***Arboreal diversity characteristics of tree cover forms in an agricultural landscape of northwest ecuador***

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**ABSTRACT**

The aim of this article was to describe the diversity characteristics of trees present in four common forms of tree cover of an agricultural landscape situated in the Norwest Ecuador and, to detect the best form of tree cover to increase the arboreal diversity. In four forms of tree cover by four site, we draw tree plots of an area of 100 m2. In each plot, we count every tree and then we measured it high and DBH. We calculated indices of abundance, richnnes and structure of the community (diversity and evenness), then we elaborate cluster to visualized beta diversity. We census 3 746 trees belonging to 18 species. Highest levels of three density and richness were found in polyspecies live fences. This form of tree cover was similar to insolates trees in pastures in 42 %. Polyspecies live fences have exhibited better levels of diversity than other form of tree cover implemented in agricultural landscapes of northwestern Ecuador.

**Key words:** Agrosystems, live fences, plantations, dendrology.

1. **INTRODUCTION**

In tropical agricultural landscapes, studies of tree diversity are very scarce. Much of this diversity still maintained in certain patches, riparian forests, or in certain agrosystems such as live fences and in silvopastoral or agroforestry systems. The characterization of the remaining arboreal diversity in agricultural landscapes is important to assess their conservation level in anthropogenic environment, as well to generate basic information that could be related to other elements of landscape diversity such as bats or beetles [1, 2].

In the northwestern of Ecuador, most studies of plant diversity in general have been carried out in sites belonging to the National System of Protected Areas [3, 4], and for the case of agricultural landscapes there is a previous study carried out by Villacís and Chiriboga [5] regarding its relationship with the socioeconomic variables of livestock farms. Human settlements has increased unsustainably with the passage of time [6, 7] so landscape is dominated by agricultural systems, responsible for a loss of more than 81% of the original vegetal cover [8, 9].

Hence, the objective of this study is to determine the characteristics of arboreal diversity present in common tree covers of an agricultural landscape located in northwestern Ecuador, and to detect the form of tree cover that best favors the increase of plant diversity indexes.

1. **MATERIALS AND METHODS**

We selected four sites located in the provinces of Pichincha (Puerto Quito Town), Santo Domingo de los Tsáchilas (Santo Domingo Town) and Los Ríos (Patricia Pilar Town). The climate is hot-humid, with a precipitation of 3 088.3 mm; the average annual temperature is 24.5 ° C; the rainy period begins in January and extends until May, starting in June the dry season [10].

Area corresponds to Tropical Moist Forest life zone [11], Northwest Tropical zoogeographic zone [12] and vegetation formation of Evergreen Lowland Forest [13]. Zone is considered southernmost portion of the Chocó-Darién hotspot [14], that is why it hosts high levels of biodiversity and endemism [14, 15, 1].

In each selected site, four common tree cover were chosen (polyspecies live fences, monospecific live fences, scattered trees in paddocks, and cocoa plantations). Three plots of 100 m2 were drawn by way of tree cover, giving 48 plots (3 plots \* 4 tree covers \* 4 sites). In each plot, all the trees present were counted, which were identified (at the species level) and measured (height and diameter at breast height).

We estimated their indicators of abundance (absolute abundance and density [individual m-2]), richness (absolute richness and non-parametric estimator Chao 2), diversity (Shannon index), and evenness (Pielou index). We used rank-abundance curves and Montecarlo analysis with 10 000 iterations (null model) to detect the tree cover with the best ecological indexes of arboreal diversity.

In order to show, at the same time, the similarity and distance of the composition of species (Beta Diversity), between sites and between tree covers of the landscape [16], a cluster analysis (nearest neighbor method) was performed using Bray-Curtis similarity index [17].

1. **RESULTS AND DISCUSSION**

A total of 3746 trees belonging to 31 species were counted, being the most frequent *Erythrina smithiana*, *Theobroma cacao* and *Cordia alliodora* (Table 1).

Four out of ten arboreal species are exotic; eight out of ten trees belong to species of agricultural interest, which indicates that the tree composition of the agricultural landscape studied changed in relation to the tree species of the nearby natural areas [4]. In any case, some arboreal species of the agricultural landscape have also been reported in the natural areas located in the area of influence of the study (*Aegiphila alba*, *Cecropia* sp., *Erythrina poeppigiana*, *Guadua* sp., *Helicostylis tovarensis*, *Inga* sp., *Ireartea deltoidea*, *Phyllantus juglandifolius*, y *Tabebuia* sp.) [4].

