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Natural and Artificial Occurrence, Structure, and Abundance of *Juglans neotropica* Diels in Southern Ecuador

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Abstract: This study investigated the presence and characteristics of *Juglans neotropica* in three ecosystems in Southern Ecuador: Montane Evergreen Forest, Evergreen Seasonal Lower Montane Forest, and Semideciduous Foot Montane Forest. The main focus was the species' multipurpose nature as both a fruit and timber source. Six study sites, totaling at least 0.5 hectares each, were established, with four in Loja province and two in Zamora Chinchipe province. The results showed significant differences in dendrometric variables across the sites, with the most favorable growth recorded in The Tundo, where trees exhibited an average diameter at breast height (DBH) of 45.16 cm, basal area (G) of 1.41 m^2, total height (TH) of 19.22 m, canopy height (CH) of 13 m, cubic volume (CV) of 3.55 m^3, and total volume (TV) of 5.22 m^3. The species displayed a clumped distribution pattern, as indicated by a Morisita index greater than 1. Regarding abundance, the highest density of 297 trees per hectare was found in Argelia, while Victoria had the lowest density of 46 trees per hectare. The research provides a better insight into the occurrence, forest structure characteristics, and distribution of *Juglans neotropica*, an important multipurpose species, in Southern Ecuador.

Keywords: fruit; forest; ecosystem; wood; native; Ecuador

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1. Introduction

Understanding the distribution of a species is of utmost importance as it represents the geographic area where the species occurs and interacts with the ecosystem over time, be it short, medium, or long term [1]. While some species have a wide natural distribution, others have a limited range. A broader distribution increases the likelihood of encountering genetic variation, as different populations adapt to diverse local environments [2].

The *J.* genus belongs to the Juglandaceae family, which originated on the Asian continent approximately 56 million years ago. This genus includes species such as *J. ailantifolia*, *J. mandshurica*, and *J. regia*, with the latter being the most extensively cultivated and widely distributed across both the old and the New World. This is primarily due to its highly nutritious fruits and valuable wood [3,4].

Around 23 million years ago, other American walnut species emerged, retaining physical characteristics inherited from their Asian counterparts. These species migrated from North America to Central America, specifically Mexico, with *J. olanchana* as the epicenter of speciation for other Central and South American species. Among these species, *J. boliviana* is found in Bolivia, *J. australis* in Argentina, and *J. neotropica* in Colombia. The latter species also extends its presence to Peru and was discovered in Ecuador around the 15th century [5].

Understanding the historical distribution patterns and speciation events of *Juglans* species is essential for various reasons. First, it provides insight into the evolutionary processes that have shaped the genetic diversity and adaptations observed in different populations. Second, it aids in conservation efforts by identifying regions of high species richness and potential genetic reservoirs. Last, it enables the development of informed strategies for the management and sustainable use of these valuable resources [6].

By examining the distribution of *Juglans* species across time and space, researchers can unravel the intricate relationships between the organisms and their environment [7]. This knowledge can contribute to the conservation and sustainable utilization of these species, ensuring their survival in the face of environmental changes and human activities. Moreover, it offers opportunities for further research of the ecological interactions, evolutionary history, and potential applications of these remarkable trees.

In this study, we aim to expand our understanding of the distribution patterns and evolutionary dynamics within the *J. neotropica* species. By examining historical records, genetic data, and ecological factors, we seek to shed light on the factors influencing the distribution and diversification of *J. neotropica*. Through this research, we hope to contribute to the broader knowledge of evolution, conservation, and sustainable management practices [8].

Juglans neotropica, commonly known as "Nogal" or "Tocte," is a woody plant native to the South American Andes, specifically Ecuador, Colombia, Peru, and Bolivia. This species is of particular interest due to its wide distribution and cultural significance in Ecuador. It has been reported in various provinces of Ecuador, including Bolívar, Loja, Azuay, Tungurahua, Chimborazo, Pichincha, Napo, and Galapagos [9].

In Ecuador, *J. neotropica* is predominantly found in the inter-Andean region, encompassing the valleys and foothills of the Andes mountain range. The species thrives in diverse ecosystems characterized by different altitudinal ranges. Within the Southern Montane Evergreen Forest of the Eastern Cordillera of the Andes, *J. neotropica* is distributed between 2200 and 3000 m above sea level (masl). Specifically, it can be found in towns such as The Argelia, The Zañe, The Tibio, and The Merced. Furthermore, in the Catamayo-Alamor Semideciduous Foot Montane Forest ecosystem, which ranges from 400 to 1600 masl, *J. neotropica* is present in the provenances of The Tundo and The Victoria. Notably, in The Tundo provenance, walnut trees were also observed in the Evergreen Seasonal Montane Forest ecosystem, situated under Catamayo-Alamor, at altitudes ranging from 1600 to 2000 masl [10].

The distribution of *J. neotropica* extends beyond South America, with a surprising occurrence in New Zealand, specifically in the city of Auckland. However, its presence in South America, particularly in Ecuador, holds historical and cultural significance. There is evidence of its cultivation in the Equatorial Andes since pre-Columbian times, highlighting its long-standing importance to local communities [11].

The factors involved in the spatial distribution of plant species propose three approaches. First, the methods that discretize the space occupied by trees. These involve dividing the study area into predefined units and counting the trees in each, which reflects the population density. The variance of this intensity is linked to the spatial distribution of each tree. Second, methods based on distance calculation focus on the relationship between a randomly selected tree and its nearest neighboring tree. The tree-tree distance is compared with the point-tree distance, with values of less than 1, indicating regular distributions and greater than 1, indicating aggregate distributions. [12]

J. neotropica is currently classified as an endangered species, facing severe threats that have greatly hindered its regeneration in the early stages of growth [13]. Anthropogenic activities, such as the recruitment of natural regeneration and expansion of agricultural land into forested areas, have played a significant role in this decline [14]. Regarding the regulatory and protection entities responsible for endangered species in Ecuador, particularly *J. neotropica*, there is currently a lack of comprehensive information regarding its occurrence, distribution, abundance, and overall conservation status. As a result, the conservation efforts for this species have been hindered.

