of the Lambayeque region have little information available, because the vast majority of studies are in the private sector. However, a relevant study reported that in the various types of dry forests located in the hamlet of El Choloque (Tongorrape, Motupe, Lambayeque), in nine circular plots of 30 m radius, within an area of 159.3 ha, the capture and storage of C, as a mitigation against climate change, was analyzed in the species *Bursera graveolens*, *Loxopterygium huasango*, *Prosopis limensis* and *Parkinsonia praecox*, obtaining a potential of capture of C by primary biomass (foliage and leaf litter) of 0.52 t C ha^{-1} , a potential of storage of C at the level of the aerial biomass (major branches and shaft) of 4.23 t C ha^{-1} in a forest with an average age of 25 years and in the soil of $42.19 \text{ t C ha}^{-1}$ (Chávez, 2018).

Considering that there are still gaps in the estimation of biomass and carbon accumulation, as well as their valuation in the dry forests of the Lambayeque region, the objective of this research was to determine these elements in the Cerro Tres Puntas de Pilasca, Salas, Lambayeque region (Perú), as a real contribution of the seasonally dry tropical forests of the Lambayeque region.

MATERIALS AND METHODS

Study area

The study area was located in the Pilasca farmhouse, 5 km from the district of Salas, in the province and region of Lambayeque, Peru (Figure 1), at the coordinates $6^{\circ}14'16,23''$; S $79^{\circ}35'34,81''$ W and $6^{\circ}12'46,46''$ S ; $79^{\circ}33'59,58''$ W , comprising In addition, the Cerros Tierra Blanca and Gato, which belong to the Salas district and



the Cerro Tres Puntas, which belongs to the Motupe district, covering an extension of approximately 2,975 hectares, with an elevation between 1,545 and 1,986 meters a.s.l. The area corresponds to a very rough and dangerous topography, with enormous rocks and deep, dry ravines and scarce rocky clearings where primitive and subsistence agriculture thrives, predominating medium and large sized trees and shrubs no higher than 5 m high, as well as a very varied herbaceous vegetation.

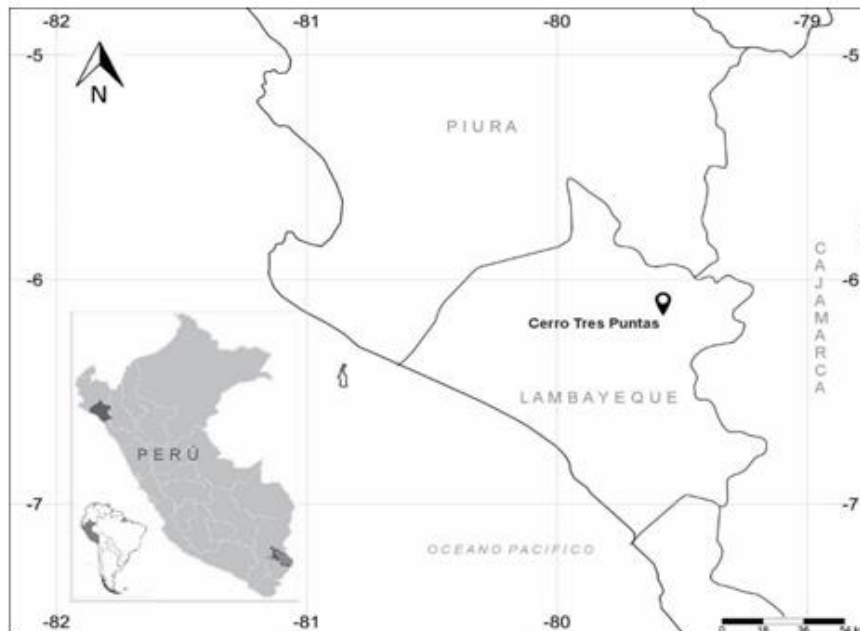


Figure 1. - Map of the Lambayeque region (Perú)

Sample collection and processing

The field work was carried out between the months of March and June 2018. Due to the difficult accessibility and dangerousness of the terrain, the Gentry woody plant sampling method (1995) was used, with adaptations for the study area. Four sampling units (line transects) were established in the field, covering 11.4 ha, as indicated in the work of [Delgado-Paredes et al., \(2020\)](#). In each transect, the height and diameter (1.30 cm from the ground) ≥ 5 cm of all tree individuals were recorded. Likewise, botanical collections were made for their subsequent identification. botanical samples were identified from physical-virtual literature, consultations to specialists and visits to herbaria. All families were classified according to [APG IV \(APG, 2016\)](#). Finally, they were deposited in the Pedro Ruiz Gallo Herbarium (HPRG).