In monospecies fences (CM) and in cocoa plantations (C), the proportional abundance of species was one, since they are tree cover formed by a single tree species. The polyspecies fences (CP) had the highest number of trees per m2, this variable being significantly different when compared to CM and C (Fig. 1).

Most abundant arboreal species was *Cordia alliodora*, followed by *Erythrina smithiana* and *E. poeppigiana* in CP and, by *Spondias mombin* and *Carica* *papaya* in insolates trees of pastures (ADP) (Fig. 2).

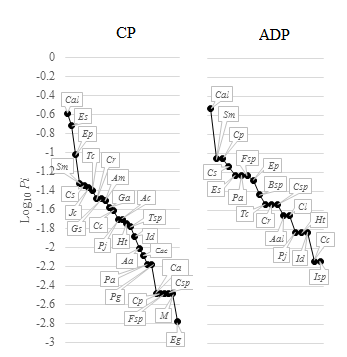
Because they are composed by a single tree species, CM and C exhibited richness, diversity and evenness values equivalent to zero; normally alfa diversity indices are equivalent to zero in sites where a single species are registered [18], cause for the calculations of several indices of diversity to the number of species (richness –*S*–) one unit must be subtracted (*S*-1).

**Table 1.** Proportional abundance of tree species (*Pi*) present in four forms of tree cover and in the agricultural landscape studied.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Species** | **Acronim** | **Origen** |  | **Tree cover** | | | | |  | **Landscape** |
|  | **CP** | **CM** | | **C** | **ADP** |  |
| *Erythrina smithiana* | *Es* | Exotic |  | 0.164 | 1.000 | |  | 0.247 |  | 0.352 |
| *Theobroma cacao* | *Tc* | Native |  | 0.043 |  | | 1.000 | 0.014 |  | 0.159 |
| *Cordia alliodora* | *Cal* | Native |  | 0.214 |  | |  | 0.203 |  | 0.132 |
| *Spondias mombin* | *Sm* | Native |  | 0.072 |  | |  | 0.188 |  | 0.064 |
| *Erythrina poeppigina* | *Ep* | Exotic |  | 0.109 |  | |  |  |  | 0.050 |
| *Citrus* x *sinensis* | *Cs* | Exotic |  | 0.062 |  | |  | 0.059 |  | 0.038 |
| *Citrus reticulata* | *Cr* | Exotic |  | 0.048 |  | |  | 0.007 |  | 0.023 |
| *Guadua angustifolia* | *Ga* | Native |  | 0.040 |  | |  |  |  | 0.018 |
| *Jatropha curcas* | *Jc* | Native |  | 0.033 |  | |  |  |  | 0.015 |
| *Baccharis* sp. | *Bsp.* | Native |  |  |  | |  | 0.087 |  | 0.014 |
| *Annona muricata* | *Am* | Native |  | 0.031 |  | |  |  |  | 0.014 |
| *Persea americana* | *Pa* | Exotic |  | 0.010 |  | |  | 0.056 |  | 0.014 |
| *Gliricidia sepium* | *Gs* | Exotic |  | 0.027 |  | |  |  |  | 0.013 |
| *Coffea canephora* | *Cc* | Native |  | 0.024 |  | |  | 0.002 |  | 0.012 |
| *Tabebuia* sp. | *Tsp* | Native |  | 0.025 |  | |  |  |  | 0.012 |
| *Annona cherimola* | *Ac* | Exotic |  | 0.022 |  | |  |  |  | 0.010 |
| *Ireartea deltoidea* | *Id* | Native |  | 0.020 |  | |  | 0.003 |  | 0.010 |
| *Ficus* sp*.* | *Fsp* | Desconocido |  | 0.001 |  | |  | 0.050 |  | 0.009 |
| *Carica papaya* | *Cp* | Exotic |  | 0.005 |  | |  | 0.021 |  | 0.006 |
| *Cecropia* sp. | *Csp* | Native |  | 0.005 |  | |  | 0.021 |  | 0.006 |
| *Aegiphila alba* | *Aa* | Native |  | 0.011 |  | |  |  |  | 0.005 |
| *Psidium guajaba* | *Pg* | Native |  | 0.010 |  | |  |  |  | 0.005 |
| *Phyllantus juglandifolium* | *Pj* | Native |  | 0.007 |  | |  | 0.003 |  | 0.004 |
| *Helicostylis tovarensis* | *Ht* | Native |  | 0.007 |  |  | | 0.003 |  | 0.004 |
| *Artocarpus altilis* | *Aal* | Native |  |  |  |  | | 0.016 |  | 0.003 |

