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DISPERSED TREES AND THEIR EFFECT ON THE PRODUCTIVITY OF PADDOCKS IN THE ECUADORIAN AMAZONIA

ÁRBOLES DISPERSOS Y SU EFECTO EN LA PRODUCTIVIDAD DE LOS POTREROS EN LA AMAZONÍA ECUATORIANA

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Abstract

Fifty paddocks of ten years of establishment associated with tree species were randomly selected; an inventory of all dispersed species with breast height diameters (DBH) $\geq$ 5 cm was made. Dasometric variables as DBH, total height and crown area were measured in each tree. Frecuency, richness, abundance, importance value index, biodiversity index based on proportional abundance of species (Shannon, Simpson) and species richness (Margalef) were determinated. 22 tree families were registered, 83.8% correspond to timber species and 16,2% to fruit species, the family with the highest number of individuals was Boraginaceae with 194,96% of variation of the basal area was explained by BDH. As far as this increased and the structure of tree species do not shown any influence in dry matter production, cover and quality of the three found pasturages, due to low tree cover (3,69 $\pm$ 0,67%) and to the number of dispersed trees in the paddocks (5 to 7 trees ha^{-1}). The impact of tree cover showed that it affects significantly on the growth of the plants, demonstrating that Marandú has the best shadow tolerance respect to Dallis and Saboya. It is concluded that the amazonian livestock system of northem central Ecuador according to the biodiversity indexes could be considerate as low levels, but with a medium richness of dispersed tree species on paddocks. The importance value index allowed identifying 4 species with the highest ecological weight over the average (3,4%) *Cordia alliodora, Cedrela odorata, Schizolobium parahybum* and *Psidium guajava*.
Keywords: Floristic composition, tree cover, nutritional quality, diversity indexes, wealth indexes.

Resumen

Se seleccionaron potreros con 10 años de establecimiento asociados con especies arbóreas, se realizó el inventario de las especies dispersas con diámetros de altura al pecho (DAP) $\geq$ 5 cm. En cada árbol se midieron las variables dasométricas DAP, altura total, área de copa. Se determinó su frecuencia, riqueza, abundancia, índice de valor de importancia, índice de biodiversidad basada en la abundancia proporcional de especies (Shannon, Simpson) y de riqueza de especies (Margalef). Se registraron 22 familias, el 83,8% corresponden a especies maderables y el 16,2% a especies frutales, la familia con mayor número de individuos fue Boraginaceae con 194 individuos. El DAP explico el 96% de la variación del área basal, a medida que este se incrementó y las estructuras de las especies arbóreas no demostraron influir en la producción de materia seca, cobertura y calidad de las pasturas, debido a la baja cobertura arbórea (3,69 $\pm$ 0,67%) y al número de árboles dispersos en los potreros (5 a 7 árboles ha^{-1}). El impacto de la cobertura arbórea demostró que incide significativamente en el crecimiento de las plantas, demostrando que el cultivar Marandú tiene una mejor tolerancia a la sombra respecto al Dallis y Saboya. Se concluye que los ecosistemas ganaderos Amazónicos del centro norte del Ecuador de acuerdo a los índices de biodiversidad estarían considerados como bajos, pero con una riqueza media de especies dispersas en potreros. Se identificó 4 especies con mayor peso ecológico superior al promedio (3,4%) *Cordia alliodora*, *Cedrela odorata*, *Schizolobium parahybum* y *Psidium guajava*.
Palabras claves: Composición florística, cobertura arbórea, calidad nutritiva, índices de diversidad, índice de riqueza.

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1 Introduction

In the Ecuadorian Amazon Region (EAR) pastures, constitute the main reason for land use change, from the original ecosystem of forest to surface with intervention for productive activities, so that the cultivation of pastures constitutes 73 % to 84 % of the productive use of the soil in the RAE (Nieto y Caicedo, 2012). The traditional systems of livestock production in the RAE are based on pastures in monocultures, which are extensively grazed and the woody component is usually absent. All this means that the pastures are degraded and low productive indicators are presented (MAGAP, 2014). This type of production system contributes significantly to a loss of natural soil fertility, water pollution, desertification, reduction of biological diversity and high greenhouse gas emissions (Tobar López y Ibrahim, 2008). Several studies show that the most important reasons for the introduction of trees in pastures is the provision of shade and food for livestock, obtaining products such as firewood, timber and fruits (Esquivel et al., 2003; Restrepo, 2002). The versatility of the services provided by the trees and forage shrubs favor the adoption and design of silvopastoral systems (SSP) (Lombo Ortíz, 2012; Esquivel et al., 2003; Restrepo, 2002).

Betancourt et al. (2003) mentions that cattle spend more time in rumination and resting in paddocks with low tree cover, which directly influences the production of meat and milk. Casasola Coto (2000) agrees that in places with greater tree cover, forage consumption rises by up to 3.7%, in addition there is evidence of a decrease in caloric stress and rectal temperature. Similar studies in the humid tropics of Ecuador have shown that the SSP contribute significantly in the decrease of the environmental temperature of the paddocks in hours of higher incidence (Criollo Rojas, 2013), they contribute to the improvement of the nutritional quality and the yield of forage in base dry when the pasture is associated with fruit trees of guava (*Psidium guajaba*) as shade and fodder shrubs (*Leucaena leucocephala Lam.*) for browsing (Caicedo et al., 2017; Villacis y Chiriboga, 2016). Other benefits of the inclusion of trees in pasture, either in the form of live fences or scattered trees, is that they can contribute to the conservation of agrobiodiversity, functioning mainly as biological corridors for local fauna (Beer et al., 2003). Trees also contribute to the formation of structural networks, and provide a series of ecosystem services such as carbon fixation (Tobar López y Ibrahim, 2008). Livestock farms in the RAE with these silvopastoral practices conserve the forest more, with an average larger area for conservation (Ochoa y Valarezo, 2014).