Data analysis

To facilitate the logical-structural interpretation of the study, the arboreal individuals were classified according to their dendrometry and botanical identification. The biomass calculation was estimated from the allometric ratio for tropical trees, as a function of diameter, height and wood density. For the calculation, it was used the formula of [Chave et al., \(2014\)](#): $B = 0.0673 * (De * ((Di)^2) * A)^{0.976}$; Where, B = Biomass ($t\ ha^{-1}$), De = Density ($g\ cm^3$), Diameter (cm), A = Height (m). For the density of each tree the database present in The World Agroforestry Centre (ICRAF) was used. When no data were obtained at the species level, results were used at the genus or family level. When no data were obtained, a global average of $0.62\ g\ cm^3$ was used. Finally, average estimates of biomass by family were compared and correlated with altitude, the latter from linear regression, choosing as confidence



parameters the r-square (R²) and significance less than 5 %. All the calculations, analysis and graphs were made through the statistical environment R 3.6.3 (R Core Team, 2020).

For the valuation calculation, the carbon conversion from the total biomass obtained was used, using Brown and Lugo's (1992) formula: $C=B*0.5$, where C = Carbon (t C ha⁻¹) and B = Biomass (t ha⁻¹). Subsequently, to define the value of carbon, the formula described by the IPCC (2003) and Mogas and Riera (2005) was used, where one ton of C is equal to 3,667 tons of CO₂ and was adjusted to the value proposed by the Electronic System for Negotiating Carbon Dioxide Emission Rights (SENDECO₂, 2017) and the Banco de la Nación del Perú (BN) as of December 2018, where one ton of CO₂ is equivalent to US\$19.83 per hectare.

RESULTS AND DISCUSSION

There were 410 individuals recorded, comprised of 17 species, 17 genera and 10 families. Table 1 shows the relationship of arboreal species registered in the four transects evaluated in the seasonally dry forest of Cerro Tres Puntas (Salas-Motupe, Lambayeque, Peru), highlighting the Fabaceae family with the highest number of species (Table 1).

Table 1. - Arboreal species present in the evaluated area of the Cerro Tres Puntas seasonally dry tropical forest species present in the evaluated area of the Cerro Tres Puntas seasonally dry tropical forest (Salas-Motupe, Lambayeque, Perú)

| Nº | Family | Species | Common name | No indiv. |
|----|---------------|---|----------------|-----------|
| 1 | Anacardiaceae | <i>Loxopterygium huasango</i> Spruce ex Endl. | hualtaco | 20 |
| 2 | Boraginaceae | <i>Cordia lutea</i> Lam. | overo | 29 |
| 3 | Burseraceae | <i>Bursera graveolens</i> (Kunth) Tr. & Pl. | palo santo | 4 |
| 4 | Fabaceae | <i>Albizia multiflora</i> (Kunth) Barneby & J.W. Grimes | angolo | 8 |
| 5 | | <i>Caesalpinia glabrata</i> Kunth | charán | 5 |
| 6 | | <i>Erythrina smithiana</i> Krukoff | frejolillo | 32 |
| 7 | | <i>Pithecellobium excelsum</i> (Kunth) Mart. | chaquiro | 21 |
| 8 | | <i>Prosopis limensis</i> Benth. | algarrobo | 9 |
| 9 | | <i>Senna atomaria</i> (L.) Irwing & Barneby | chapa | 15 |
| 10 | | <i>Vachellia macracantha</i> (Willd.) Seigler & Ebinger | faique | 154 |
| 11 | Lauraceae | <i>Beilschmiedia sulcata</i> (Ruiz & Pav.) Kosterm | palta de zorro | 1 |
| 12 | Malvaceae | <i>Eriotheca ruizii</i> (K. Schum.) A. Robins | pasayo | 6 |
| 13 | | <i>Guazuma ulmifolia</i> Lam. | guazumo | 11 |
| 14 | Moraceae | <i>Ficus obtusifolia</i> Kunth | higuerón | 17 |
| 15 | Olacaceae | <i>Ximenia americana</i> L. | ciruelillo | 17 |
| 16 | Sapindaceae | <i>Sapindus saponaria</i> L. | choloque | 6 |

In the diameter classification, individuals with minimum diameters of 5.0 and maximum of 219.9 cm were recorded, resulting in the diameter class of 10 to 19.9 cm with the largest number of individuals (128) (Figure 2), while in the analysis of the altimetric class, up to 39.9 m in height were recorded, resulting in the altimetric class of 5 to 9.9 m with the largest number of individuals (205) (Figure 3).



