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DISTRIBUTION OF THE GENUS *CEDRELA* IN ECUADOR

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The genus *Cedrela* in Ecuador has four species: *C. odorata*, *C. montana*, *C. fissilis* and *C. nebulosa*. *Cedrela* was one of the economically most important timber in the past, due to its wood properties. The genus has a long history of overharvesting and selective logging; as a consequence a substantial genetic degradation have occurred in Ecuador. Currently, three species of *Cedrela* are included in the IUCN Red List. *C. odorata* and *C. nebulosa* are listed as vulnerable species and *C. fissilis* as endangered species. In spite of their conservation status and priority, few studies related to geographical distribution have been done. Then, the geographic distribution at local level had been carried out to provide a valuable tool to the conservation and management of these species. Field sampling and herbarium compilation showed *C. montana* is restricted to the Ecuadorian highlands in the western and eastern Andean montane region between 805 to 3200 masl (meters above sea level). *Cedrela nebulosa* is located in Andean region about 1400 to 2300 masl. *C. odorata* is the most widely distributed, occupying areas in the Amazon (200—1300 masl), Pacific (330—825 masl) and insular regions (350 masl). While, *Cedrela fissilis* is only found in the Amazon Region about 200 to 510 masl. This basic information about current distribution and abundance of cedar species is primordial to generate sufficient tools to formulate the strategies of management and conservation of these species in the country. The widespread distribution of *C. odorata* have been found in the Amazonian and Pacific regions, indicating that it is adapted to tropical rainforest and tropical monsoon climates. To prove if there are adaptations to both habitats morphological, ecological and phylogenetic studies must be carried out.

Key words: *Cedrela*, endangered species, ecoregion, altitude

INTRODUCTION

Each year between 2010 and 2015, worldwide 7,6 million hectares (ha) of forest were lost due to the deforestation. South America is not an exception, is one of the continents with the highest rate of deforestation (2 million ha/year) [6]. Same as Ecuador with one of the highest rates of the Continent according to the Food and Agriculture Organization of the United Nations (annual rate of 1.8% for the 2001—2010 period) and the main causes are related to urban sprawl, expansion of agricultural and pasturelands, lack of

adequate government policies, high demand for timber products, logging and forest fires [15; 16; 26].

Although, the annual rate of deforestation in Ecuador has been reduced in recent years, it continues affecting a large range of species, such as *Cedrela*. Cedar is demanded by the timber and construction industries due to the high quality of its wood in terms of color, fragrance, strength and durability [3; 8; 17).

In Ecuador, the genus *Cedrela P. Browne* (Meliaceae) includes 4 species: *Cedrela odorata, C. fissilis, C montana* and *C. nebulosa* [21]. These species have shown a huge decrease in their population size and distribution due to their high quality timber. According to CITES data between 2002 to 2009, Ecuador exported 342 m^3 of cedar wood, however in the international market, this wood replaced collapsed sales of other species such as mahogany, this lasted a couple of years before collapsing the exports. Furthermore, the selective logging of big and better formed trees is a common practice in Ecuador, which erodes the genetic quality of the remain populations [21; 25]. Other threats to the future survival of this genus are the expansion of human settlements, conversion of land for agricultural and livestock use, the construction of highways and the extraction of oil and minerals [26]. All of these threats trigger the genetic diversity diminish and generate problems in the conservation and management policies of these plants. As a consequence of the selective logging of cedar, *C. fissilis* is an endangered species and *Cedrela odorata* is considered as a vulnerable species [10].

Despite the economic and ecological relevance of the genus *Cedrela*, studies on the current status and the distribution of its species in Ecuador are scarce [11; 21; 22]. This study provides information about the distribution of *Cedrela* genus in Ecuador, which can be a valuable contribution to the management of these species.

METHODS

Georeference data was obtained of herbarium specimen.s from the National Herbarium of Ecuador (QCNE), Herbarium of the Pontificia Universidad Católica del Ecuador (QCA), Ministry of the Environment (MAE) and Walter Palacios, the expert in Meliaceae. In addition, data was included from field collections of the Phylogeography of Cedrela [14]. Two hundred forty seven specimens (247) were collected and georeferenced (Garmin Etrex Summit and Magellan Meridian Platinum GPS).