In the provinces of the northern center of the RAE (Orellana, Napo, Sucumbíos) cattle farms with natural pastures represent 43 % and with improved pastures 56 % of the area associated with timber and fruit trees (Subía et al., 2017; Virginio Filho, Caicedo y Astorga, 2014). With this background, the present study aimed to characterize the arboreal component (composition, richness, abundance, diversity and structures) in pastures with at least 10 years of establishment, in addition, it is intended to know the impact of tree cover on growth, coverage, phytomass production and nutritional quality of the forage resource present in the pastures of the northern central region of the Ecuadorian Amazon.

2 Materials and methods

2.1 Study area

The study was carried out in farms of small and medium livestock producers in areas selected by the Project "Improvement of productivity in critical areas of the Coast, Sierra and Amazonia, located in the Province of Orellana, in the parish of La Belleza del Cantón Francisco of Orellana located between 100 and 720 meters above sea level, at 77°4′17.84 ″ and 77°1′54.27″ west longitude, 0°48′33.06 ″ and 0°49′28.76 ″ south latitude, is characterized by its clay soil with a thin texture, acid pH (4.5 to 5.5) of irregular topography, precipitation of 3126.9 mm / year, average annual temperature of 26.19 °C, relative humidity of 81 % GADMFO (2014); GADPRLB (2015). In the Enokanqui parish of La Joya de los Sachas canton located between 200 and 313 meters above sea level, at 76°52 ′28.43 "west longitude, 0°12′52.74"south latitude, with characteristics of brown or black soils, pH moderately slightly acidic (5.5 to 6.5) and a flat topography, rainfall of 3500-4000 mm / year, average annual temperature of 26.5 °C, relative humidity of 85 % (GADMCJS, 2015; GADPRE, 2015).

2.2 Research method

In the study area, 50 paddocks were selected at random with pastures of 10 years of establishment associated with dispersed forest species. For the estimation of the forage produced, the average of 20 frames of 1m × 1m was used following zig-zag transepts, where a sampling point was located every 10 m. The analysis of dry matter and bromatology was carried out in the food quality laboratory of the Central Experimental Station of the Amazon (EECA).

An inventory was made of all dispersed tree species with breast height diameters (DBH) $\geq$ 5 cm and were identified by species of each jigger. In each tree the dasometric variables DAP, total height (Ht) and crown area (Ac) were measured by perpendicular calculation of the major and minor diameter. The total percentage of tree cover per paddock was estimated from the sum of all existing tree crown areas divided by the total area of the reference paddock (Villanueva Najarro et al., 2013), using the following formula:

$$CAB = \frac{\sum Acp}{Ap} \times 100 \tag{1}$$

CAB = Tree coverage
Acp= crown area
AP= Pasture area (ha)

The importance value index (IVI) was calculated based on the ecological parameters of relative abundance, relative dominance and relative frequency, determined according to the formulation of Stiling Stiling (1996, citado por Villavicencio Enríquez y Valdez Hernández (2003)) y Lamprecht (1962, citado por Trujillo et al. (2012)):

Relative abundance (AR)

$$AR = \frac{Number\ of\ individuals\ of\ a\ specie}{Total\ of\ individuals} \times 100 \tag{2}$$

Absolute frecuency (FA)

$$FA = \frac{Number\ of\ pastures\ in\ which\ the\ species\ appears}{Total\ paddocks\ sampled} \tag{3}$$

Relative frequency (FR)

$$FR = \frac{Absolute\ frequency\ by\ species}{Frequency\ of\ all\ species} \times 100 \tag{4}$$

Dominance (DA)

$$DA = \sum Basal\ area\ (AB)\ of\ individuals \tag{5}$$

$$AB = \frac{\pi}{4 \times DAP^2}$$

Relative dominance (DR)

$$DR = \frac{Dominance\ by\ species}{Dominance\ of\ all\ speciess} \times 100 \tag{6}$$

Importance value index (IVI)

$$IVI = AR_i + FR_i + DR_i \tag{7}$$

The diversity analysis was carried out using indexes based on proportional abundance of species (Shannon, Simpson) and species abundance(Margalef) according to the following formulas (Cited by Del Río et al. (2003); Trujillo et al. (2012); Martella et al. (2012):

Shannon-Weaver (H′) index

$$H' = -\sum \frac{n_i}{N} \times log\frac{n_i}{N} \tag{8}$$

ni: number of individuals of the species n
N: Total number of individuals of all species

Margalef's diversity index (Rm)

$$Rm = \frac{S-1}{logN} \tag{9}$$

S: Number of species
N: Total number of individuals of all species

Simpson dominance index (Ds)

$$Ds = 1 - \sum \left(\frac{n_i}{N}\right)^2 \tag{10}$$

N: total number of individuals of all species
ni: total number of elements belonging to the species

2.3 Statistical analysis

A non-parametric analysis of variance of Kruskall-Wallis was used to evaluate the differences of the structure variables of the arboreal component (tree cover, basal area, tree density), Pearson correlation analysis and linear regression between the coverage variable were performed. tree and the agronomic variables of the pasture (height, cover, dry matter, nutritional quality). The statistical analyzes were carried out through the InfoStat program (Di Rienzo et al., 2016).

