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*Review article*

# *The vegetation levels of the Sierra Maestra and the priority species for reforestation*

*Los pisos de vegetación de la Sierra Maestra y las especies prioritarias para su reforestación*

*Os andares de vegetação da Serra Maestra e as espécies prioritárias para sua reflorestação*

*Euclides Fornaris Gómez*[1*], *Orlando J. Reyes Domínguez*[2], *José A. Chang Portos*[2]

[1] Eastern Center for Ecosystems and Biodiversity (Bioeco), Santiago de Cuba, Cuba.

[2] Municipal University Center of Palma Soriano. Palma Soriano, Santiago de Cuba, Cuba.

[*] Corresponding author: euclides@bioeco.cu

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## *ABSTRACT*

The Sierra Maestra is characterized by the large number of forest formations present in it, a consequence of the diversity of ecological conditions. Although these formations are largely altered, there is still a good representation of the composition of the original forests. This study aims to contribute to the conservation of this important natural heritage through restoration, rehabilitation and/or enrichment actions, with the species considered as priorities. These priorities were determined based on 180 phytocenological inventories that inventoried a total of 100 species present in the four vegetation levels found, following the altitudinal zoning proposed by several authors. These levels are: 1. Level of semi-deciduous forests and scrublands (Wetland zone, semi-deciduous microphyllous forests and scrublands and Semi-deciduous mesophyllous forest zone); 2. Evergreen Forest level; 3. Montane rainforest level and 4. Cloud Forest level. The selection of species is based on their high presence and dominance abundance. A characterization of the ecological factors present in the different ecotopes is presented, together with a map showing the distribution of vegetation belts. The criteria raised can be reflected in the strategies to be followed for forest management for conservation purposes in the Sierra Maestra.

**Keywords:** forest formations, vegetation levels, altitudinal zonation, ecological factors, management strategies.

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***RESUMEN***

La Sierra Maestra se caracteriza por el gran número de formaciones boscosas presentes en ella, consecuencia de la diversidad de condiciones ecológicas. Aunque estas formaciones se encuentran en gran medida alteradas, todavía existe una buena representación de la composición de los bosques originales. Este estudio pretende contribuir a la conservación de este importante patrimonio natural mediante acciones de restauración, rehabilitación y/o enriquecimiento, con las especies consideradas como prioritarias. Estas prioridades se determinaron con base en 180 inventarios fitocenológicos que inventariaron un total de 100 especies presentes en los cuatro pisos de vegetación encontrados, siguiendo la zonificación altitudinal propuesta por varios autores. Estos pisos son: 1. Piso de bosques y matorrales semideciduos (Zona de humedales, bosques y matorrales semideciduos micrófilos y Zona de bosques semideciduos mesófilos); 2. Piso de bosques siempreverdes; 3. Piso de la pluvisilva montana y 4. Piso de bosques nublados. La selección de las especies se basa en su alta presencia y abundancia dominancia. Se presenta una caracterización de los factores ecológicos presentes en los diferentes ecotopos, junto con un mapa que muestra la distribución de los cinturones de vegetación. Los criterios planteados se pueden reflejar en las estrategias a seguir para la gestión forestal con fines de conservación en la Sierra Maestra.

**Palabras clave**: formaciones boscosas, pisos de vegetación, zonificación altitudinal, factores ecológicos, estrategias de manejo.

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***RESUMO***

A Serra Maestra caracteriza-se pelo grande número de formações florestais nela presentes, consequência da diversidade de condições ecológicas. Embora estas formações estejam bastante alteradas, ainda existe uma boa representação da composição das florestas originais. Este estudo pretende contribuir para a conservação deste importante património natural através de ações de restauro, reabilitação e/ou enriquecimento, com as espécies consideradas prioritárias. Estas prioridades foram determinadas com base em 180 inventários fitocenológicos que inventariaram um total de 100 espécies presentes nos quatro níveis de vegetação encontrados, seguindo o zoneamento altitudinal proposto por vários autores. Esses pisos são: 1. Piso de florestas semidecíduas e arbustivas (Zona de zonas húmidas, florestas semidecíduas micrófilas e arbustivas e Zona de florestas semidecíduas mesófilas); 2. Solo de florestas perenes; 3. Chão da floresta tropical de Montana e 4. Chão da floresta nublada. A seleção das espécies é baseada na sua elevada presença e abundância dominância. É apresentada uma caracterização dos fatores ecológicos presentes nos diferentes ecótopos, juntamente com um mapa mostrando a distribuição dos cinturões de vegetação. Os critérios propostos podem reflectir-se nas estratégias a seguir para a gestão florestal para fins de conservação na Sierra Maestra.

