DISPERSED TREES IN PASTURELANDS OF CATTLE FARMS IN A TROPICAL DRY ECOSYSTEM

[ÁRBOLES DISPERSOS EN LOS POTREROS DE RANCHOS GANADEROS EN UN ECO-SISTEMA DE TRÓPICO SECO]

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SUMMARY

In many tropical cattle farms of Central America, farmers commonly retain trees in pastures to obtain timber and provide shade and fodder to cattle. However, little is known about the diversity, abundance, richness and species composition of dispersed trees in pastures of cattle farms in the dry tropics. Therefore, the objective of this study was to characterize and describe the pattern of tree cover dispersed in pastures of cattle farm systems assessing their roles in sustaining farm productivity. The study was conducted in 16 cattle farms in a tropical dry ecosystem in Costa Rica. A total of 5,896 trees, from 36 families and 99 species, were found dispersed in pastures (836 ha). Trees were present on 100% of the farms and in 85% of pastures and they occurred as individual trees (54%) and clustered (46%). The most abundant families are *Bignonaceae*, *Sterculeaceae* and *Boraginaceae.* The most common tree species were *Tabebuia rosea* (Bertol.) DC, *Guazuma ulmifolia* Lam, *Cordia alliodora* (Ruiz & Pav.) Oken and *Acrocomia aculeata* (Jacq.) Lodd. ex Mart, which together accounted for 60% of the total number of trees. Tree species with smaller crowns are found at higher densities than tree species with large crowns. Pastures mean crown cover was 7% (SE $\pm$ 0.54) and mean tree density was 8.1 trees ha^{-1} (SE $\pm$ 0.66). We conclude that farmers are managing a low tree diversity, cover (m^2 ha^{-1}) and density (trees ha^{-1}) for fulfilling different farm needs that contribute to farm productivity but minimizing interference with pasture productivity.

Keywords: Abundance; Diversity; Richness; Silvopastoralism; Tree cover.

RESUMEN

Por lo general, la mayoría de los productores ganaderos de América Central retienen algunos árboles dispersos en los potreros para obtener beneficios adicionales a la ganadería tales como madera, alimentos, sombra y frutos para el ganado. Sin embargo, muy poco se sabe acerca de la diversidad, abundancia, riqueza, composición de las especies de árboles dispersos en las pasturas de ranchos ganaderos del trópico. Debido a esto, se planteo el siguiente estudio cuyo objetivo fue caracterizar y describir la cobertura de arboles dispersos en los potreros de ranchos ganaderos y el papel que juegan estos en la productividad del rancho. El estudio se realizó en 16 ranchos ganaderos en un ecosistema tropical seco de Costa Rica. Se encontró un total de 5,896 árboles dispersos en las pasturas (836 ha) pertenecientes a 36 familias y 99 especies. Los árboles estuvieron presentes en el 100% de los ranchos y en el 85% de los potreros. Se encontraron árboles individuales (54%) o formando grupos (46%). Las familias de árboles más abundantes encontradas fueron *Bignonaceae*, *Sterculeaceae* y *Boraginaceae* mientras que las especies más comunes encontradas fueron *Tabebuia rosea* (Bertol.) DC, *Guazuma ulmifolia* Lam, *Cordia alliodora* (Ruiz & Pav.) Oken y *Acrocomia aculeata* (Jacq.) Lodd. ex Mart, las cuales representan cerca del 60% del total de árboles dispersos encontrados en los potreros. Se encontró que las especies de árboles con dosel pequeño se encuentran en mayor abundancia que aquellas con dosel grande. La cobertura arbórea de los potreros fue del 7% (SE $\pm$ 0.54) mientras que la densidad fue de 8.1 árboles ha^{-1} (SE $\pm$ 0.66). Se concluye que los productores mantienen una baja diversidad (m^2 ha^{-1}), cobertura (%) y densidad (árboles ha^{-1}) para satisfacer diferentes necesidades de tal forma que contribuyan a incrementar la productividad del rancho pero minimizando la interferencia con la producción de pasto.