3 Results and discussion

3.1 Floristic composition

A total of 315 individuals were registered, belonging to 29 species and 22 families in a sampling area of 86.35 ha, 3 pastures associated with the tree species were identified: Common Saboya (*Panicum maximum*), representing 37% of the paddocks evaluated, followed by Marandú (*Brachiaria Brizantha*) 34% and Dallis (*Brachiaria decumbens*) with 29%. 83.8% correspond to timber species and 16.2% to fruit species. The tree family with the highest number of species was Lauraceae with 3 species (Avocado, Canelo, Jigua), followed by *Meliaceae* (Cedro, Manzano colorado), *Malvaceae* (Boya, Zapote), *Annonaceae* (Chirimoya, Guanábana), *Arecaceae* (Coco, Chonta), with two species, while the family with the largest number of individuals was *Boraginaceae* with 194 individuals, representing 61.6%, of relative abundance in relation to the total of individuals (n = 315), followed by *Meliaceae* and *Myrtaceae* with 20 and 17 individuals. (Table 1). Subía et al. (2017) indicate that the most representative silvopastoral systems found in the northern center of the RAE are production systems of the traditional type (scattered trees) and that on the livestock farms studied wood species of wood type belonging to the *Lauraceae* family were found (Laurel) and fruit trees of the *Fabaceae* family (Guaba) representing 43% of pastures associated with traditional silvopastoral systems. With the same criteria, Vargas et al. (2014) mentions that cocoa, coffee and livestock farming with agroforestry systems in the RAE are associated mainly with forest and fruit species, which contributes to the conservation of biodiversity and the sustainable management of agricultural and livestock activity in the region.

3.2 Species and dasometric variables

Table 1. Distribution of richness and abundance of tree species in the families registered in paddocks of the north-central Amazon

Family	Diversity	Abundance	
	Nº. species	Absolut	Relative
Lauraceae	3	13	4.1
Meliaceae	2	20	6.3
Malvaceae	2	6	1.9
Annonaceae	2	3	1.0
Arecaceae	2	10	3.2
Myristicaceae	1	2	0.6
Moraceae	1	1	0.3
Myrtaceae	1	17	5.4
Vochysiaceae	1	2	0.6
Sapindaceae	1	1	0.3
Rutaceae	1	8	2.5
Rubiaceae	1	1	0.3
Polygonaceae	1	4	1.3
Boraginaceae	1	194	61.6
Bombacaceae	1	1	0.3
Bignoniaceae	1	2	0.6
Anacardiaceae	1	3	1.0
Caesalpinaceae	1	13	4.1
Lamiaceae	1	3	1.0
Fabaceae	1	4	1.3
Euphorbiaceae	2	5	1.6
Cecropiaceae	1	2	0.6
Total	29	315	100

Table 2 shows the scientific and common name of the species identified, as well as the averages of the dasometric measurements. The average height was 7.58 ± 0.23 m in a range between 2.15 and 28.27 m, 83% of the species recorded heights between 2.15 and 10.86 m. The average DAP was 36.24 ± 1.40 cm in a range of 11.14 and 198.94 cm, 95% of the species recorded DBH between 11.14 and 73.74 cm. The area of the cups registered averages of 73.14 ± 5.06 m^2, 97% of the species registered ranges of crown area between 0.64 and 256.09 m^2, the tree species Higueron (*Ficus obtusifolia Kunth*) was the one that registered the highest height (28.27). m), DAP (175.1 cm) and crown area (604.8 m^2).

The main timber and fruit trees with more frequency in the pastures according to the number of trees (>8), recorded diametric classes of between 10-38 cm (Cedar 73%, Laurel 84%) and 39-65 cm (Pachaco 84%) for the case of timber (Figure 1a). In fruit trees the registered ranges of diameter classes were between 22-30 cm for Avocado with 80%; Chonta 63%, Guava 47% and 31-39 cm with a frequency for Avocado of 20%; Chonta 13%, Guava 29% (Figure 1b).