**Palavras chave**: Formações florestais, zonas de vegetação, zoneamento altitudinal, fatores ecológicos, estratégias de gestão.

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## *INTRODUCTION*

The Sierra Maestra, the largest mountain range in Cuba, has experienced significant degradation of its forest ecosystems as a result of historically unsustainable exploitation. The altitudinal heterogeneity of this region, combined with climatic and soil factors, has led to a complex zoning of vegetation, which has been of interest to ecologists. Anthropogenic pressure has significantly altered this original distribution. In light of this scenario, Cuban forest policy has prioritized ecological restoration as a fundamental strategy to recover the functionality of these ecosystems and guarantee their long-term conservation.

The distribution and composition of this complex mosaic of ecosystems are closely linked to environmental gradients such as temperature, precipitation and soil characteristics (Álvarez and Mercadet, 2012). Altitude, in particular, exerts a determining control over the altitudinal zonation of vegetation, giving rise to a series of bioclimatic zones with distinctive ecological attributes (Samek and Travieso, 1968; Samek, 1975; Reyes, 2011).

Altitudinal gradients induce significant variations in various environmental factors, such as atmospheric humidity. There are also marked edaphic differences associated with the intensity of weathering and leaching processes. Other factors, such as exposure to winds, geology and precipitation patterns, also influence the distribution and composition of vegetation.

The types of Cuban plant formations have been described by several authors, including the works of Capote and Berazaín (1984), Borhidi (1996), Ricardo-Nápoles *et al.* (2009), among others. Their work is based on geographic, climatic, geological, ecological and/or physiognomic characteristics, which allows for the establishment of specific management regimes adapted to the conditions of each forest type. Classification, together with altitudinal zoning, is essential for the planning and execution of restoration actions.

The main objective of the study is to propose the most suitable native tree species for the restoration and rehabilitation of forest ecosystems, for which the ecological conditions of the different vegetation levels in the Sierra Maestra are characterized. The aim is to select species with a high potential for adaptation and growth in each altitudinal level, thus contributing to the recovery of biodiversity and the functionality of the forest ecosystems in the region.

*Selection of species through floristic inventories*

In order to select the most suitable species for the restoration of the different altitudinal levels of the Sierra Maestra, an exhaustive analysis of 180 vegetation inventories was carried out between 2000 and 2015 in large areas of the Sierra Maestra. These inventories, carried out for the first time in the Sierra Maestra, consist of 625 m2 plots located in well-preserved forested areas, and allowed the evaluation of the composition, structure and abundance of plant species in each level. The phytocenological method was used, based on the grouping of inventories according to their floristic similarity, to identify the characteristic plant associations of each altitudinal level. The physical-geographical elements, such as elevation, slope, exposure, geology, soil, traces of fire and grazing, among other characteristics, are described in the sampling sites.

The species recommended for restoration were selected based on their high presence and abundance in the plant associations corresponding to each floor, according to studies carried out by various authors (Reyes, 2011; Reyes and Acosta, 2005, 2019; Reyes *et al.*, 2010). Priority was given to those species whose natural distribution coincides with the environmental characteristics of each site (ecotope), thus guaranteeing their adaptation and success in restoration. The scientific names of the species were updated according to Greuter and Rankin (2017).

*Mapping the vegetation cover of the Sierra Maestra and delimitation of the altitudinal zones*

To determine the spatial distribution and classification of vegetation cover in the Sierra Maestra, a methodology based on remote sensing and geographic analysis was used. Sentinel-2 images from 2018 were used, with a spatial resolution of 10 m.

From these images, vegetation indices were generated and supervised and unsupervised classifications were carried out, with the aim of identifying and delimiting the different vegetation units. In addition, auxiliary information from thematic maps (precipitation, temperature, slope, orientation, lithology, land use) and cartography at a scale of 1:25 000 was integrated.