In terms of its ecological guild, *J. neotropica* exhibits a semi-heliophytic nature, requiring shade during its initial stages of growth but becoming heliophytic as an adult, dominating the upper canopy of the forest. Additionally, as a deciduous species, the leaf litter of *J. neotropica* plays a vital role in maintaining ecosystem balance by providing a source of energy, contributing nutrients, and forming humic substances in the soil. The most significant impact of this species is observed in South America's dry and montane forests, which serve as its natural habitat [15,16].

Understanding the distribution patterns and ecological preferences of *J. neotropica* is crucial for its conservation and sustainable management. Moreover, investigating the factors that contribute to its successful adaptation to different altitudes and ecosystems can provide valuable insight into the species' ecological resilience and potential for the future cultural significance of *J. neotropica* in Ecuador, shedding light on its ecological role and potential conservation strategies. By analyzing existing literature and conducting field surveys, we aim to contribute to the broader understanding of this valuable species and promote its sustainable use and preservation in Ecuador and beyond.

2. Materials and Methods

2.1. Study Area

The study area of this research is situated in Southern Ecuador or Zone 7, encompassing the geographic coordinates 3°30′ and 5°0′ south latitude, and 78°20′ and 80°30′ west longitude. It shares borders with zones 5 and 6 to the north, Peru to the south and east, and Peru and the Pacific Ocean to the west [17] This region holds great ecological significance due to its distinct topographic, altitudinal, climatic, and soil characteristics.

To conduct the present study, we conducted fieldwork in the three provinces within Zone 7 that had documented occurrences of the species *J. neotropica*. These provinces are Loja (11,065.6 km^2), El Oro (5866.6 km^2), and Zamora Chinchipe (10,559.7 km^2), collectively covering an area of 27,491.9 km^2, which represents approximately 11% of the total land area of Ecuador [17]

In order to provide a comprehensive analysis of *J. neotropica* and its associated factors, we selected these provinces as they exhibit diverse characteristics that are vital to understanding the species' distribution and ecology. By focusing on these specific regions, we aim to contribute valuable insight into the habitat preferences, population dynamics, and conservation implications of *J. neotropica* within Zone 7.

Through our investigation, we seek to shed light on the ecological importance of this area and provide valuable information that can guide future conservation efforts. The findings of this study will help to improve our understanding of *J. neotropica's* habitat requirements, enabling more effective conservation strategies to protect this species and its associated ecosystems in Southern Ecuador.

2.2. Occurrence

To determine the occurrence of the species in Southern Ecuador, we consulted databases from nationally and internationally recognized entities such as Geo-Cat, Tropics Database, and the Ecuadorian Biodiversity System (BNDB). These platforms contain a comprehensive collection of regional and international botanical data sourced from various institutions, collectors, and research projects, both public and private.

Additionally, we gathered information from the decentralized Autonomous Governments (GAD's), public institutions such as MAATE, and private landowners. We also accessed data from the National University of Loja's Reinaldo Espinosa Herbarium and the Private Technical University of Loja, which house collections of books containing valuable information on the flora of the Andean forest.

To validate the occurrence of the species, we carefully verified the geographic details of all the collected information. Furthermore, we utilized internet resources to obtain reports on the species' occurrence. Notably, the most reliable and accurate information came from residents and owners of private land where the species was suspected to exist.

All the collected information was meticulously entered into the ARCGIS 10.8 geographic information system to generate precise geographic locations for the occurrence of the species.

By following this comprehensive methodology, we ensured that our research on the occurrence of the species in Southern Ecuador was based on reliable data from reputable sources and validated through geographic verification and resident reports. The utilization of the ARCGIS 10.8 system further enhanced the accuracy of our findings.

2.3. Structure

Following the identification of species occurrence, a series of field trips were conducted to select suitable sites where *J. neotropica* was found. These field trips spanned a duration of 12 months. Each site was visited a minimum of three and a maximum of five times, depending on the forest size.

To assess the parameters and structural indices, a comprehensive forest inventory was conducted, employing two distinct methods:

1. Statistical Method: A 100% inventory was performed for areas ≤one hectare. For areas larger than one hectare, a simple random sampling approach was implemented.
2. Objective-based Method: An inventory was carried out for the management of natural forests, with the intensity ranging from 1% to 5% of the total area [18].

To determine the reliability and representativeness of the sampled area, the sampling intensity formula (*I*) was applied.

$$I = \frac{Sample\ surface}{Population\ area} \times 100 \quad (1)$$

where:

I = Sampling intensity
Ss = *Surface* of the *sample*
Pa = *Population area*
100 = Constant

By applying these methods, we ensured a rigorous and comprehensive assessment of the forest structure, allowing for accurate data collection and analysis. The statistical method provided a systematic approach, while the objective-based method facilitated the management of natural forests. The combination of these approaches ensured a robust evaluation of the species' habitat and supported the reliability of our findings.

Making multiple visits to each site and the implementation of various inventory methods enabled us to capture a comprehensive picture of the forest's structure and characteristics. This approach contributes to the overall validity and reliability of our study, ensuring that our conclusions are well-founded and representative of the larger population of interest.