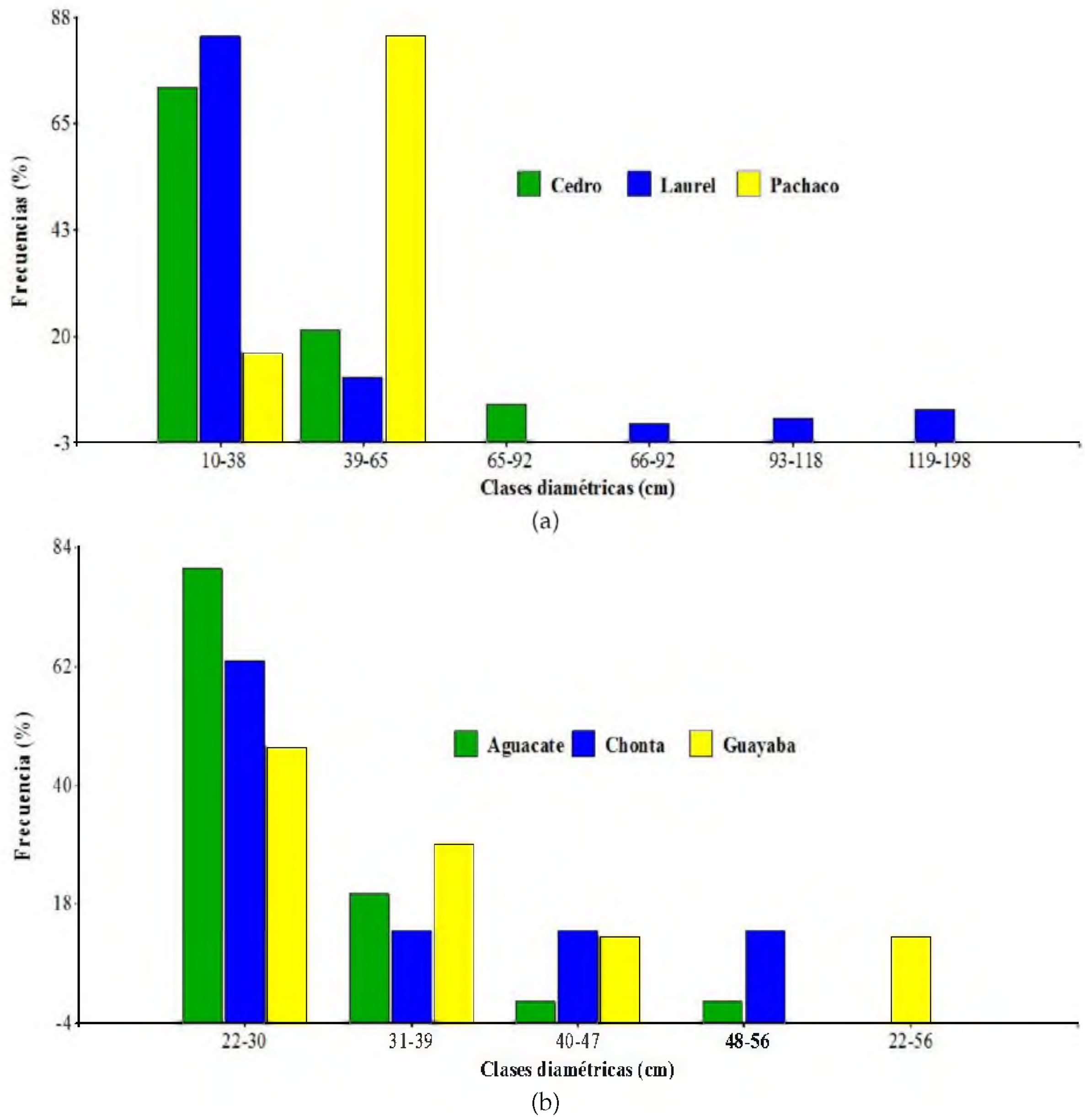

Figure 1. Diameter class of the main foresters (a) and fruit trees (b) in the 50 pastures evaluated in the northern center of the RAE

Table 2. Species and dasometric variables of scattered trees in paddocks of the Amazon north center

Scientific name	Common name	Average			
		N°. Trees	Height (m)	DAP (cm)	Crown area (m^2)
Cordia alliodora	Laurel	194	7.1	32.8	51.8
Cedrela odorata	Cedro	19	7.3	36.9	52.4
Psidium guajava	Guayaba	17	4.6	33.0	88.3
Schizolobium parahybum	Pachaco	13	8.7	44.5	152.0
Bactris gasipaes	Chonta	8	6.7	34.4	87.4
Citrus sinensis	Naranjo	8	10.2	35.5	69.1
Nectandra hihua	Jigua	6	10.9	45.3	76.9
Matisia cordata bonpl	Zapote	5	10.8	46.5	96.8
Persea americana	Aguacate	5	8.8	53.4	217.0
Myroxylon pereirae	Bálsamo	4	10.2	37.8	91.8
Sapium sp.	Lechero	4	10.6	44.6	109.9
Triplaris cumingiana	Fernán Sánchez	4	5.2	33.7	140.3
Spondias anacardiaceae	Ciruelo	3	8.8	25.3	37.4
Vitex gigantea	Pechiche	3	8.7	32.1	140.1
Annona cherimola	Chirimoya	2	8.3	31.0	58.5
Cecropia peltata	Guarumo	2	6.8	34.9	86.8
Cocos nucifera	Coco	2	14.8	70.0	191.8
Dialyanthera gracilipes	Sangre de gallina	2	10.2	44.7	170.8
Erisma uncinatum	Arenillo	2	10.8	82.3	404.4
Octea floribunda	Canelo	2	13.9	66.4	78.2
Tabebuia sp.	Guayacán	2	7.8	34.5	120.6
Annona muricata	Guanábana	1	7.5	23.9	91.6
Calycophyllum spruceanum	Capirona	1	8.3	31.2	208.4
Crescentia cujete	Lechero	1	5.1	22.6	26.7
Ficus obtusifolia Kunth	Higuerón	1	28.3	175.1	604.8
Guarea kunthiana	Manzano colorado	1	5.4	27.7	12.9
Nephelium lappaceum	Achotillo	1	7.2	95.5	122.7
Ocrhoma pyramidale	Boya	1	7.9	82.4	4.0
Trichistandra sp	Ceibo	1	8.1	65.3	39.3

3.3 Importance value index (IVI)

The IVI allowed to identify 4 species with greater ecological weight than the average (34%) and 25 less than average species. The Laurel forest species (*Cordia alliodora*) registered an IVI of 49.1%, followed by Cedro (*Cedrela odorata*) and Pachaco (*Schizolobium parahybum*) with an IVI of 7.1% and 5.5% (Table 3), becoming the 3 most important forest species in the paddocks of the north central Amazon from the ecological point of view, abundance, frequency and dominance.

The fruit species occupy the second order of ecological importance, being thus the species of Guava (*Psidium guajava*), Chonta (*Bactris gasipaes*), Avocado (*Persea americana*), Orange (*Citrus sinensis*) and Zapote (*Matisia cordata bonpl*) with an IVI of the 5.4%; 3.2%; 3.0%; 2.8% and 2.3% respectively (Table 3). The hegemony of these species is associated with the ease of propagation through natural regeneration and high seed production. Grijalva (2012) in its report on forest genetic resources of the country, mentions that the Laurel as a native species and the Pachaco as an exotic species are considered among the 10 main species used with timber value authorized by the Ministry of the Environment (MAE), in the same report refers to the Cedar as one of the main threatened species in the country, considering a medium-term closure, meaning as such the prohibition of cutting of this species by the MAE through ministerial agreement N°.167 °. On the other hand, ° mentions that species such as Laurel, Cedro and Guava are kept in paddocks for their rusticity in the management of pastures, for their high production and easy dispersal of seeds and for the projection of shade that these species provide for livestock.