Palabras clave: Abundancia; Diversidad; Riqueza; Silvopastoralismo; Cobertura arbórea.

INTRODUCTION

In the dry tropical areas, pastures are commonly established either immediately after cutting and burning primary forest or after two to five years of shifting cultivation with crops, such as maize (*Zea mayz*) and beans (*Phaseolus vulgaris*), followed by planting with grasses (Ibrahim *et al*., 2000). While large areas of forest have been converted to pastures, the benefits of the conversion are temporarely due to the rapid depletion of soil nutrient reserves resulting in pasture degradation. Consequently, this causes a decrease in animal productivity which in turns negatively affects the profitability of livestock enterprises (Rueda *et al*., 2003) for which farmers are forced to search for alternative farming systems. Nowadays, evidence suggest that silvopastoral systems, which are an integrated farming systems that combine trees with pastures and livestock, are alternative farming systems that can play an important role to increase productivity, profitability and sustainability of livestock farms (Devendra and Ibrahim, 2004; Kallenbach *et al*., 2006) although their establishment generally carry higher investments cost (Scherr and Current, 1997). However, many farmers often retain dispersed trees and live fences within pasturelands to minimize risks and diversify production, obtaining benefits such as timber, fence posts, firewood, food in addition to shade and forage to cattle (Gibbons and Boak 2002; Devendra and Ibrahim, 2004; Harvey *et al*., 2011).

Despite the large number of trees than can be seen at landscape levels, most of the research on traditional silvopastoral systems in the dry and semidry tropics has focused on the evaluation of the nutritive value of native trees and shrubs for feeding cattle, especially during the dry season (Solorio *et al*., 2000; Ku, 2005). While these studies provide a solid basis for the use of trees and shrubs in cattle farm enterprises, limited information is available about tree resources dispersed in pasturelands of dry tropical areas and what factors contribute to tree species pattern distribution in pasturelands. Knowledge of tree cover and species composition and how they vary across pasturelands could help for the design of better silvopastoral systems aimed to improve productivity of traditional cattle farms systems in the dry tropical areas. Therefore, the objective of this study was to characterize and describe the diversity, abundance, richness, density and pattern of tree cover dispersed in pastures of cattle farm systems.

MATERIALS AND METHODS

Study Site

The study was conducted in Cañas, Guanacaste (10^{o}11´N, 84^{o}15´W; 684.20 km^2), located in Costa Rica. The area is classified as a Tropical Dry Forest (Holdridge 1978) with elevations ranging from 60 to 250 m.a.s.l. (Arauz, 2001). Annual rainfall ranges from 1000 to 2500 mm, with most rain falling from May to November (wet season) and the dry season occurring from December to April. During 8 months of the year evapotranspiration is higher than precipitation. Mean annual temperature is 27.6 ºC. Average mean temperature varies between 23 ºC and 31 ºC during the year. Relative humidity fluctuates between 62 – 89 and 52 – 77% in the wet and dry seasons, respectively. Soils in the lowlands are of volcanic type origin, mainly vertisols, with an average depth of 100 cm. In the upland and slope areas, soils are mainly inceptisols with rock formations on the soil surface. Soils are well drained, texture varies from fine to medium and fertility goes from medium to very high (Arauz, 2001).

Farm selection

For the inventory of tree resources in pastures, biophysical and socioeconomic information available from an existing semi-structured survey of 53 livestock farms was used to define the livestock farming systems from the region. Farms were first grouped by production system as either beef (just cattle) or mixed (agriculture and cattle) cattle farms. Beef cattle farms were subdivided by size: small (1- 50 ha), medium (51 – 100 ha) and large (> 100 ha) whereas mixed farms were not subdivided because most of this farms were small (< 50 ha). Thus, in order to include all farm type and sizes, twelve beef cattle farms (four small, five medium and three large) and four small mixed farms were selected based on availability and farmer willingness to cooperate in the study. Within each farm, all plots were identified and classified as forest, crop land, pastures, riparian forest, charrales (areas under vegetal succession) and human settlements, directly in the field by walking the entire farms and for pasture plots, (referred from now on as paddocks), size, slope and distances to main and secondary farm roads were estimated in a satellite image using geographic information systems (ArcView 3.3).