2.3.1. Structural Parameters

To assess the structural characteristics of the study area, individuals with a diameter at breast height ($DBA_{1.30m}$) of $\geq$ 10 cm were georeferenced. These individuals, commonly referred to as stems in forestry, were located using a Garmin Montana 650 GPS device.

Once the inventory and georeferencing of *J. neotropica* individuals were completed, various dasometric parameters were calculated, including DBH, TH, CH, G(m^2), and V(m^3). The DBH data of the inventoried individuals were then organized into diameter classes of 10 cm widths, following the established protocol [19] (Table 1).

Table 1. Dasometric parameters.

Denomination	Formula	
Diameter at breast height, above ground level	$DBH_{1.30\ m}$	
Total height	TH (m)	
Commercial height	CH (m)	
Basal area of an individual	$\hat{g} = \frac{\pi}{4} \times DBH^2$	(2)
Basal area of the population	$\hat{G}m^2 = \frac{\pi}{4} \times DBH^2$	(3)
Volume of the stem in cubic meters	$Vm^3 = \hat{G}m^2 \times CH \times F$	(4)

2.3.2. Structural Indices

Subsequently, a structural valuation index was calculated:
Morisita index:

$$I_\delta = q \sum_{i=1}^{q} ní \frac{ní - 1}{N(N-1)} \quad (5)$$

where:

$I\delta$ = Spatial distribution index
q = number of frames
$ní$ = Number of individuals in í-th square
N = Total number of individuals in all q squares

Values of less than 1 indicate a regular or uniform distribution, while a value equal to 1 suggests a random distribution, and values greater than 1 indicate an aggregated distribution (Morisita 1959). Uniform distribution implies that the population is equally spaced, random indicates that it is spaced at random, and clustered distribution means that the population is distributed in groups (Figure 1).

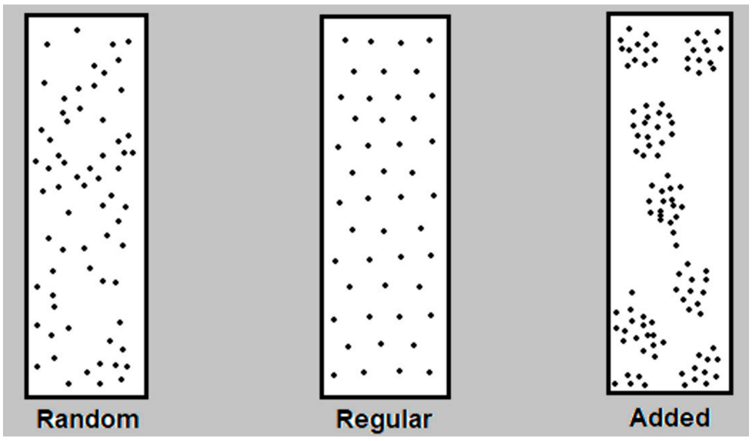

Figure 1. Spatial distribution models. Amaral et al., 2015 [20].

2.4. Abundance

To assess the abundance of *J. neotropica*, we followed the guidelines set forth in [21], as outlined in ministerial agreement 125, article 11. According to these guidelines, a species is considered to have low abundance when the density is less than one tree per three hectares (0.33 trees/ha^{-1}). Hence, we determined the abundance of *J. neotropica* by identifying the reference tree in each site and applying the specified criteria. This approach allows for an accurate evaluation of the species' abundance and facilitates comparisons across different sites.

Finally, the following formula was applied:

$$Ai = \sum n \quad (6)$$

where:

Ai = Absolute abundance
$\sum n$ = Number of individuals of a species present in an area

3. Results

3.1. Ocurrence the J. neotropica

The natural and artificial occurrence of *J. neotropica* species was observed in six locations within southern Ecuador, encompassing the provinces of Loja, El Oro, and Zamora Chinchipe. These occurrences were identified in forested areas measuring $\geq$0.5 hectares. Specifically, four instances were recorded in the province of Loja, while the remaining two were documented in the province of Zamora Chinchipe (Table 2).

Table 2. Occurrence of *J. neotropica* Diels growth sites in Southern Ecuador.

PROVINCE	CANTON	FOREST SITE	AREA (ha)
Zamora C hinchipe	Zamora	"Tibio" (a1)	0.8
		"Merced" (a2)	3
Loja	Sozoranga	"Tundo" (b1)	120
	Macará	"Victoria" (b2)	0.9
	Loja	"Zañe" (b3)	92
		"Argelia" (b4)	0.7
El Oro	No records	No records	0

In this study, the provenances were located in terms of political and geographical location, as can be seen in Figure 2.