Table 3. Abundance (A), dominance (D), frequency (F) and importance value index (IVI) of the most common tree species in paddocks of the north central Amazon (n = 50)

Trees species	Percentaje (%)			
	A	F	D	IVI
Cordia alliodora (Laurel)	61.6	30.7	55.0	49.1
Cedrela odorata (Cedro)	6.0	10.0	5.1	7.1
Schizolobium parahybum (Pachaco)	4.1	8.0	4.4	5.5
Psidium guajava (Guayaba)	5.4	7.3	3.3	5.4
Bactris gasipaes (Chonta)	2.5	5.3	1.7	3.2
Persea americana (Aguacate)	1.6	3.3	4.0	3.0
Citrus sinensis (Naranja)	2.5	4.0	1.8	2.8
Matisia cordata bonpl (Zapote)	1.6	3.3	1.9	2.3
Ficus obtusifolia Kunth (Higuerón)	0.3	0.7	5.0	2.0
Nectandra hihua (Jigua)	1.9	2.0	2.0	2.0
Sapium sp. (Lechero)	1.3	2.7	1.4	1.8
Myroxylon pereirae (Bálsamo)	1.3	2.7	1.0	1.6
Triplaris cumingiana (Fernán Sánchez)	1.3	2.7	0.8	1.6
Erisma uncinatum (Arenillo)	0.6	1.3	2.4	1.4
Cocos nucifera (Coco)	0.6	1.3	1.9	1.3
Vitex gigantea (Pechiche)	1.0	2.0	0.6	1.2
Octea floribunda (Canelo)	0.6	1.3	1.5	1.1
Spondias anacardiaceae (Ciruelo)	1.0	2.0	0.3	1.1
Dialyanthera gracilipes (Sangre de gallina)	0.6	1.3	0.9	1.0
Nephelium lappaceum (Achotillo)	0.3	0.7	1.5	0.8
Cecropia peltata (Guarumo)	0.6	1.3	0.4	0.8
Annona cherimola (Chirimoya)	0.6	1.3	0.4	0.8
Ocrhoma pyramidale (Boya)	0.3	0.7	1.1	0.7
Tabebuia sp. (Guayacán)	0.6	0.7	0.4	0.6
Trichistandra sp (Ceibo)	0.3	0.7	0.7	0.6
Calycophyllum spruceanum (Capirona)	0.3	0.7	0.2	0.4
Guarea kunthiana (Manzano colorado)	0.3	0.7	0.1	0.4
Annona muricata (Guanábana)	0.3	0.7	0.1	0.4
Crescentia cujete (Lechero)	0.3	0.7	0.1	0.4
Total	100	100	100	100

3.4 Structural patterns of trees in pastures

The average coverage of the tree cover was 3.69 ± 0.67%, while the majority of pastures (92%) recorded tree cover of between 0.15 and 9% (Figure 2b) evidenced a low percentage of shade due to the density of trees present, the majority of pastures (48%) were included in densities of 5 to 7 trees ha^{-1} (Figure 2a), under this context there is evidence of a low presence of trees per unit area, Esquivel et al. (2003) emphasize that there is a great diversity of scattered tree species in pastures, but at low density so as not to interfere with livestock activity, another factor to consider is the damage and mortality of seedlings caused by grazing livestock and the regulation of shade by farmers through the frequent use of herbicides or chapeas (Camargo et al., 2000).

According to Paredes y Subía (2014) in diversified farms with agroforestry systems with cocoa and high potential coffee in the RAE, they found tree cover of between 3 and 76% with an average of 26.5%, while Villanueva Najarro et al. (2013) indicate that in cattle ranches the tree cover in paddocks found were 10 and 20% in the subhumid tropical forest of Costa Rica.