The map of geographical distribution of the genus *Cedrela* in Ecuador was generated using data collected and vegetable formations division of the continental Ecuador [2; 12; 20; 23]. ArcGIS 10.3 Software was used in this study.

RESULTS AND DISCUSION

On large scale, there was a clear division in the geographical distribution of Cedar species in Ecuador: *Cedrela montana* is distributed in the Andean Region between 805 and 3200 meters above sea level; *C. nebulosa* in the Andean Region in heights between 1420 to 2300 masl; *Cedrela odorata* was the most widespread species located in three regions: Pacific (330—825 masl), Amazonian (200—1300 mas) and Insular region at 350 m. *Cedrela fissilis* was found only in the Amazon Region at elevations between 200 and 510 masl (Fig. 1 and 2).

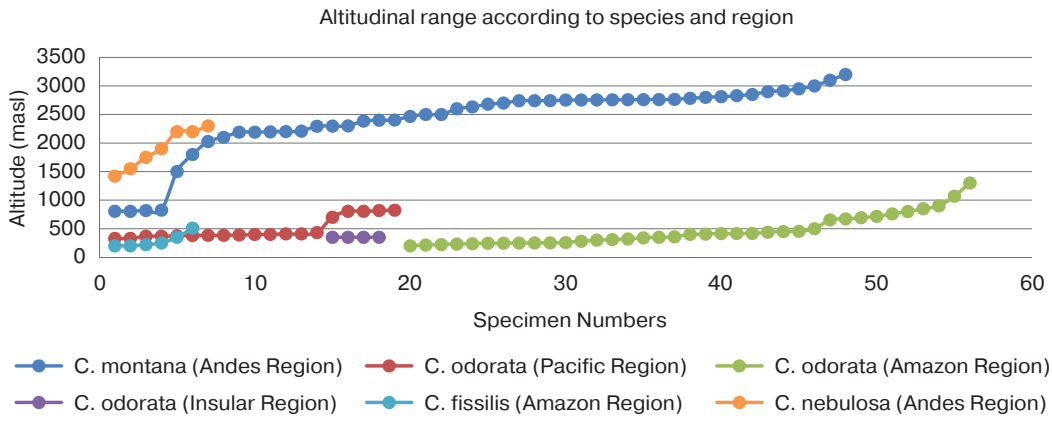

Fig. 1. Scatter plot of Cedar species distribution by altitudinal range and region

The Cedar distribution in the Ecoregions of Ecuador classified by [23; 20] showed a notorious preference of each species to different formations. As shown in Figure 2, the most widely distributed species was *Cedrela odorata*, found in the following Ecoregions: Lowland Evergreen Forest of the Amazon, and Flooded Lowland Forest of the Amazon at heights from 200 to 1300 masl. In the Pacific Region it was presented in Lowland Evergreen Forest, Piedmont Evergreen Forest of the Coast Mountains and Deciduous Forest of Lowlands, at heights from 330 to 825 masl. In Galápagos Islands *C. odorata* was found in the Xeric Scrub Ecoregion at 350 masl.

Cedrela montana was restricted to the Andean Region in the following Ecoregions: Lower Montane Evergreen Forest and Montane Mist Forest of the Western Andes, Lower Montane Evergreen Forest of the North and Central Andes, and High Montane Evergreen Forest of the Eastern Andes in heights between 805 and 3200 masl. In the previous Ecoregion and in the Montane Mist Forest of the Eastern Andes, the species *C. nebulosa* was also located in heights between 1420 to 2300 masl. *Cedrela fissilis* appeared only in the Amazon Region in the Lowland Evergreen Forest and Flooded Forest of the Amazon at heights between 200 to 510 masl (Fig. 2).

The regions where *Cedrela* species were located are enclosed in three different biodiversity hotspots. *C. odorata* in the Coast Region (Mache Chindul Ecological Reserve and Maglares Churute Nature Reserve) is located in Chocó-Darién-Western Ecuador Hotspot [4]. Both, *Cedrela odorata* and *C. fissilis* in the Amazon and *Cedrela montana* is in the Hotspot of the Tropical Andes (Table 1).