## *DEVELOPMENT*

Based on the results obtained from phytocenological studies and the conformation of the climatic zones present in the region, species are proposed for the restoration of protection and conservation forests, through enrichment actions, with the aim of reestablishing the specific composition of mixed forests that reflect the diversity and complexity of these natural ecosystems. This strategy seeks not only to restore the original floristic composition, but also to reestablish the ecological processes and ecosystem functions associated with native vegetation.

To achieve this goal, it is recommended to select no less than ten species per restoration site, prioritizing those with conservation value, ecological functionality and ability to adapt to changing climate conditions. The number of recommended species and their random distribution per site seeks to promote ecological integrity and ecosystem resilience.

The proposed altitudinal zoning is based on the work of Reyes (2011) and on the criteria established by Samek and Travieso (1968) and Samek (1975). This zoning allows the identification of the most suitable species for each altitudinal level and facilitates the planning of restoration actions. The zoning is as follows:

1. Floor of semi-deciduous forests and scrublands
    a. Wetlands, semi-deciduous forests and microphyllous scrubland area
    b. Zone of mesophilous semi-deciduous forests
2. Evergreen forest floor
3. Floor of the montane rainforest

4. Cloud forest floor

Phytocenological inventories (inv.) were analysed on the floor of semi-deciduous forests and scrublands, distributed between 0 and 400 m asl on the northern slope and 0 and 500 m asl on the southern slope (Figure 1). In the latter, two zones were distinguished: a lower one dominated by wetlands, forests and microphyllous semi-deciduous scrublands (94 inv.) up to approximately 100 m asl, occasionally up to 300 m asl (Figures 2 and 3), and an upper one characterized by mesophyllous semi-deciduous forests (28 inv.). The uverales (6 inv) and mangroves (50 inv) were predominant in the lower zone (Figures 4 and 5), while the microphyllous semi-deciduous forests (38 inv) were distributed in both zones. The northern slope, lacking coast and wetlands, presented only the zone of mesophyllous semi-deciduous forests.


***Figure 1.*** *- Altitudinal ranges where the vegetation levels are distributed in the Sierra Maestra*

***Figure 2.*** *- Rhizophora mangle mangrove (Photo: Orlando J. Domínguez)*

***Figure 3.** - Coastal and precoastal scrub ( xeromorphic ) (Photo: Orlando J. Domínguez)*

***Figure 4.** - Uveral (Photo: Orlando J. Domínguez)*

***Figure 5.** - Microphyllous semi-deciduous forest (Photo: Orlando J. Domínguez)*

The area of wetlands, forests and semi-deciduous microphyllous scrub is characterized by highly variable and stressful ecological conditions. The incident solar radiation is intense, with an average photoperiod of 7-8 hours (Barceló, 2017 and Guevara *et al.*, 2019a). The thermal regime shows a marked seasonality, with mean annual temperatures ranging between 24 and 26/ °C, mean annual maximums of 30-32/ °C and mean annual minimums of 22-24/ °C. Relative humidity (Guevara *et al.*, 2019b), although moderately high (75-80 % annual average), shows a significant diurnal variation, with minimum values around midday (70-75 %) and maximums during the early hours of the day (80-85 %). The high evapotranspiration, estimated between 1 700 and 1 900 mm annually (Guevara *et al.*, 2019c) exacerbates the physiological drought conditions to which the plant species in this area are subjected.

The climatic regime, characterized by a marked seasonality and a significant marine influence, conditioned the distribution of vegetation. Annual rainfall, less than 1 000 mm and with a pronounced dry period, together with the high permeability of the soils, favored the development of xerophytic formations such as microphyllous semi-deciduous forest and coastal scrubland. In the areas with greater marine influence, mangroves, halophytic grasslands and associated communities were identified. The presence of mesophyllous semi-deciduous forests in some areas is attributed to the influence of groundwater.