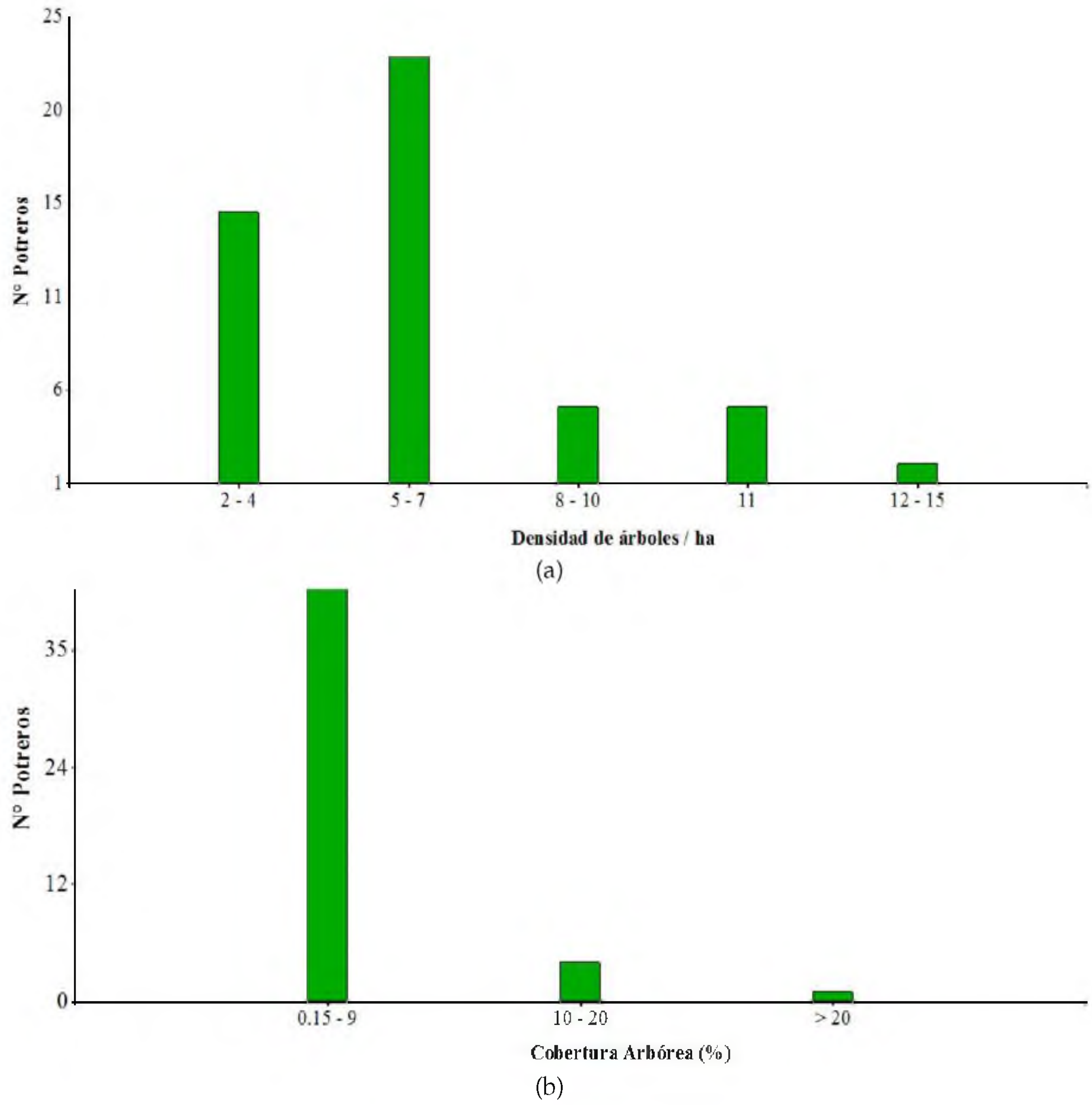

Figure 2. Distribution of density (a) and coverage (b) of trees/ha dispersed in the 50 paddocks evaluated in the northern center of the RAE.

No significant differences were found for the basal area, tree cover, tree density ($p>0.05$, Table 4), these results reflect that the management of the vegetation cover is not influenced by the type of pasture. It was found that the DAP explained 96% of the variation of the basal area, as it increases (Figure 3).

Table 4. Summary of structural variables in three pastures of the north central Amazon

Variables	Pasture		
	Dallis	Marandú	Saboya
Basal area (m^2ha^{-1})	0.56 ± 0.09 a	0.57 ± 0.13 a	1.53 ± 0.72 a
Tree cover (%)	4.80 ± 1.61 a	3.27 ± 0.78 a	3.69 ± 1.01 a
Tree density	6.47 ± 0.65 a	6.15 ± 1.02 a	6.25 ± 0.65 a

Equal letters within the same row indicate no significant (p>0.05) according to Kruskall-Wallis

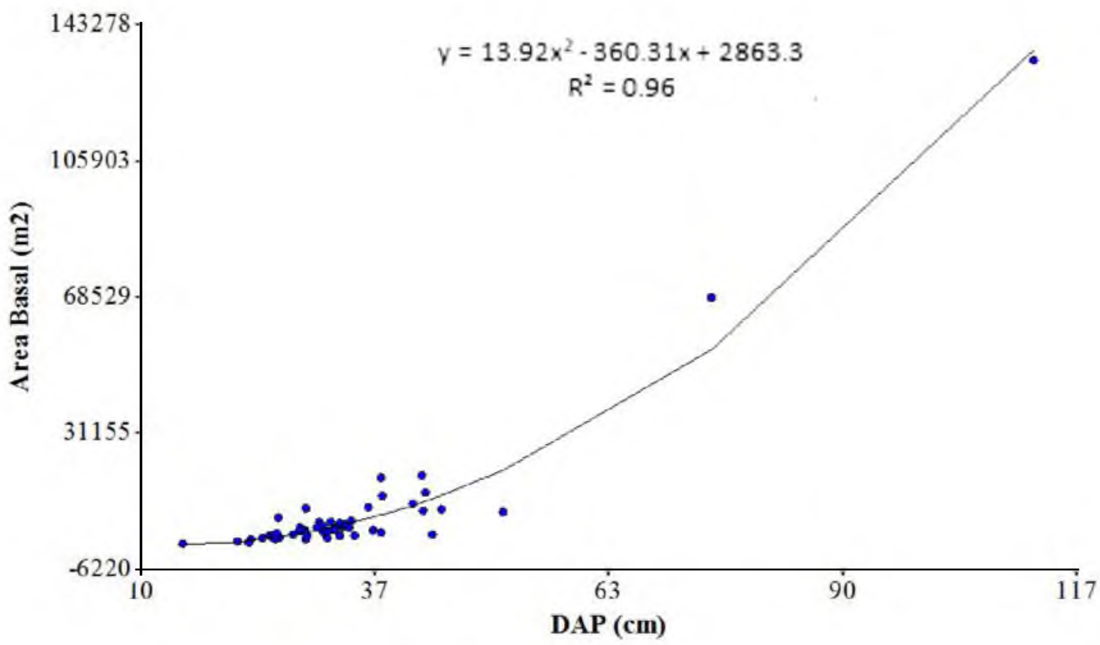

Figure 3. Increase of DAP with respect to basal area

3.5 Indices of structural diversity of forest stands

The paddocks presented a diversity of H'= 1.99 according to the Shannon index (H'), which indicates that the livestock ecosystems of the north central Amazon have a low biodiversity of trees, a result similar to that found by Paredes y Subía (2014) where it reported the lowest value in biodiversity in production systems with pastures, mainly due to the scarce presence of forest species.

Considering the criteria reported by Martella et al. (2012), values <a 2 of this indicator are considered low and >to 3 are high, the ecosystems with the highest values are tropical forests and coral reefs, and the lowest the desert areas, the higher this index the ecosystem is highly biodiverse.

The wealth index was intermediate (Rm = 3.95) according to the Margalef index (Rm), considering that values <a 2 are related to areas with low diversity and values>a5 areas of high diversity (Campo y Duval, 2014). Simpson (1949) dominance index (Ds) was 0.61, explaining the dominance of one species over the others, this index is strongly focused on the most abundant species in the sample and is less sensitive to species richness (Martella et al., 2012; Del Río et al., 2003).