Tree inventory

A detailed inventory of all trees larger than 10 cm in diameter at breast height (dbh), dispersed within a pasture area delimited by fences, refereed from now on as paddocks (n =196), was carried out on all selected farms (total area of pastures = 836 ha). The inventory was based on tree population within each paddock. Dispersed trees were identified to species level directly in the field with the participation of local farmers. For those individuals that could not be identified in the field, leaf and fruit specimens were collected and identified later by taxonomists at the Santa Rosa National Park herbarium located in Guanacaste, Costa Rica. Riparian trees, live fences, and forest patches (groups of trees covering > 0.25 ha) were excluded from pasture tree inventory because they were not considered to be as dispersed in pastures. In order to characterize the types of dispersed trees, these were classified according to main use as either timber, forage (trees producing foliage and/or pods that are eaten by cattle) or fruit bearing trees. Other uses (e.g. firewood, fence posts, etc) were not considered because its slight use in the zone (Harvey *et al*., 2011). Decisions to assign species to categories were based on personal communication with farmers, secondary information (data collected by other individuals from the study area and specialized literature such as field plant identification manuals (Jimenez *et al*., 1999). In some cases, tree species, were classified in more than one category due to their various reported main uses. Simultaneously, trees were also categorized according to how they were distributed in pastures, either as individuals or clusters (defined as trees forming groups where their crowns overlapped). For each tree, the diameter at breast height (dbh), total height, stem height (distance from the soil base to the first steam bifurcation), and crown cover were measured directly in the field. Diameter at breast height was measured with a diametric tape and expressed in centimeters. Tree heights were measured with a hand-held laser instrument (Impulse 200 LR), which calculates the heights in meters based on sensor readings of distances and vertical angle measurements. Crown cover, defined as the paddock percent that was directly under crowns of individual trees, was measured from the readings of two perpendicular measurements covering the longest axes of the crown (Bellow and Nair 2003). For trees in clusters, the overlapped canopy was considered as a single canopy and the two longest perpendicular axes were measured. Tree crown cover area was calculated utilizing the following formula: $A = (\pi * R1 * R2)$; where A = Area (m^2); π = 3.1416; R1 = Radius of crown axe 1 (in m); R2 = Radius of crown axe 2 (in m). Total paddock crown cover percent was calculated as the sum of all tree crowns measured in the field for a particular paddock divided by the total paddock area and multiplied by 100.

Farm and paddocks characteristics

Farm size ranged from 18 to 241.3 ha, with an average of 67.0 ha (SE $\pm$ 14.9). The percentage of area sow with grass in mixed farms (47%) was significantly (P < 0.05) lower than in all types of beef cattle farms, which had very similar grass percentages (mean = 81%). Most paddocks (72%) contained improved grass species. Among the improved species, *Brachiaria brizantha* (28% of total pasture area) and *Brachiaria decumbens* (27% of total pasture area) were the most frequent, while *Hyparrhenia rufa* (21% of total pasture area) and *Paspalum spp* (6% of total pasture area) were the most frequent naturalized/native grass species. The number of paddocks within the farms varied from 4 to 27. Paddock size varied from 0.1 to 39.5 ha (SE $\pm$ 0.33), slope varied from 0.5 to 29.0 % and paddock mean height above sea level varied from 45 to 195 m.