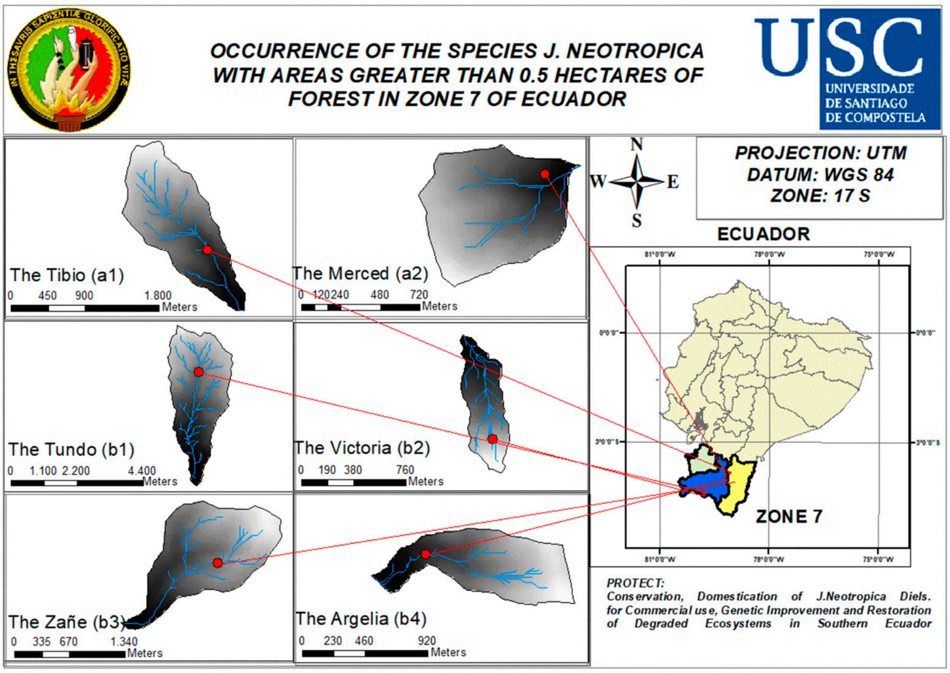

Figure 2. Geographic location of occurrences of the specie *J. neotropica* in areas greater than 0.5 hectares of forest in southern Ecuador.

3.2. Structural Parameters

In terms of structural parameters, we successfully determined the dasometric variables for all the locations with areas exceeding 0.5 hectares. The data obtained represent the number of individuals recorded within the sampled areas, appropriately adjusted to hectares to facilitate interpretation (Figure 3).

(**a1**) (**a2**) (**b1**) (**b2**) (**b3**) (**b4**)

Figure 3. Measurement of structural parameters in the different locations of southern Ecuador, Tibio (**a1**), Merced (**a2**); Tundo (**b1**) Victoria (**b2**), Zañe (**b3**), Argelia (**b4**).

3.2.1. Horizontal Structure

The analysis of the horizontal structure across all provenances revealed significant variations in diameter classes and the number of individuals within each class. The Tundo Protected Forest exhibited the highest diversity, with 12 distinct diameter classes. Additionally, this provenance recorded the largest individuals in terms of diameter ($DBH_{1.30}$), with an impressive measurement of 134 cm (Figure 4). These findings emphasize the importance of considering provenance when assessing the horizontal structure of forest stands, as it can significantly influence the distribution and size of trees within a given area. These results contribute to our understanding of forest dynamics and have implications for sustainable forest management practices.

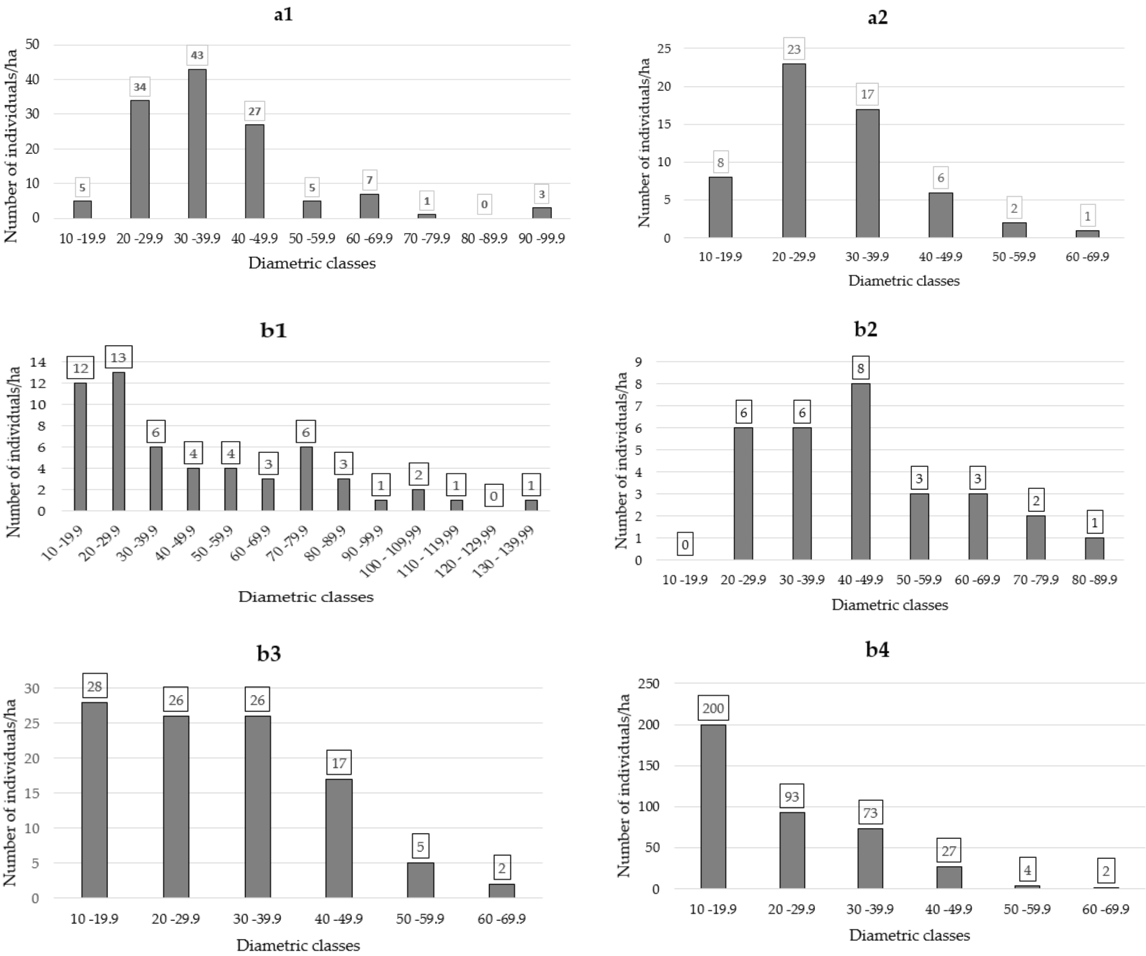

Figure 4. Number of individuals per class diameter classes in different locations of the study area at **DBH$_{(1.30cm)}$**. Tibio (**a1**), Merced (**a2**), Tundo (**b1**), Victoria (**b2**), Zañe (**b3**), Argelia (**b4**).