3.6 Effect of tree cover on pasture productivity

The Dallis, Marandu, Saboya pastures did not present significant differences (p>0.05) for cover, dry matter and crude protein, when analyzing the impact of the tree cover effect on these variables. In contrast, the plant height in the Marandu pasture (p <0.05, Table 5) was significantly higher than Dallis and Saboya, reflecting a better tolerance to tree cover, coinciding with that reported by Carvalho (1997), in his study of association of pastures with trees, concluding that the grasses that most tolerated the shade were *Brachiaria brizantha cv. Marandú, Panicum maximum and Brachiaria decumbens.*

Table 5. Impact of tree coverage on agronomic variables in three pastures of the northern central Amazon

Variables	Pasture		
	Dallis	**Marandu**	**Savoy**
Plant height (cm)	78.77 ± 1.90 b	84.90 ± 2.13 a	79.44 ± 1.77 b
Coverage (%)	81.20 ± 1.13 a	81.55 ± 1.29 a	80.37 ± 1.04 a
Dry matter (kg/ha^{-1})	2018.54 ± 137.58 a	2187.68 ± 157.25 a	2143.28 ± 126.53 a
Raw protein (%)	9.77 ± 0.50 a	10.16 ± 0.57 a	9.34 ± 0.46 a

Equal letters within the same row indicate no significant difference (p>0.05)

4 Conclusions

The main scattered timber species found in the paddocks of the north central Amazon were Laurel, Cedar, Pachaco and in the fruit trees Guava, Avocado, Chonta according to their abundance, diversity and IVI. The DAP explained 96% of the variation of the basal area, as it increased and the structures of the arboreal species did not show influence in the production of dry matter, cover, crude protein of the 3 pastures found, due to the low tree coverage (3.69 ± 0.67%) and the number of scattered trees in the paddocks (5 to 7 trees ha^{-1}), the impact of the tree cover showed that it significantly affects the growth of the plants, demonstrating that the cultivar Marandu has a better tolerance to the shade with respect to the Dallis and Savoy. The Amazonian livestock ecosystems of the north center of Ecuador according to the biodiversity indexes would be considered as low, but with an average richness of scattered species in paddocks. The IVI allowed identifying the species Laurel, Cedar, Pachaco and Guava with greater ecological weight than the average (3.4%).

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References

Beer, J, C Harvey, M Ibrahim, J. M Harmand, E Somarriba y F. Jiménez. 2003. "Servicios ambientales de los sistemas agroforestales." *Agroforestería en las Américas* 10(37–38):80–87. [online] available: https://goo.gl/rJJda4.

Betancourt, K, M Ibrahim, C Harvey y Vargas B. 2003. "Efecto de la cobertura arbórea sobre el comportamiento animal en fincas ganaderas de doble propósito en Matiguás, Matagalpa, Nicaragua." *Agroforestería en las Américas* 10(39–40):47–51. Disponioble en: https://goo.gl/K6149R.

Caicedo, W, N Criollo, A Vera, L Riera, J Grijalva, R Ramos y C. Congo. 2017. *Evaluación preliminar de sistemas silvopastoriles como alternativa de la producción ganadera en la Amazonía ecuatoriana.* Agroforestería sostenible en la Amazonía Ecuatoriana. [online] available: https://goo.gl/tveSMA pp. 91–98.

Camargo, J. C, M Ibrahim, E Somarriba, B Finegan y D. Current. 2000. "Factores ecológicos y socioeconómicos que influyen en la regeneración natural de laurel en sistemas silvopastoriles del trópico húmedo y subhúmedo de Costa Rica." *Agroforestería en las Américas* 7(26):46–49. [online] available: https://goo.gl/Rh6Luq.

Campo, A. M y V. S. Duval. 2014. "Diversidad y valor de importancia para la conservación de la vegetación natural. Parque Nacional Lihué Calel (Argentina)." *Anales de Geografía de la Universidad Complutense* 34(2):25–42. [online] available: https://goo.gl/xWtMMn.

Carvalho, M. M. 1997. "Asociaciones de pasturas con árboles en la región centro del sur de Brasil." *Agroforestería en las Américas* 4(15. [online] available: https://goo.gl/UJzBne).

Casasola Coto, F. 2000. Productividad de los sistemas Silvopastoriles Tradicionales en Moropotente, Estelí, Nicaragua. Master's thesis Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica. [online] available: https://goo.gl/5qDVPQ.

Criollo Rojas, N. J. 2013. Evaluación de alternativas silvopastoriles que promuevan la intensificación y recuperación de pasturas degradadas y contribuyan a reducir el impacto ambiental de la actividad ganadera en la amazonía ecuatoriana al segundo año de establecimiento. In *Tesis de grado, Escuela Superior Politécnica de Chimborazo, Ecuador*. Vol. [online] available: https://goo.gl/NihpcD.

Del Río, M, F Montes, I Cañellas y G. Montero. 2003. "Revisión: Índices de diversidad estructural en masas forestales." *Investigación Agraria: Sistemas y Recursos Forestales* 12(1):159–176. Disponioble en: https://goo.gl/8CXsCk.

Di Rienzo, J. A, F Casanoves, M. G Balzarini, L González, M Tablada y C. W. Robledo. 2016. *InfoStat versión 2016.* Grupo InfoStat, FCA, Universidad Nacional de Córdoba, Argentina. [online] available: https://goo.gl/YPxHzZ.

Esquivel, H, M Ibrahim, C. A Harvey, C Villanueva, T Benjamin y F. Sinclair. 2003. "Árboles dispersos en potreros de fincas ganaderas en un ecosistema seco de Costa Rica." *Agroforestería en las Américas* 10(39–40):24–29. [online] available: https://goo.gl/pj2Ph7.