For restoration / rehabilitation and/or regeneration in this territory, it is proposed to use species adapted to this ecotope, such as: *Phyllostylon rhamnoid* (J. Poiss ) Taub., *Cordia geranium* L., *Bursera simaruba* (L.) Sargent., *Colubrina elliptica* (Sw.) Brizicki, *Carpodiptera cubensis* Griseb . subsp. *cubensis*, *Thouinia patentinervis* Radlk., *Caesalpinia cubensis* Greenm., *Bucida molinetii* (M. Gómez) Alwan & Stace , *Guapira obtusata* (Jacq.) Little, *Sideroxylon salicifolium* (L.) Lam., *Lysiloma latisilique* (L.) Benth., *Nectandra coriacea* (Sw.) Griseb ., *Citharexylum caudatum* L., *Drypetes alba* Poit ., *Caesalpinia bladder* L. and *Casearia sylvestris* Sw . subsp . *sylvestris.*

On the northern slope of the southern coastal terraces of the Sierra Maestra on soils originating from marl, the following are proposed: *Cedrela odorata* L., *Colubrina arborescens* (Mill.) Sarg., *Swietenia mahogany* (L.) Jacq., *Tabebuia* spp., *Calycophyllum candidissimum* (Vahl) DC. and *Sideroxylon foetidissimum* Jacq. subsp . *foetidissimum* in the cooler areas; in the other areas, those previously mentioned. In the mangroves: *Rhizophora mangle* L., *Avicennia germinans* (L.) L., *Laguncularia racemosa* (L.) Gaertn . F. and *Conocarpus erectus* L., according to the widely known zonation with respect to the sea.

The studied area of mesophilous semi-deciduous forests has a predominantly secondary physiognomy, with remnants of primary forest. The geology is heterogeneous, characterized by the presence of volcanogenic -sedimentary rocks of the El Cobre, Charco Redondo and Puerto Boniato formations (IGP, 2014). The soils are varied, with a predominance of sialitic brown on the northern slope and reddish brown fersialitic on the south. The climatic regime is characterized by an annual precipitation that ranges between 800 and 1 300 mm (Rodríguez, 2006) and average temperatures that vary between 21.3 and 26.4/ °C, being lower at higher altitudes and higher in coastal areas.

This type of forest has a great extension in the llanas and premontanas areas. To restore the plants in a different forest, the following species are proposed: *S. foetidissimum* subsp . *foetidissimum* , *L. latisiliquum* , *D. alba* , *Matayba opposite leaf* (A. Rich .) Britton, *Andira helpless* (W. Wright) DC., *C. candidissimum* , *Tabebuia* spp ., *C. gerascanthus* L., *C. odorata* , *Cedrela cubensis* Bisse , *S. mahagoni* , *C. cubensis* Greenm ., *Cordia collococca* L., *C. arborescens* (Mill.) Sarg., *Poeppigia procera* (Spreng.) C. Presl, *Calophyllum Antillanum* Britton, *Guazuma ulmifolia* Lam., *Dairy arboreal* (Rich.) Urb. subsp . *arborea, Cupania americana* L., *Cupania glabra* Sw., *Zuelania Guidonia* (Sw.) Britton y Millsp., *Genipa Americana* L., *Trichilia hairy* L., *Zanthoxylum Martinique* (Lam.) DC., *Zanthoxylum cubense* P. Wilson, *Roystonea regia* (Kunth.) OF Cook., *Samanea saman* (Jacq.) Merr . y *Piscidia piscipula* (L.) Sarg.).

On the northern slopes of the Sierra Maestra in places with shallow or very shallow soils and rainfall of 1,000 mm or more, the following are proposed: *S. foetidissimum* subsp. *foetidissimum*, *S. salicifolium*, *N. coriacea*, *C. Americana*, *M. oppositifolia*, *S. mahagoni* , *C. odorata* , *C. cubensis* , *C. arborescens* , *Lonchocarpus sericeus* (Poir .) Humboldt et al. former DC), *C. caudatum, Tabebuia* spp., *Melicoccus bijugatus* Jacq., and *Gymnanthes lucida* Sw .

The mesophytic evergreen forest floor, identified through 19 phytosociological inventories (Figure 6), constitutes an ecological transition zone between the mesophytic semi-deciduous forest and the montane rainforest, extending to approximately 800 m asl (Figure 1). The altitudinal distribution of this floor is influenced by the variability of the soils, with a predominance of brown soils in the lower parts and ferralitic soils in the upper areas. The thermal conditions, with average annual temperatures ranging between 21.3 and 24.0 °C, show a slight altitudinal decrease and a variation between slopes, which suggests the need to consider these variables in reforestation strategies.

