Ecological models: A management tool of promising species with biomass potential in the Ecuadorian Amazon.

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Abstract

The ecological models sustained by the multivariate analysis allow the simultaneous study of several variables in a large number of individuals. These are used to reduce to a tangible dimension an amount of information that otherwise would take months to understand, and detect the most relevant variables that would condition the structure of the data. The aim of this work was to determine ecological indicators for the management of promising species for the production of forest biomass in the Ecuadorian Amazon. A total of 75 sampling units, each one 20 x 20 m (400 m^2), were collected in evergreen premontane from stratified random sampling by transepts, and tree species were measured (from ≥ 10 cm to d1.30), as well as the structural (dispersion of tree crowns, sociological position, basal area, density, and value of ecological importance), and environmental variables (altitude, degree of intervention, pH, and organic matter). The species arising out of the forest inventory were ordered by multivariate analysis based on the response to different environmental variables. The results of the canonical correspondence analysis were globally significant according to the Monte Carlos test, which gave a good ordination to the sampling units and environmental variables, indicating a strong gradient. According to the sociological position of the 178 inventoried species, only 56 (31.4%) had a continuous vertical distribution. An uneven distribution was found in the number of individuals in height and diameter. Out of all species *Iriartea deltoidea* showed greater ecological importance with significant response in function to the altitudinal gradient, whereas *Otoba glycycarpa*, *Pentagonia amazonica* and *Wettinia maynensis* presented multiple answers, which allowed to identify the appropriate conditions for the management of these species. This will allow to establish multi-functional plantation programs for the production of forest biomass.

Keywords

Ecological models; Forest management; Biomass; Multivariate analysis.

Introduction

Ecuador is characterized by its extensive biodiversity, rich in forest ecosystems, with approximately 11.5 million hectares. This represents 42% of the total area of the country, of which 80% are in the Amazon region. 13% of the forest ecosystems are located in the littoral region and 7% in the mountains (Neill, 2012). The tropical rainforests of the Ecuadorian Amazon have an important socioeconomic function and of ecological services, which significantly contribute to the maintenance of biodiversity in the region (Jorgensen and León 1999, Palacios and Jaramillo 2010). Besides, the forest ecosystems constitute an important carbon reservoir, storing more than one billion tonnes of carbon. Their destruction would release about six billion tonnes to the atmosphere (FAO, 2010). A correct management, focused to search the promising species with biomass potential, is necessary in order to achieve a balance between the practices of resources' uses and conservation. An active participation of the scientific community is required. Principally, in the development of ecological tools for the sustainable management of the forest resources. This will allow to make use of forest resources with industrials purposes and at the same time protect and conserve their potential. The aim of this work was to determine ecological indicators that allow the management of promising species for the forest biomass production in the Ecuadorian Amazon.

Materials and methods

This research was carried out in a tropical rainforest, Napo province, Ecuadorian Amazon, Arosemena Tola's town, Km 44 via Puyo-Tena. For the study, an inventory in 75 plots of 20 x 20 m (400 m2) was performed. Woody vegetation with diameters greater than 10 cm (d1.30 ≥ 10 cm) was studied. A canonical correspondence analysis (CCA) for the vegetation management and environmental variables

were conducted. For the management of vegetation and environmental variables the CANOCO calculation software was used (Ter Braak, 1987). The environmental variables included in the analysis were: altitude (Alt), degree of intervention (GI), pH and organic matter (OM).

Results and discussion

The results of canonical correspondence analysis (Table 1) were globally significant according to the Monte Carlos test with 499 permutations (Trace = 0.875, F = 1.56, p = 0.020). The four axes offered a good solution to the ordination of the sampling units and the environmental variables. The total variability present in the data (inertia = 10,686) for the first three axes was 85.1% for the relationship between the species and the environmental variables, indicating a strong gradient. The four environmental variables analysed showed a high correlation to the first canonical axis with positive correlations of altitude and organic matter. Nevertheless, a negative correlation for the degree of intervention and pH were obtained. The values determined were higher 56% for the four variables.

Table 1. Results of canonical correspondence analysis (CCA) of species and environmental variables.

Axes	**1**	**2**	**3**	**4**	**Total variance**
Eigenvalues:	0,389	0,200	0,154	0,131	10,686
Species-environment correlations:	0,941	0,840	0,892	0,830	
Cumulative percentage variance of species data:	3,6	5,5	7,0	8,2	
of species-environment relation:	44,5	67,4	85,1	100,0	
Sum of all eigenvalues					10,686
Sum of all canonical eigenvalues					0,875
Axes-environment variable correlations					
Altitude (Alt)	**0,9304**	0,1048	0,0757	-0,0171	
degree of intervention (GI)	**-0,6115**	0,4143	-0,3493	0,3539	
pH	**-0,5650**	0,4416	0,4065	-0,3278	
Organic matter (MO)	**0,5638**	-0,2234	0,4816	0,4386	

The positive end of the first axis described an increase in altitude and organic matter, while the negative end increased the degree of intervention and pH (Figure 1 a) and b). Figure 1 (a) shows that 90% of species abundance is represented by 15 species, while in the figure 1 (b) only five species represent 80% of abundance. This result indicates that in a low percentage of species was concentrated the greater weight. This species were that represented the highest sociological position and ecological importance in the forest community.