The *C. odorata* distribution determine that is adapted to two habitat types: tropical rainforest and tropical monsoon where the climate is warm dry and warm humid in the regions of the Central and Insular Coast and in the North Coast and Amazon Regions, respectively. Adaptations due to growth in different regions have been recorded in previous studies [18; 19], where it was established that *C. odorata* populations of Xeric (high solar radiation and low humidity) and Mesics environments (higher humidity and lower radiation) of Costa Rica differ in morphological and adaptive characteristics such as seed weight, seedling size, root neck diameter (RND) of the seedling, leaf size, weight of the sheet. In Xeric environment *C. odorata* populations showed higher values in the morphological characteristics than *C. odorata* of Mesics habitat as an adaptation to survive in drought.

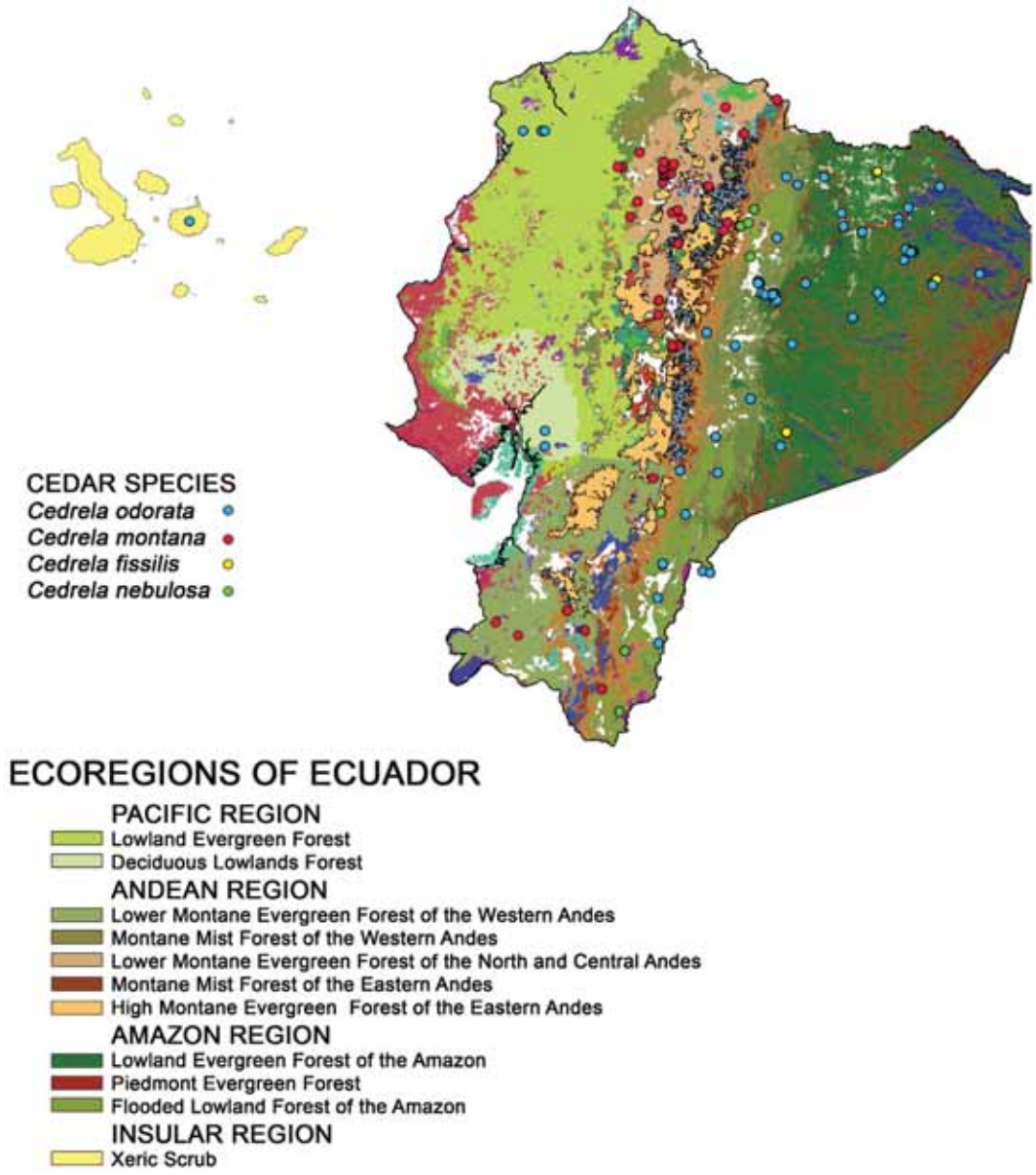

Fig. 2. Map of *Cedrela* Distribution in Ecuador based in the plant formations classification of Sierra *et al* (1999) and Olson (2002). Symbology: *C. odorata,* blue circle; *C. montana*, red circle; *C. fissilis*, yellow circle and *C. nebulosa*, green circle (ArcGis 10.3)