***Figure 6.*** *- Mesophilous evergreen forest (Photo: Orlando J. Domínguez)*

The precipitation regime in the area ranges between 1 200 and 1 800 mm per year, showing spatial variability. Relative humidity, on the other hand, showed an altitudinal gradient, fluctuating between 77 and 85 % at 500 m above sea level and 84 and 92 % at higher altitudes. Relative sunshine, measured in the afternoons, showed a marked seasonality, with values between 20 and 30 % for seven months and 30 and 40 % the rest of the year.

These climatic parameters, especially precipitation and humidity, have a decisive influence on the altitudinal distribution of vegetation, as evidenced by the phytocenological studies carried out. This climatic pattern, together with the data obtained in the phytocenological inventories, is essential to define the most suitable forest species for each altitudinal zone and thus guarantee the success of the reforestation proposal.

In this case the following species are considered for restoration / rehabilitation / restoration: *Guarea guide* (L.) Sleumer, *Pseudolmedia spurious* (Sw.) Griseb., *Sideroxylon jubilation* (Urb.) TD Penn., *C. collococca* L., *Oxandra laurifolia* (Sw.) A. Rich., *Ocotea leucoxylon* (Sw .) Laness., *Sapium laurel* (A. Rich.) Griseb ., *Eugenia aeruginea* DC., *Trichilia glabra* L., *Terminalia tetraphylla* ( Aubl .) Gere y Boatwr ., *Prunus western* Sw ., *C. antillanum* , *Cojoba arbórea* (L.) Britton y Rose , *Z. martinicensis* , *Z. cubense* , *C. gerascanthus* , *R. regia* , *C. odorata* , *C. cubensis* , *Spondias mombin* L., *S. foetidissimum* subsp . *foetidissimum* , *Zuelania guidonia* , *A. inermis* , *C. sylvestris* subsp . *sylvestris, Chionanthus domingensis* Lam., *M. oppositifolia, C. caudatum, B. pendula, C. candidiasis, Poeppigia procera* (Spreng.) C. Presl, *Eugenia axillaris* (Sw.) Willd., *Dendropanax arboreal* (L.) Decne. y Plancho.), *C. Americana, C. glabra, Trophis racemosa* (L.) Urb., *Licaria triandra* (Sw.) Kosterm., *P. piscipula, Erythroxylum areolatum* L., *Prunus myrtle leaf* (L.) Urb., *Aiouea Montana* (Sw .) R. Rohde, *Ocothea floribunda* (Sw .) Mez, *Protium cubense* (Rose) Urb., *Alchornea latifolia* Sw ., *Ocotea globosa* Schlecht . y Cham., *Magnolia orbiculata* (Britton and P. Wilson) Palmarola, *Tabebuia cramped* Britton and *C. sylvestris* subsp . *myricoides* .

The montane rainforest floor (Figure 7; 33 inventories) develops on deep to very deep, leached red alitic and ferralitic soils with acidic to very acidic characteristics (pH H, O 4.0-5.5) and low cation exchange capacity (< 7 cmol (+) kg{[1]). These edaphic conditions, together with an annual rainfall of 1 600 to 2 000 mm and a dry season between November and April, favor the development of this type of vegetation, which is found between the mesophilous evergreen forest and the cloud forest, around 1 400 m asl (Figure 7).

***Figure 7.*** *- Pluvisilva montana in Barrio Nuevo (Photo: Orlando J. Domínguez)*

The climatic conditions in this altitudinal zone are characterized by high relative humidity, which fluctuates between 87% and 92% throughout the year. The average annual temperature in Gran Piedra (1,100 m asl) is 18.4/°C, with average minimum temperatures of 15.7/°C and average maximum temperatures of 22.4/°C. The combination of high humidity and moderate temperatures results in low evaporation rates. In addition, relative sunshine is significantly reduced during most of the year, not exceeding 20% in nine months, due to the frequency of horizontal precipitation, especially around midday. These climatic factors, together, have a decisive influence on the distribution and composition of vegetation in this altitudinal zone.

The phytocenological study reveal a clear association between the distribution of vegetation and the climatic conditions of this altitudinal zone. The climatic patterns described have favoured the development of vegetation adapted to humid and shady environments. Low evaporation and high soil humidity allow the establishment of species with high water requirements, while the reduced sunlight limits the presence of heliophilous species.