Among the different provenances studied, The Argelia naturalized forest displayed the highest density of individuals per hectare, with a remarkable count of 399 ind/ha. This finding highlights the exceptional abundance and richness of this particular forest ecosystem.

The analysis of the Morisita Index (Iδ) revealed a distribution pattern greater than 1 in all the studied sampling units of the various provenances. This finding indicates an aggregated distribution pattern. (Table 3).

Table 3. Morisita index by locations.

ECUADOR			
ZONE 7			
OCCURRENCES			
PROVINCES	**CANTONS**	**FORESTS**	**MORISITA INDEX**
ZAMORA CHINCHIPE	ZAMORA	Tibio (a1)	1.18
		Merced (a2)	1.22
LOJA	SOZORANGA	Tundo (b1)	120
	MACARA	La Victoria (b2)	1.30
	LOJA	El Zañe (b3)	1.26
		Argelia (b4)	1.02
EL ORO	No register	No register	0

3.2.2. Vertical Structure

In relation to the vertical structure observed in all the identified provenances, our findings demonstrate that the arboreal component of *J. neotropica* attains impressive heights, ranging from 24 to 36 m, depending on the provenance. Notably, the tallest individuals were found within the Tibio Protected Forest and the Tundo provenances. (Figure 5).

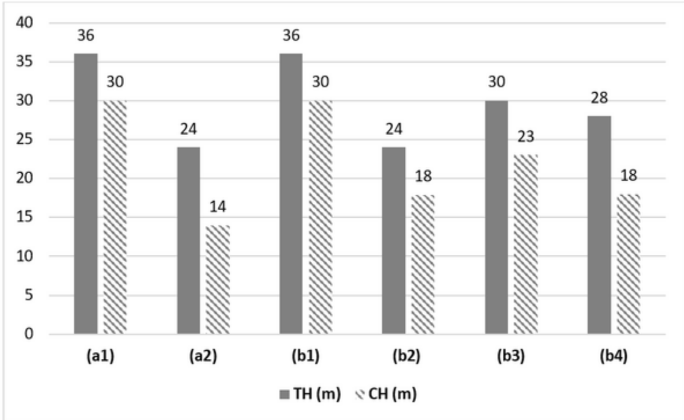

Figure 5. Vertical structure in the different locations of the study area The Tibio (**a1**), The Merced (**a2**), The Tundo (**b1**), The Victoria (**b2**), The Zañe (**b3**), The Argelia (**b4**).

3.2.3. Growth Variability

Regarding the growth behavior of dasometric variables among provenances in southern Ecuador, our study successfully demonstrated significant differences between the *J. neotropica* forests' dasometric variables using ANOVA. These findings highlight the variability in growth patterns across different provenances. The results contribute valuable insight into the understanding of tree growth in this region and have important implications for forest management and conservation strategies. Our study underlines the need for considering provenance-specific factors when developing sustainable forestry practices. These findings provide a solid foundation for future research and decision-making in the context of forest ecosystems in Southern Ecuador (Figure 6).