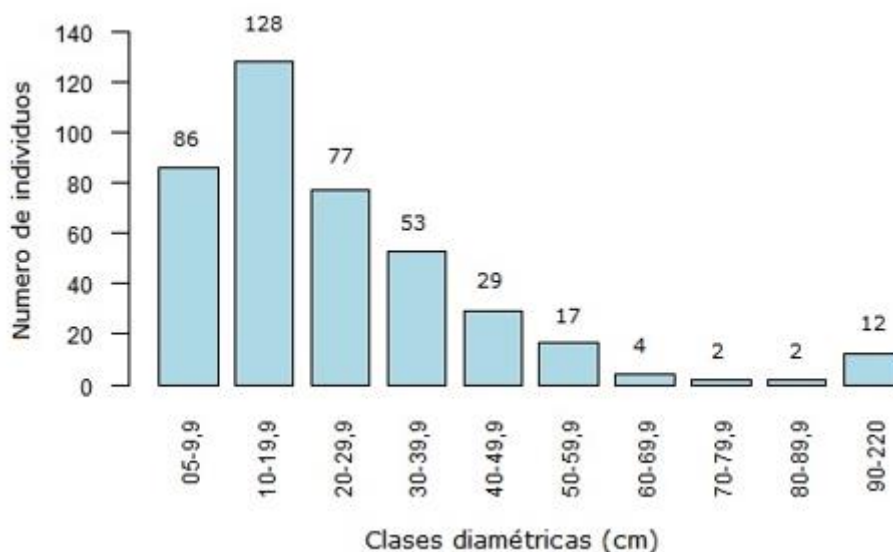


Figure 2. - Diameter structure of arboreal vegetation in the evaluated area of the Cerro Tres Puntas seasonally dry tropical forest (Salas-Motupe, Lambayeque, Perú)

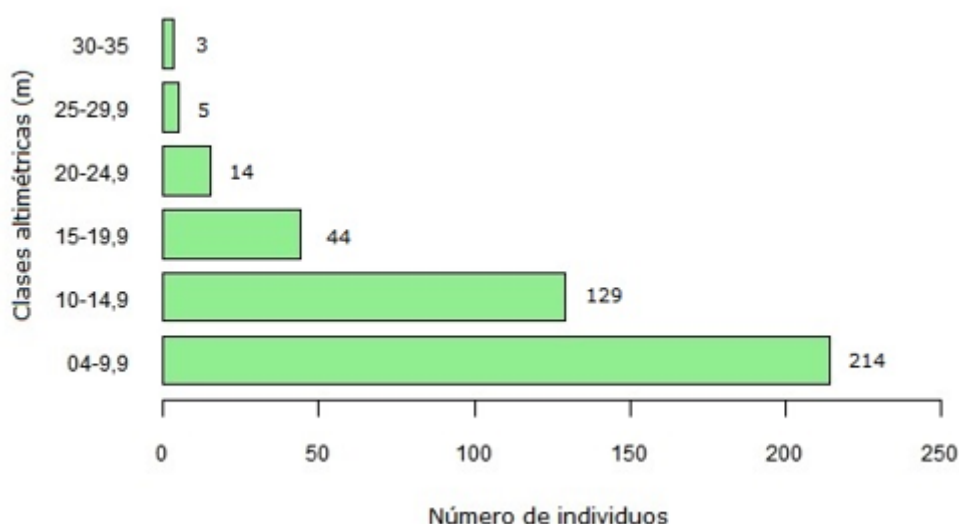


Figure 3. - Altimetric structure of arboreal vegetation in the evaluated area of the Cerro Tres Puntas seasonally dry tropical forest (Salas-Motupe, Lambayeque, Perú)

The estimated biomass for the four transects evaluated in the Cerro Tres Puntas seasonally dry tropical forest yielded an average of 796.62 t ha⁻¹, where the lowest values corresponded to transects one and two with S 288 t ha⁻¹, increasing in transect three up to 428 t ha⁻¹, while in transect four the increase was up to more than five times with 2 182.11 t ha⁻¹ (Figure 4). It was also observed a trend in the increase of biomass at the same time that the altitude increased. However, no significance was found for the relationship ($R^2= 0.48$; $P=0.29$) (Figure 4). Likewise, it could be seen that the families that contribute the most biomass to the Cerro Tres Puntas de Pilasca were Moraceae and Lauraceae, with 8,457.95 t ha⁻¹ and 5,738.79 t ha⁻¹, respectively, while in the rest of the families the biomass was less than 1,000 t ha⁻¹ (Table 2), even though these values usually vary with the number of species and individuals sampled.