**Figure 1.** Tree density between forms of tree cover.

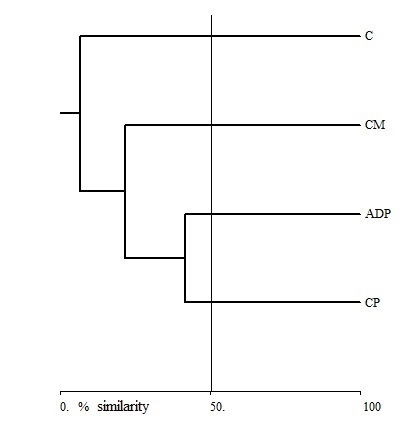
Richness did not present significant differences between CP and ADP; however, the greatest richness was presented in CP (Fig. 2). The species observed represented 100 % of the expected species, according to the non-parametric estimator Chao 2. Shannon diversity did not show significant differences between CP and ADP. Pielou's evenness was significantly different between forms of tree cover.



**Figure 2.** Rank-abundance curves of tree species recording in four forms of tree cover. Acronims are explained in Table 1. CP= Polyspecies life fences, ADP= insolates trees of pastures.

Although, indices ​​of tree richness and diversity did not show statistical differences between CP and ADP, their highest values ​​were found in CP. According to Moreno [19], when ecological indices induce difficulty of interpretation, the differences in diversity between ecosystems can be explained by returning to the data of richness and proportional abundance of species. So the 27 tree species registered in CP, allow infer that this is the tree coverage with greater diversity in the agricultural landscapes of the Ecuadorian northwest. This result is because some agricultural covers have the capacity to retain primary plant species present in the forests. Chacón and Harvey [20] recorded some tree species of primary vegetation in live fences, this characteristic makes the arboreal richness of the types of agricultural land use does not differ much from species from nearby forests [21].

According Bray-Curtis index, forms of tree cover shares low percentage of species similarity (Fig. 3), however the most similarities were ADP and CP that make up a conglomerate with a similarity of 42 %, both forms of tree cover are similar to CM by 21 %, and the these (CP, ADP and CM) are similar to C in just 7 % (Fig. 3).



**Figure 3.** Beta diversity of trees presents in trees cover, dendrogram based in the Euclidean distance of Bray-Curtis index. ADP= dispersed trees in pastures, C= cocoa plantations, CM= monospecies live fences, CP= polyspecies live fences.

The agricultural landscape studied is one of the areas with the highest level of degradation of the natural habitat [9, 8]. Today, the area of influence of the study is occupied, in a high percentage, by production units dedicated to agriculture, livestock and mixed production (agriculture-livestock) [5]. Therefore, the present plant diversity depends on the criterion of the producer who is the one who finally decides which tree he keeps standing. In any case, certain trees of wild species are kept in live polyspecies fences and scattered trees in paddocks, which shade the cattle and even improve the nutritional levels of the pastures [22]. Therefore, its maintenance favors the presence of wild animal species [1, 2] and the agricultural production of the farms.

1. **CONCLUSIONS**

*Erythrina smithiana, Theobroma cacao* and *Cordia alliodora,* are the most frequent species in the tree cover forms of the Ecuadorian northwestern agricultural landscape.

Polyspecies live fences presented the highest arboreal richness and are considered the tree cover that best favors the increase of the vegetal diversity indices.