As there are still relatively extensive areas in successional stages less developed than homeostasis I, in general, the following species are proposed for restoration / rehabilitation / enrichment: *Chionanthus domingensis* , *O. leucoxylon* , *M. oppositifolia* , *Cyrilla silvae* Berazain , *A. montana* , *P. occidentalis* , *Guatteria moralesii* (M. Gomez) Urb., *A. latifolia* , *Clethra cubensis* A. Rich ., *Myrsine coriacea* ( Sw .) R. Br. ex Roem and Schult., *P. myrtifolia, Persia hypoleuca* (A. Rich.) Mez, *P. spuria*, *Sideroxylon jubilee*, *Hieronyma nipensis* Urb.G , *Prestoea acuminate* subsp . *montana* (Graham) Greuter and R. Rankin), *Pinus maestrensis* Bisse) and *D. arboreus*

Individually, for the Sierra de la Gran Piedra, they propose: *Ocotea wedge-shaped* (Griseb.) M. Gómez, *C. americana, B. pendula*, *Myrcia fenzlian* O. Berg ., *Clusia tetrastigma* Vesque, *C. arborea* , *C. sylvestris* subsp . *myricoides*, *Allophylus cominia* (L.) Sw ., *Coccoloba diverse foliage* Jacq ., *Brunellia comocladifolia* subsp . *cubensis* Four-legged , *Tabebuia hypoleuca* (C. Wright) Urb., *T. angustata* , *Tabebuia Brooksian* Britton, *Magnolia orbiculata* , *C. caudatum* , *O. globosa* , *Eugenia floribunda* ( Willd .) O. Berg , *Guettarda monocarp* Urb., *C. sylvestris* subsp . *sylvestris*, *Hieronyma pale* Mull. Arg., *C. Americana, Guatteria blainii* ( Griseb .) Urb., *Z. martinicensis* , *S. jubilla* y *P. spuria* . As a substitute species of *Syzygium jambos* (L.) Alston when restoring the galley forest in this mountain range, the following can be used: *Chinanthus domingensis*, *C. arborea*, *Tabebuia* spp., *M. oppositifolia*, *P. acuminata* subsp . *montana* , *C. Americana* , *D. arboreus* and *A. latifolia* , the planting must be dense with the aim of achieving rapid cover.

In turn, particularly, for the Sierra del Turquino, are further proposed: *M. cubensis* subsp . *cubensis*, *Ixora ferrea* Willd., *Miconia pteroclad* Urb., *Viburnum villosum* Sw., *C. clusioides* (Griseb.) D'Arcy, *T. brooksiana* and *O. spathulata* .

The cloud forest floor (Figure 8) is home to a rich biological diversity and plays a key role in regulating water in the region. It extends from the montane rainforest to Pico Real del Turquino (1,972 m asl) and was characterized through six phytocenological inventories. The soils in this altitudinal floor are predominantly yellowish, leached ferralitic (alitic) soils, with chemical properties that reflect acidic conditions (pH H, O 4.45-5.45) and low nutrient content (CCB 1-5 cmol (+).kg{[1]). It has temperatures below 16/ °C (Planos *et al*., 2013) at the lower levels and close to 13.0/ °C at the top of Turquino, with the lowest temperatures recorded during the month of January.

***Figure 8.*** *- Cloudy rain in Pico Bayamesa (Photo: Courtesy Antonio Núñez Jiménez Foundation)*

This region receives an average rainfall of 2 000 mm per year, with a significant contribution from horizontal precipitation (fog and low clouds) that generate conditions of high relative humidity. This humidity, which averages between 85 % at 1 500 m asl and 82 % at the top of Turquino during the rainy season, favors the development of a rich epiphytic community, many of which even develop on leaf litter. However, plants experience water stress during the day, especially during dry periods, where relative humidity can drop to 36-40 % during the warmest hours (Reyes *et al.*, 2011). This water dynamic, characterized by high environmental humidity and frequent physiological drought events, significantly influences the composition and structure of vegetation in this altitudinal zone.

In the cloud forest floor, due to its current state, no silvicultural interventions are proposed. Only exceptionally, if there are extensive clearings, can they be used for restoration / rehabilitation: *C. silvae* , *M. cubensis* subsp . *cubensis, C. clusioides, Alsophylla major*, *Cyathea child* (Jenm.) Domin, *M. coriacea, Ixora ferrea, C. doingness, B. comocladifolia* subsp . *cubensis* and *O. spathulata*

In those altitudinal strata with an adequate density of seedlings and young regenerations of forest species of interest, release practices should be implemented, consisting of the selective opening of the canopy to stimulate the growth and development of these individuals.