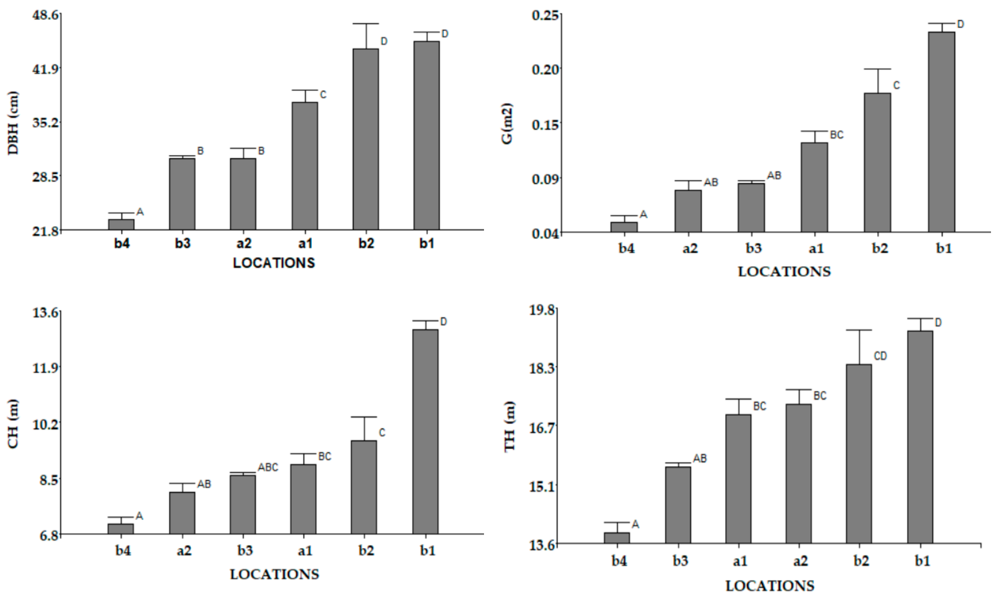

Figure 6. *Cont.*

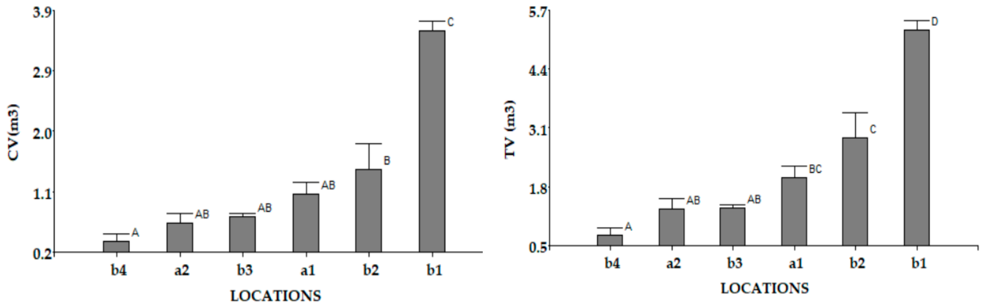

Figure 6. Analysis of variance of dasometric variables in the different locations of the study area Tibio (**a1**), Merced (**a2**), Tundo (**b1**), Victoria (**b2**), Zañe (**b3**), Argelia (**b4**). Means with a common letter are not significantly different ($p > 0.05$).

3.3. Abundance

The number of registered individuals of the *J. neotropica* species varied across different localities per hectare (Figure 7), with a minimum of 29 in Victoria and a maximum of 399 in Argelia.

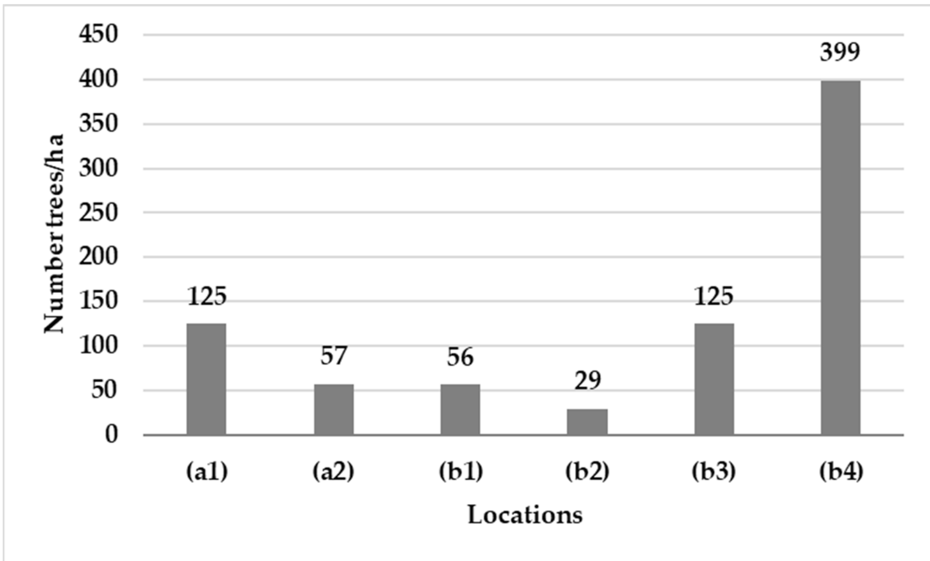

Figure 7. Number of individuals of the species recorded per hectare in the different locations of the study area Tibio (**a1**), Merced (**a2**), Tundo (**b1**), Victoria (**b2**), Zañe (**b3**), Argelia (**b4**).

4. Discussion

4.1. Occurrence

The occurrence of the *J. neotropica* species was investigated in southern Ecuador, specifically in the provinces of Loja and Zamora Chinchipe, excluding the province of El Oro. Six localities with areas greater than 5000 m^2 were identified as potential habitats for the species. Previous studies support the findings of this research regarding the occurrence of the species in the identified localities.

One study conducted by [22] reported the presence of the Tundo walnut forest in the canton of Sozoranga in the province of Loja. This forest comprises 96 hectares of native forest, located at altitudes ranging from 800 to 2645 m above sea level (masl). The area has a strongly inclined relief, which aligns with the findings of our study regarding the occurrence of the *J. neotropica* species.

Additionally, [23] documented the occurrence of the species in the canton of Loja in the Loja province, specifically in the Argelia sector. In this location, a planted forest approximately 70 years old has provided a suitable habitat where the *J. neotropica* species has naturalized effectively. The forest covers an area of 0.7 hectares and spans an altitudinal range of 2170 to 2250 masl, corroborating the findings of our study.

However, our research has revealed new occurrences of the *J. neotropica* species in previously unreported locations. The first location is Cerro el Zañe in the canton of Loja, characterized by an altitudinal range of 2100 to 2800 masl and a strongly inclined relief. The second location, the Victoria, corresponds to the canton of Macará in Loja and spans an altitudinal range of 1400 to 1600 masl. Furthermore, the species has been observed in the Merced, with an altitudinal range of 200 to 2200 masl, as well as in The Tibio, with an altitudinal range of 2400 to 2600 masl, in the canton of Zamora in Zamora Chinchipe. The precise locations of these occurrences have been reported for the first time in this study.

According to [14], the *Juglans* species exhibits a relative gregariousness in mature forest conditions, resulting in its scarcity within natural ecosystems. This pattern aligns with the findings of our research, further supporting the similarity between our study and previous observations of *Juglans* species.

4.2. Structure

Regarding the structural parameters of the forest in the discovered provenances of the *J. neotropica* species, all the dendrometric variables were correctly identified. However, the limited availability of research related to this species makes it challenging to compare our findings with other studies. Nevertheless, a study by [24] notes that the planted forest of *J. neotropica* in the Argelia exhibits very similar dendrometric variables to those observed in our study. The results underline the significance of the Argelia as a biodiverse habitat, showcasing its potential for conservation efforts and sustainable management. The high density of individuals within this forest emphasizes its ecological value and warrants further investigation into the factors contributing to its remarkable success. These findings provide valuable insight for forest management strategies and conservation initiatives in similar ecosystems.