The leaves of *C. odorata* sampled in dry and humid environments showed differences in size. In addition, in the research developed by [14] about molecular phylogenetics of Cedar in Ecuador using chloroplasidic genes cpDNA and transcripted internal spacers (ITS) was suggested a possible incipient speciation and/or a subspecies status over *C. odorata* populations. The two lineages found for this species were correlated with the region of distribution, one from the Central Coast Region and Insular Region (dry climate) and the other from the North Coast and Amazon Region (humid climate). However, to

corroborate this hypothesis it is suggested to perform morphological and ecological studies to determine the parameters on which the dry and humid environments caused a selective pressure and therefore its adaptation.

Table 1

Summary of cedrela species location according to hotspot and plant formations

Species	Hotspot (h) or Region (r)	Plant formation (Sierra et al., 1999; Olson, 2002)
Cedrela odorata	Amazonía (r)	Lowland Evergreen Forest of the Amazon
		Piedmont Evergreen Forest
		Flooded Lowland Forest of the Amazon
	Choco-Darien (h)	Lowland Evergreen Forest
		Deciduous Lowlands Forest
	Island (r)	Xeric Scrub
Cedrela montana	Tropical Andes (h)	Lower Montane Evergreen Forest of the Western Andes
		Montane Mist Forest of the Western Andes
		Lower Montane Evergreen Forest of the North and Central Andes
		High Montane Evergreen Forest of the Eastern Andes
Cedrela nebulosa	Andes (h)	High Montane Evergreen Forest of the Eastern Andes
		Montane Mist Forest of the Western Andes
Cedrela fissilis	Amazon (r)	Lowland Evergreen Forest of the Amazon
		Flooded Lowland Forest of the Amazon

Cedrela montana and *C. nebulosa* share the same Andean region, however the first one is more widely distributed. This ecoregions are characterized by the frequent presence of moving fog. The climate is pluvial humid to hyperhumid and the soil is well moist and drained. The altitudinal range between both species also varies slightly, being that *C. montana* can reach a higher altitude of up to 3200 masl. Finally, *C. fissilis* was the least dispersed and in a lower altitudinal range, it was located only in the Amazon region.

CONCLUSION

With the exception of the studies of [21], there is only scarce information on current distribution of cedar in Ecuador; with this study is cleared the distribution of cedar taking to consider the altitude and the ecoregions where each species develops. Also we found that *C. odorata* of tropical rainforest and tropical monsoon climates shows morphological differences like the size leaf. To prove if there are adaptations to both habitats morphological, ecological and phylogenetic studies must be carried out.

The distribution of cedar has been observed to be restricted to tree main regions depending of each species. All of these regions coincide with highly deforested areas, hence, *Cedrela genus* must be consider a priority conservation group due to their vulnerability to extinction as a result of anthropogenic activities that destroy or modify the environment; In general, deforestation in Ecuador has shown a high rate and is one of the main cause to the climate change with important implications for ecosystem functioning and biodiversity conservation [24]. The deforestation plays an important role in increasing global warming because has enhanced emission of greenhouse gases such as carbon dioxide, methane, and nitrous oxide, especially it has contributed 6—17% of global anthropogenic CO_2 emissions to the atmosphere [1; 5; 9]. Therefore, deforestation

avoidance is helpful for supporting reduced greenhouses gases and also provides other benefits such as conservation of ecosystem biological diversity, prevention of forest fragmentation, protection of watersheds, improvement of local livelihoods, and provision of additional income for developing countries [13; 16].

The threat of species is the direct consequence of *Cedrela* logging, in particular *C. fissilis* which is as a rare species (restricted distribution and sparse populations) and in danger of extinction. Therefore, the cedar reforestation can improve the current state of Cedrela in Ecuador; in order to have a good reforestation management, the actual distribution and the habitat preferences of each species must be considered. In addition, because cedar distribution concurs with biological 'hotspot', it has a high conservation value [24] owing hotspots have been considered such prior areas to research about of the origin of the biologic diversity [7].

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