The Sierra Maestra exhibits a marked environmental heterogeneity, characterized by altitudinal, edaphic and climatic gradients that vary significantly between sectors. This variability determines the presence of two to four altitudinal levels of vegetation, forming a mosaic of ecosystems with their own characteristics. The complex interaction of abiotic factors in this mountain system, despite a relative lithological homogeneity (El Cobre group), generates a mosaic of ecological conditions that influence the distribution and composition of plant communities.

As mentioned, the altitudinal zones of the Sierra Maestra show a clear zonation of vegetation, directly influenced by altitudinal gradients and their corresponding variations in ecological factors. In this context, altitudinal variations induce significant changes in soil properties, observing a transition from fersialitic, brown, reddish and brown soils in the lower areas to yellowish ferralitic (alitic) soils leached in the summits. In parallel, the cation exchange capacity (CEC) decreases with altitude, from values of 24 to 65 cmol (+).kg-1 in the soils of the lower parts to 2.5 cmol (+).kg-1 in the most exposed soils of the higher areas (Renda *et al*., 1981).

The temperature and relative humidity gradient between the coastal area and Pico Turquino is notably pronounced, with differences of up to 10/°C and 15%, respectively (Planos *et al*., 2013). This climatic gradient, by modulating the processes of evapotranspiration and saturation deficit, generates a large mosaic of microclimates that significantly influence the water dynamics of ecosystems. In combination with soil characteristics, these climatic variations explain the marked floristic and functional heterogeneity of vegetation in the different altitudinal zones of the Sierra Maestra.

The area of wetlands, forests and semi-deciduous microphyllous scrublands has highly specialized vegetation, a product of extreme environmental conditions. Low forests and microphyllous scrublands dominate, characterized by their marked sclerophyll, slow growth and various morphological and physiological adaptations to optimize water capture and conservation, such as small and thick leaves, deep roots and storage systems. These plant communities, adapted to extreme arid conditions, play a fundamental role in the conservation of biodiversity and in the balance of the ecosystems of the Sierra Maestra.

The montane rainforest floor is characterized by high environmental humidity, a product of orographic condensation of low clouds, a phenomenon that can represent up to 50% of the total annual precipitation (Samek and Travieso, 1968). This microclimate favors the development of exuberant and highly specialized vegetation, with a high degree of epiphytism (Reyes and Acosta, 2005). The combination of high rainfall, high relative humidity and low insolation generates unique conditions that make this altitudinal floor an ecosystem of great ecological relevance.

It is striking that the cloud forest floor, despite its name, exhibits significantly lower relative humidity levels than the underlying montane rainforest floor. The almost constant absence of air saturation at this altitudinal level suggests a pattern of preferential condensation at the lower floor, followed by advective transport upwards. This phenomenon could explain the recurrent water stresses in the cloud forest, which induce the development of microphyllous and sclerophyllous foliage, contrasting sharply with the megaphyllous and mesophyllous vegetation characteristic of the montane rainforest (Reyes *et al.*, 2011). These findings underline the complexity of the interactions between orography, atmospheric dynamics and vegetation in tropical mountain systems, and highlight the importance of considering these processes in the planning of ecological restoration strategies.

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## *CONCLUSIONS*

The results obtained allow us to identify the native tree species with the greatest restoration potential for each altitudinal level of the Sierra Maestra. This selection is based on the high frequency and abundance of these species, as well as on their adaptation to the particular environmental conditions of each altitudinal level, which guarantees a greater probability of success in ecological restoration projects.

The detailed characterization of the altitudinal zones of the Sierra Maestra has allowed us to establish clear relationships between vegetation and environmental variables. This information is essential for selecting the most appropriate native species for each altitudinal zone and designing specific restoration strategies that promote the recovery of biodiversity and the functionality of these mountain ecosystems.

The present study provides a solid scientific basis for the planning and implementation of ecological restoration projects in the Sierra Maestra. The selection of native species with high potential for adaptation and growth, combined with the understanding of the ecological dynamics of each altitudinal level, contributes significantly to the recovery of the structure and function of degraded forest ecosystems.

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***Conflicts of interest:***

The authors declare that they have no conflicts of interest.

***Authors' contribution:***

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