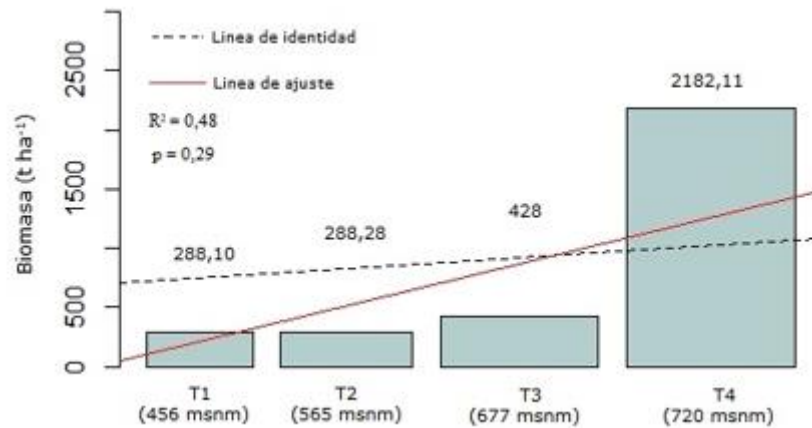


Figure 4. - Biomass (t ha⁻¹) of arboreal vegetation and its relationship to altitudinal levels in the evaluated area of the Cerro Tres Puntas seasonally dry tropical forest (Salas-Motupe, Lambayeque, Perú). T= transect

Table 2. - Biomass (t ha⁻¹) of arboreal vegetation and its relationship with altitudinal levels in the evaluated area of Cerro Tres Puntas seasonally dry tropical forest (Salas-Motupe, Lambayeque, Perú)

| Families | Nº Individuals | Biomass (t ha ⁻¹) |
|----------------------|-------------------|-------------------------------|
| Anacardiaceae | 20 | 502,82 |
| Boraginaceae | 29 | 23,13 |
| Burseraceae | 4 | 103,8 |
| Fabaceae | 244 | 177,42 |
| Malvaceae | 17 | 338,88 |
| Moraceae | 17 | 8 457,95 |
| Olacaceae | 17 | 58,23 |
| Lauraceae | 1 | 5 738,79 |
| Sapindaceae | 6 | 150,94 |
| Ulmaceae | 55 | 997,84 |

Undoubtedly, these individuals, still preserved at all costs by the Pilasca community, are the most important chronological reference in the forest. In the estimation of total accumulated biomass in community forests in the Frailesca region of Chiapas, Mexico, it was demonstrated that this was in relation to the age of the tree, since older individuals such as the *Pinus maximinoii*, from 40 to 100 years and *Quercus rugosa*, from 20 to 70 years, stored 158 and 117 Mg ha⁻¹, respectively, while younger individuals such as *Quercus robur*, from 20 to 40 years, stored only 5.9 Mg ha⁻¹ of carbon, (Rodríguez-Larramendi *et al.*, 2016). This close relationship between



normalized diameter (m), tree age and photosynthetic processes that lead to biomass accumulation and carbon sequestration in different forest species has been observed in other species such as *Gliricidia sepium* and *Leucaena leucocephala*, in silvopastoral systems (Gómez-Castro *et al.*, 2010), where atmospheric carbon sequestration increased with age.

These kinds of studies, in the seasonally dry tropical forests of Perú and especially in the seasonally dry tropical forests of northern Perú and even more so in the Lambayeque region, are almost non-existent. In a forest of Tongorrape, Motupe (Lambayeque), with an average age of 25 years, where the species *Bursera graveolens*, *Loxopterygium huasango*, *Prosopis limensis* and *Parkinsonia praecox* were evaluated, with diameter > 5.0 cm, the potential of carbon capture by primary biomass (foliage and leaf litter) was 0.52 t C ha⁻¹, to which was added the aerial biomass (major branches and shaft) of 4.23 t C ha⁻¹, in the lapse of five months (Chávez, 2018); Figures that only allow a slight comparison with the results obtained in the study presented, carried out in the Cerro Tres Puntas.

Regarding the economic valuation of the Cerro Tres Puntas seasonally dry tropical forest, determined from the transformation of tons of biomass into tons of carbon, from 796.62 t ha⁻¹ of biomass was obtained 398.31 t C ha⁻¹. Likewise, it was found that there are 1 460.6 t CO₂ ha⁻¹, which when multiplied by the value of CO₂ in December 2018, according to SENDECO₂ and the Banco de la Nación del Perú was 28 963.70 USD per hectare.

CONCLUSIONS

The study of the arboreal biomass, accumulated carbon and economic valuation of the BTES, Cerro Tres Puntas de Pilasca (Salas-Motupe), of the Lambayeque region, determined an average of 796.62 t ha⁻¹, identifying the species *Ficus obtusifolia* (Moraceae) and *Beilschmiedia sulcata* (Lauraceae) as the ones with the highest biomass with 8 457.95 t ha⁻¹ and 5 738.79 t ha⁻¹, respectively, as well as the transformation of tons of carbon that reached 1 460.6 t CO₂ ha⁻¹, meaning an economic valuation of 28 963.70 USD ha.

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The authors have participated in the writing of the work and analysis of the documents.



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