GADMCJS. 2015. Resumen ejecutivo del Plan de Desarrollo y Ordenamiento Territorial. La Joya de los Sachas, Ecuador. In *Gobierno Autónomo Descentralizado Municipal La Joya de los Sachas.*

GADMFO. 2014. Plan de Desarrollo y Ordenamiento Territorial. Francisco de Orellana, Ecuador. In *Gobierno Autónomo Descentralizado Municipal Francisco de Orellana.*

GADPRE. 2015. Plan de Desarrollo y Ordenamiento Territorial. Enokanqui, La Joya de los Sachas, Ecuador. In *Gobierno Autónomo Descentralizado Parroquial Rural Enokanqui.*

GADPRLB. 2015. Plan de Desarrollo y Ordenamiento Territorial. Enokanqui, La Joya de los Sachas, Ecuador. In *Gobierno Autónomo Descentralizado Parroquial Rural Enokanqui.*

Grijalva, J. 2012. *Situación de los Recursos Genéticos Forestales. Informe País Ecuador.* Preparado por el Programa Nacional de Forestería del INIAP con aval del INIAP/FAO/MAE/MAGAP/MMRREE. Documento sometido a la Comisión Forestal de la FAO-Roma, para preparación del Primer Informe sobre el Estado de los Recursos Genéticos Forestales en el Mundo. 95 p.

Lamprecht, H. 1962. "Ensayo sobre unos métodos para el análisis estructural de los bosques tropicales." *Acta Científica Venezolana* 13(2):57–65. [online] available: https://goo.gl/E3pYj2.

Lombo Ortíz, D. F. 2012. Evaluación de la disponibilidad de biomasa y capacidad de rebrote de leñosas forrajeras en potreros del trópico seco de Nicaragua. Master's thesis Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica. [online] available: https://goo.gl/C5QSPj.

MAGAP. 2014. Proyecto agenda de transformación productiva amazónica - reconversión agroproductiva sostenible en la Amazonía Ecuatoriana. In *Ministerio de Agricultura y Ganadería, Ecuador.*

Martella, M. B, E. V Trumper, L. M Bellis, D Renison, P. F Giordano, G Bazzano y R. M. Gleiser. 2012. "Manual de Ecología. Evaluación de la biodiversidad." *Reduca (Biología). Serie Ecología* 5(1):71–115. [online] available: https://goo.gl/VPptCq.

Nieto, C y C. Caicedo. 2012. Análisis reflexivo sobre el desarrollo agropecuario sostenible en la amazonía ecuatoriana. In *Ecuador: INIAP, Estación Experimental Central de la Amazonia. (Publicación Miscelánea no. 405). [online] available: https://goo.gl/co89yJ*.

Ochoa, D y J. Valarezo. 2014. "Caracterización y análisis de rentabilidad de los sistemas de producción ganaderos presentes en el cantón Yantzaza, Ecuador." *CEDAMAZ* 4(1):76–85. [online] available: https://goo.gl/enVhwi.

Paredes, N y C Subía. 2014. *Valoración de los servicios ambientales en fincas diversıficadas con sistemas agroforestales de alto potencial*. Agroforestería sostenible en la Amazonía Ecuatoriana. [online] available: https://goo.gl/tveSMA pp. 73–90.

Presidencia de la República del Ecuador. 2007. Registro oficial N° 18 - jueves 08 de febrero del 2007. In *Dado en el Palacio Nacional al 25 de noviembre del 2009. Quito, EC.*

Restrepo, S. 2002. Relaciones entre la cobertura arbórea en potreros y la producción bovina en fincas ganaderas en trópico seco en Cañas, Costa Rica. Master's thesis Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica. [online] available: https://goo.gl/SPqrqG.

Simpson, E. H. 1949. "Measurement of Diversity." *Nature, International journal of science* 163, 688.: [online] doi: https://www.dx.doi.org/10.1038/163688a0.

Stiling, P. D. 1996. *Ecology; Theories and Applications*. Prentice Hall series in the life sciences. [online] available: https://goo.gl/14Efdm.

Subía, C, N Paredes, W Caicedo, F Fernández, A Díaz, F Bastidas y J. Chávez. 2017. *Análisis socioproductivo de los sistemas de producción agropecuaria en la zona norte y centro de la Amazonía Ecuatoriana*. Agroforestería sostenible en la Amazonía Ecuatoriana. [online] available: https://goo.gl/tveSMA pp. 49–58.

Tobar López, D y M. Ibrahim. 2008. "Valor de los sistemas silvopastoriles para conservar la biodiversidad en fincas y paisajes ganaderos en América Central." Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Costa Rica. [online] available: https://goo.gl/326cRe.

Trujillo, L. A, Y. K Cuellar, D. Y Huaca, J. E Velásquez y J. C. Suarez. 2012. "Caracterización de árboles dispersos en potreros y su efecto en la cobertura herbácea en pasturas del piedemonte amazónico colombiano." *Revista Momentos de Ciencia* 9(1):50–58. [online] available: https://goo.gl/u6sqSQ.

Vargas, Y, P Jaramillo, Y Sánchez y D. Sotomayor. 2014. *Valoración socio-productiva de fincas diversificadas con sistemas agroforestales de alto potencial.* Agroforestería sostenible en la Amazonía Ecuatoriana. [online] available: https://goo.gl/tveSMA pp. 59–72.

Villacis, J y C. Chiriboga. 2016. "Relaciones entre las variables socioeconómicas y la cobertura arbórea de fincas ganaderas del trópico húmedo del Ecuador." *Revista Cubana de Ciencias Forestales* 4(2):149–163. [online] available: https://goo.gl/8DMqtH.

Villanueva Najarro, C, D Tobar López, M Ibrahim, F Casasola Coto, J Barrantes y R. Arguedas. 2013. "Árboles dispersos en potreros en fincas ganaderas del Pacífico Central de Costa Rica." *Agroforestería en las Américas* (45):12–20. [online] available: https://goo.gl/J9Kw5R.

Villavicencio Enríquez, L y J. Valdez Hernández. 2003. "Análisis de la estructura arbórea del sistema agroforestal rusticano de café en san miguel, Veracruz, México." *Agrociencia* 37(4):413–423. [online] available: https://goo.gl/eFojC7.

Virginio Filho, E, C Caicedo y C. Astorga. 2014. *Agroforestería sostenible en la Amazonía ecuatoriana. Serie técnica N 398*. Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) y Instituto Nacional Autónomo de Investigaciones Agropecuarias (INIAP). [online] available: https://goo.gl/tveSMA.