**references**

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| [1] | W. E. Pozo-Rivera, «Relaciones de la diversidad arbórea y la estructura del paisaje agrícola tropical ecuatoriano con la biodiversidad de murciéalgos filostómidos,» Ph. D. Dissertation, Departamento de Biología Animal y Humana, Facultad de Biología, Universidad de La Habana, La Habana-Cuba, 2017. |
| [2] | J. K. Yazán-Ayala, «Diversidad de escarabajos del suelo y sus asociaciones con la diversidad arbórea en agrosistemas agrícolas tropicales del Noroeste del Ecuador,» Tesis de Ingeniería Agropecuaria, Departamento de Ciencias de la Vida y la Agricultura, Universidad de las Fuerzas Armadas ESPE, Sangolquí-Ecuador, 2018. |
| [3] | R. Ulloa, P. Suárez, F. Campos, V. Zak y M. Vasquez, «Plan de manejo del bosque protector La Perla,» Informe Inédito, Ministerio del Ambiente del Ecuador, Quito-Ecuador, 1991. |
| [4] | A. H. Gentry y C. Dodson, «Contribution of nontrees to species richness of a tropical rain forest.,» *Biotropica,* vol. 19, nº 2, pp. 149-156, 1987. |
| [5] | J. E. Villacís y C. E. Chiriboga-Novillo, «Relaciones entre las variables socioeconómicas y la cobertura arbórea de fincas ganaderas del trópico húmedo.,» *Revista Cubana de Ciencias Forestales,* vol. 4, nº 2, pp. 149-163, 2016. |
| [6] | P. W. Stahl, «Archaeofaunal accumulation, fragmented forest, and anthropogenic landscape mosaics in the tropical lowland of prehispanic Ecuador.,» *Latin American Antiquity,* vol. 11, nº 3, pp. 241-257, 2000. |
| [7] | J. N. Williams, «Human population and hotspots revised: a 2010 assessment.,» de *Biodiversity hotspots: distribution and protections of conservation priority areas.*, Berlin Heidelberg-Germany, Springer-Verlag, 2011, pp. 3-22. |
| [8] | R. Sierra, M. Tirado y W. Palacios, «Forest-cover changes from labor- and capital-intensive commercial logging in the southern Chocó rainforest,» *The Preofessional Geographer,* vol. 55, nº 4, pp. 477-490, 2003. |
| [9] | R. Sierra, F. Campos y J. Chamberlin, «Assessing biodiversity conservation priorities: ecosystems risk and representativess in Continental Ecuador,» *Landscape and Urban Planning,* vol. 59, pp. 95-110, 2002. |
| [10] | INAMHI, «Anuario Meteorológico 2015. No. 51 - 55.,» Instituto Nacional de Hidrología y Meteorología, Quito-Ecuador, 2015. |
| [11] | L. Holdridge, Ecología basasa en zonas de vida, San José: Costa Rica, 1982. |
| [12] | L. Albuja, A. Almendariz, R. Barriga, L. D. Montalvo, F. Cáceres y J. L. Román, Fauna de Vertebrados del Ecuador, Quio-Ecuador: Instituto de Ciencias Biológicas, Escuela Politécnica Nacional, 2012. |
| [13] | R. Sierra, R. Valencia y C. E. Cerón-Martinez, Propuesta preliminar de un sistema de clasificación de vegetaciónpara el Ecuador Continental, Quito-Ecuador: Proyecto INEFAN/GEF-BIRF y EcoCiencia, 1999. |
| [14] | D. Tirira, Mamíferos de bosques húmedos den Noroccidente de Ecuador, Quito-Ecuador: Ediciones Murciéalgo Blanco, 2008. |
| [15] | E. A. Noguera-Urbano, «Areas of endemism: travelling through space and unexplored dimension,» *Systematics and Biodiversity,* vol. 14, nº 2, pp. 131-139, 2016. |
| [16] | R. H. Whittaker, «Evolution and measurement of species diversity,» *Taxon,* vol. 21, nº 2-3, pp. 213-251, 1972. |
| [17] | N. McAleece, P. J. D. Lambshead, G. L. J. Paterson y J. D. Gade, BioDiversity Professional. Version 2, Scotland: The Natural History Museum and The Scottish Association for Marine Science, 1997. |
| [18] | C. E. Moreno y G. Halffter, «Spatial and temporal analysis of a, b, and c diversities of bats in a fragments landscape,» *Biodiversity and Conservation,* vol. 10, pp. 367-382, 2001. |
| [19] | C. E. Moreno, Métodos para medir la diversidad biológica, Saragoza: Manuales y Tesis SEA, Volumen 1, 2001. |
| [20] | M. Chacón y C. A. Harvey, «Live fences and landscape conectivity in a neotropical landscape.,» *Agroforestry Systems,* vol. 68, pp. 15-26. |
| [21] | T. Newbold, N. L. Hudson, S. L. L. Hill, S. Contu, C. L. Gray, J. P. W. Scharlemann, L. Boger, H. R. P. Phillips, D. Sheil, I. Lysenko y A. Purvis, «Global patterns of terrestrial assemblage turover within and among land uses,» *Ecography,* vol. 39, pp. 1-13, 2016. |
| [22] | B. W. Norton, J. R. Wilson, H. M. Shelton y K. D. Hill, «The effect of shade on forage quality,» de *Forages for plantation crops*, Indonesia, Proceedings of a workshop, 1991, pp. 83-88. |
| [23] | N. Myers, R. A. Mittermeier, C. G. Mittermeier, G. A. B. da Fonseca y J. Kent, «Biodiversity for conservation priorities,» *Nature,* vol. 403, pp. 853-858, 2000. |