Additionally, [25] mentions that young walnut trees have well-formed stems, reaching heights of 25 to 30 m with a diameter at breast height (DBH) of 90 cm. Our observations align with these findings at the study sites. This study sheds light on the remarkable vertical growth potential of *J. neotropica* and highlights the significant role played by specific provenances, such as The Tibio Protected Forest and the Tundo, in nurturing exceptionally tall individuals of this species.

In terms of Morisita's structural index, the species demonstrates an aggregated distribution behavior ($I\delta > 1.0$), indicating a preference for dominating specific sectors within the ecosystem. As described by [26], this type of distribution is not random but rather irregular, occurring in response to local habitat differences (microhabitats). The authors also highlight that added distribution is the most frequent pattern observed in nature and is a result of the inherent tendency of individuals to aggregate. Therefore, plants tend to disperse their seeds in close proximity to or in the same location where they reside.

Furthermore, the distribution of the species indicates a decreasing number of individuals over time, suggesting a gradual decline. However, it can still be found, albeit with difficulty, between 2200–3000 m above sea level (masl) in natural forest ecosystems covering areas greater than 5000 m^2.

4.3. Abundance

The abundance data obtained reveal notable differences in the number of individuals per hectare for the species *J. neotropica* across different provenances. The highest abundance was observed in the Argelia, followed by Zañe and Tibio. According to a previous study [23], the forest Argelia, being a forest plantation, exhibited the highest number of individuals per unit area in this investigation. This particular provenance, with an approximate age of 70 years, has adapted remarkably well to the prevailing climatic conditions at the site.

The Tundo Protected Forest and the Tibio provenance, which are native forests, also reported a relatively higher number of individuals per unit area according to another study [27]. Despite being located in different provinces, these forests share similar climate characteristics, which contribute to their higher abundance.

However, when considering the area extension, it is worth noting that the Tundo provenance boasts the largest forest area, covering approximately 130 hectares, whereas Argelia has the smallest extent, with only 0.7 hectares.

In terms of *J. neotropica* abundance, variations were observed in the number of individuals per hectare across the different provenances. These differences can be attributed to the severe threat posed to these ecosystems by various anthropic activities, such as livestock rearing and agriculture [28]. As a consequence, the species has been categorized as endangered by [16].

To better understand the abundance patterns and conservation status of *J. neotropica*, it is crucial to consider the interplay between provenance, climate conditions, and anthropic activities. The Algerian provenance, originating from a forest plantation, exhibited the highest abundance due to its successful adaptation to the local climatic conditions over several decades. Meanwhile, the Tundo Protected Forest and the Tibio provenance, being native forests, demonstrated a relatively higher abundance due to their favorable climate characteristics despite their geographical separation. However, the overall abundance of *J. neotropica* is alarmingly affected by human activities, with livestock rearing and agriculture exerting significant pressure on the species' survival.

5. Conclusions

In southern Ecuador, there are not many relicts or fragments of native forests of *J. neotropica*, the few fragments that exist presented a vertical structure in the form of an inverted j, which means that there is good growth dynamics, insofar as to the vertical structure, the individuals presented a dominance of the site with regard to other individuals that share their habitat. However, the number of individuals per hectare is not abundant in all locations.

The data obtained from the analysis of variance between the dasometric variables in relation to the different provenances of *J. neotropica* indicate that there are significant statistical differences, finding better growth in the fragments of forests with ecosystems of Semideciduous Forest Foot Montane of Catamayo-Alamor, which has a altitudinal variation of 400–1600 masl, as well as ecosystems of the Lower Montane Seasonal Evergreen Forest of Catamayo-Alamor, which has an altitudinal variation of 1600–2000 masl.

The number of trees found in the Argelia forest provenance is greater in relation to the other provenances because this is a naturalized plantation with more than 70 years of age. However, its forest area is very small with 0.7 hectares and with lower dasometric growth than the rest of the provenances studied.

Wild fruit trees, especially the *J. neotropica* species, play a crucial role in preserving biodiversity and providing natural resources in various ecosystems. It is essential to recognize the significance of these species in conserving flora and fauna, particularly in places like the Tundo walnut forest in the canton of Sozoranga, where favorable conditions exist for their development. The protection and promotion of these wild trees are fundamental in maintaining environmental harmony and balance, ensuring a sustainable future for later generations.