The location of the *Iriartea deltoidea, Wettinia maynensis and Jacaranda copaia* species, clearly describes a distribution pattern in relation to the altitudinal gradient. The first two species occupy the highest positions, which is related to the typical species of the premontane tropical rainforest and the last one, the lowest position, being a pioneer species (Jaramillo and de Vries, 2007) that inhabits first where clearings in the forest are found. The *Otoba glycycarpa and Grias neuberthii* species appear to be associated to the sites with the highest content of organic matter.

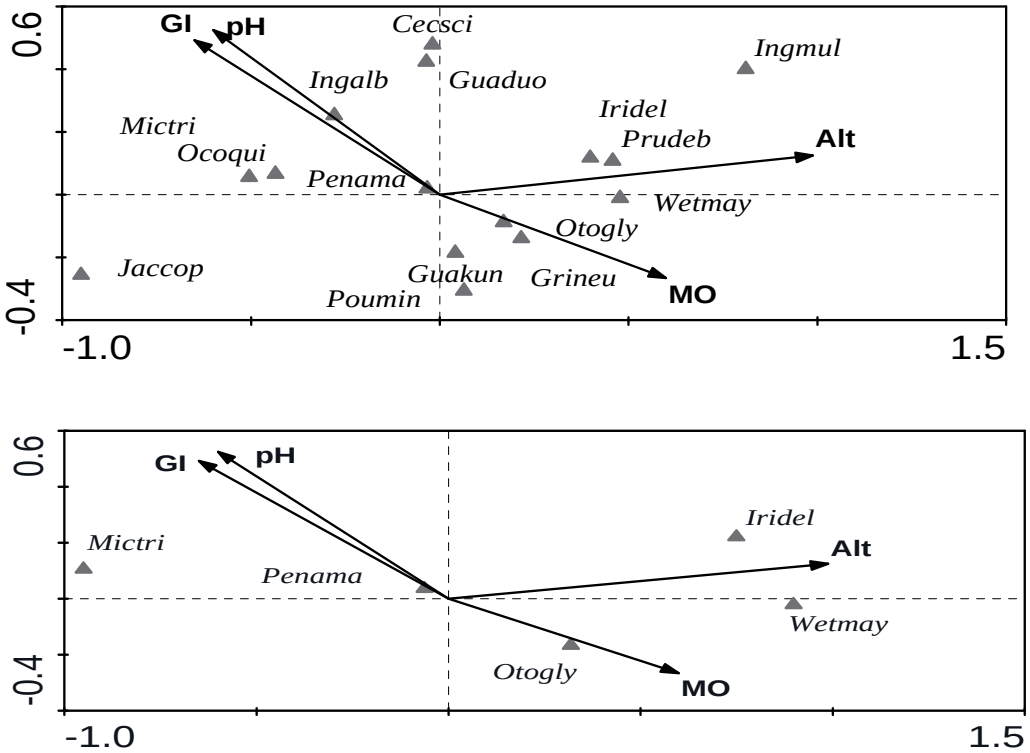

Figure 1. Projection of the environmental variables and the most abundant species of canonical correspondence analysis in relation to the axes. (A) 90% of the abundance of the species. (B) 80% of species abundance. *Legend: Cecropia sciadophylla (Cecsci); Guatteria duodecima (Guaduo); Grias neuberthii (Grineu); Guarea kunthiana (Guakun); Iriartea deltoidea (Iridel); Inga alba (Ingal); Inga multinervis (Ingmul); Jacaranda copaia (Jaccop); Ocotea quixos (Ocoqui); Otoba glycycarpa (Otogly); Miconia triangularis (Mictri); Pentagonia amazonica (Penama); Pourouma minor (Poumin); Prunus debilis (Prudeb); Wettinia maynensis (Wetmay).*

On the other hand, *Inga alba*, *Miconia triangularis and Ocotea quixo* are associated with the degree of intervention and pH. *Miconia triangularis* is an indicative of acid soils and the remaining of anthropization. The species *Pentagonia amazonica* was indifferent to the environmental gradients analysed.

Conclusions

The application of multivariate models with ecological variables is a feasible tool for the interpretation of ecological indicators that set the basis for the forest management and the correct selection of promising species with biomass potential.

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