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References

1. Zunino, M.; Palestrini, C. El concepto de especie y la biogeografía. *An. Biol.* **1991**, *17*, 85–88.
2. Futuyma, D.J.; Moreno, G. The evolution of ecological specialization. *Annu. Rev. Ecol. Syst.* **1988**, *19*, 207–233. [CrossRef]
3. Fjellstrom, R.G.; Parfitt, D.E. Phylogenetic analysis and evolution of the genus *Juglans* (*Juglandaceae*) as determined from nuclear genome RFLPs. *Plant Syst. Evol.* **1995**, *197*, 19–32. [CrossRef]
4. Guo, W.; Chen, J.; Li, J.; Huang, J.; Wang, Z.; Lim, K.J. Portal of Juglandaceae: A comprehensive platform for Juglandaceae study. *Hortic. Res.* **2020**, *7*, 35. [CrossRef] [PubMed]
5. Manning, W.E. The Genus *Juglans* in South America and the West Indies. *Brittonia* **1960**, *12*, 1–26. [CrossRef]
6. Frei, J. A Brief History of *Juglandaceae*. *Arnoldia* **2021**, *78*, 10–17.
7. Leal Carretero, F. What role does argumentation play in the methodology of social science research? *Espiral* **2017**, *24*, 9–49. [CrossRef]
8. Aradhya, M.K.; Potter, D.; Simon, C.J. Origin, evolution, and biogeography of Juglans: A phylogenetic perspective. *V Int. Walnut Symp.* **2004**, *705*, 85–94. [CrossRef]
9. Tropics. *Juglans neotropica* . 1982. Available online: https://www.tropicos.org/name/16700014 (accessed on 20 July 2023).
10. Nieto, V.M.; Rodríguez, J. Juglans neotropica Diels. In *Tropical Seed Manual*; United States Department of Agriculture Forest Service: Washington, DC, USA, 2002.
11. Bachman, S.; Moat, J.; Hill, A.V.; De la Torre, J.; Scott, B. Supporting Red List threat assessments With. In *e-Infrastructures for Data Publishing in Biodiversity Science*; Pensoft Publishers: Sofia, Bulgaria, 2011; Volume 150, p. 117.
12. Juárez Sánchez, M. Ecología y Análisis Estructural de los Bosques Mixtos de la Sierra de San Carlos, Tamaulipas. Ph.D. Thesis, Universidad Autónoma de Nuevo León, San Nicolás de los Garza, Mexico, 2003.
13. Vaca Llivigañay, J.A.; Palacios Herrera, B.G. Estructura, productividad de madera y regeneración natural de *Juglans neotropica* Diels en la Hacienda la Florencia del Cantón y provincia de Loja. *Cienc. Lat. Rev. Científica Multidiscip.* **2023**, *7*, 1640–1655. [CrossRef]
14. García, C.J. Estudio Ecológico, Silvícola y de Utilización del Nogal (*Juglans olanchana* Standl. & LO Williams) en Bosque Latifoliados de Honduras. Ph.D. Thesis, Zamorano: Escuela Agrícola Panamericana, Tegucigalpa, Honduras, 2002.
15. Toro Vanegas, E.; Roldán Rojas, I.C. Estado del arte, propagación y conservación de *Juglans neotropica* Diels., en zonas andinas. *Madera Bosques* **2018**, *24*. [CrossRef]
16. IUCN. *Red List of Threatened Species: Juglans neotropica. IUCN Red List of Threatened Species*; IUCN: Gland, Switzerland, 2022.
17. Benítez Narváez, R.M.; Capa Benítez, L.B.; Capa Tejedor, M.E. La Zona 7-Ecuador hacia el desarrollo de ciudades intermedias. *Rev. Univ. Y Soc.* **2019**, *11*, 356–361.
18. CATIE. *Forest Inventories for Broadleaf Forests in Central America*; Lorena, O., Cecelia, B., Eds.; CATIE: Turrialba, Costa Rica, 2002.
19. Lamprecht, H. *Silvicultura en Los Trópicos: Los Ecosistemas Forestales en Los Bosques Tropicales y Sus Especies Arbóreas; Posibilidades y Métodos Para un Aprovechamiento Sostenido*; Biblioteca Digital Instito Forestal: San Pedro de La Paz, Chile, 1990.
20. Amaral, M.K.; Pellico Netto, S.; Lingnau, C.; Figueiredo Filho, A. Evaluation of the Morisita index for determination of the spatial distribution of species in a fragment of Araucaria forest. *Appl. Ecol. Environ. Res.* **2015**, *13*, 361–372.
21. MAE. Las Normas para el Manejo Forestal Sostenible de los Bosques Húmedo. Acuerdo, N. 0125. 2015. Available online: https://www.informea.org/es/legislation/acuerdo-n%C2%BA-125-normas-para-el-manejo-forestal-sostenible-de-los-bosques-h%C3%BAmedos (accessed on 20 July 2023).
22. Dueñas, D.; Guevara, O.; Santacruz, S. Valoración económica de los bienes y servicios ecosistémicos del bosque protector Jatumpamba-Jorupe. *Rev. Geoespacial* **2022**, *19*, 12–32.
23. Palacios, B.; Mendoza, Z.A.; Lozano, D.; Yaguana, C. Riqueza, Estructura y Diversidad Arbórea del Bosque Montano Bajo, Zamora Chinchipe-Ecuador. *Bosques Latid. Cero* **2016**, *6*, 2. Available online: https://revistas.unl.edu.ec/index.php/bosques/article/view/233 (accessed on 20 July 2023).
24. Palacios, B.; Aguirre, Z.; Pucha, D.; Mocha, J.; Feijoo, C.; Jumbo, J.; Rojas, A. Factor de forma y productividad de una plantación de *Juglans neotropica* Diels, establecida en los predios de la Universidad Nacional de Loja. 2017.
25. Barreto, G.; Herrera, J. *INDERNED*; Publisher Guadalupe LTDA: Santafé de Bogotá, Colombia, 1990.
26. Morláns, C.; María, B. Introducción a la Ecología de Poblaciones 2014.
27. MAE. *Sistema de Clasificación de los Ecosistemas del Ecuador Continental. Subsecretaría de Patrimonio Natural. Quito*; Ministerio de Ambiente del Ecuador: Loja, Ecuador, 2013.
28. Ramos Veintimilla, R.A.; Murillo Gamboa, O.; Gallo, L.A. Potential for genetic improvement in *Juglans neotropica* Diels, at 10 months of age in Tunshi, Chimborazo/Potential of Genetic Improvement in *Juglans neotropica* Diels, at 10 months of age in Tunshi, Chimborazo. *KnE Eng.* **2020**. [CrossRef]