Data analysis

Descriptive statistics (mean, standard error, ranges, minimum and maximum), standard descriptors of vegetation composition (density, abundance, richness) diversity (Simpson and Shannon) and similarity (Jaccard) indices, were calculated for each paddock and the mean of all paddocks was considered for the farm level. Diversity indices were calculated using the Biodiversity Pro (McAleece *et al*., 1997) and Estimates (Colwell, 1997) software programs. Jaccard index was calculated from the equation

$$Cj = \frac{j}{a + b - j}$$

where j = the number of species found in both sites; a = the number of species in site A; b = the number of species in site B. Simpson index was calculated from the equation $D = \Sigma\ p_i^2$ and Shannon index was calculated from the equation $H' = -\Sigma\ p_i \ln p_i$ where p_i is the proportion of individuals found in the $_i$th specie and ln = is natural logarithm. A one-way analysis of variance was performed to test differences between tree measurements for the most abundant species and across different farm types using Duncan multiple comparison tests to test mean differences. Multiple regression models were used to examine paddock descriptors (slope, size, distances and pasture types), as well as tree characteristics (height, dbh), in relation to crown cover and tree density (dependent variables) of paddocks (n = 196). All data was analyzed using InfoStat 4.1 (Infostat 2004).

RESULTS

The total inventoried area was 1,073 ha, of which pasturelands comprised 836 ha (78%) and crown cover of dispersed trees in pasturelands was 53 ha; this represented 5% of the total inventoried area and 6.4% of total pasturelands. The remaining areas comprised primary forest (2%), riparian forest (15%), cropped (3%) and fallows (1.5%) land among other land uses such as human settlements, cattle facilities and internal roads (0.5%). A total of 5,896 trees (dbh > 10 cm), from 36 families and 99 species, were found dispersed in 196 paddocks on the inventoried farms. Of these trees, 50% were categorized as timber trees, 27% as forage trees and 27% as fruit bearing trees (species can be assigned more than one use). Dispersed trees were found on all of the farms and in 170 (86%) of the 196 paddocks inventoried. Dispersed trees in pastures were arranged almost equally between isolated individual trees (54%) and trees in clusters (46%). Of the 99 tree species recorded, 20 were represented only by one individual whereas seven species by two individuals. The most abundant and frequent tree species found dispersed in pastures were *Tabebuia rosea*, *Guazuma ulmifolia*, *Cordia alliodora, Acrocomia aculeata, Byrsonima crassifolia* (L.) Kunth in Humb. Bonpl & Kunth and *Tabebuia ochracea* (A.H. Gentry) which together account for 60% of the total number of inventoried trees. Other common scattered tree species found were *Pachira quinata* (Jacq.) W.S. Alverson, *Bursera simaruba* (L.) Sarg, *S. saman*, *Cedrela odorata* L., *Andira inermis* (W: Wright) Kunth ex DC. and *E. cyclocarpum*. Tree data analysis among the most dominant scattered trees show that *E. cyclocarpum* had significantly larger mean crown area, dbh and height (P < 0.05) than any other species followed by *S. saman* which had larger crown area and height than the other tree species, but significantly smaller than *E. cyclocarpum* (P < 0.05; Table 1).

The overall mean dbh of the 5,896 trees measured was 44.8 cm (± SE 0.33) with a range from 10 to 269.7 cm. Most trees (71%) had dbh between 20-60 cm and very few (4%) larger than 100 cm (Figure 1).

The most frequent tree species with large dbh (> 100 cm) were *G. ulmifolia* (n=54), *E. cyclocarpum* (n=29), *Ficus* spp. (n=23), *S. saman* (n=18), *P. quinata* (n=11), *O. veraguensis* (n=10) and *B. crassifolia* (n=10) which all together accounted for 2.6% of total trees. Dbh of the most abundant timber tree species such as *T. rosea, C. alliodora and T. ochracea* was 35.60 ± 0.59, 39.55 ± 0.60 and 33.43 ± 0.88 cm, respectively.

Total number of trees per paddock averaged 30 trees and varied from 0 to 202 trees but crown cover (%) and tree density (trees ha^{-1}) showed a similar trend distribution within paddocks (Figure 2). Mean crown cover on paddocks was 7% (SE ± 0.54) and mean tree density was 8.1 trees ha^{-1} (SE ± 0.66) with large variability among paddocks. Crown cover of individual paddocks varied from 0 to 49% whereas tree density ranged from 0 – 70 trees ha^{-1}. Mean tree height (m) averaged 11.1 m and varied between 6.3 to 17.7 m among paddocks.

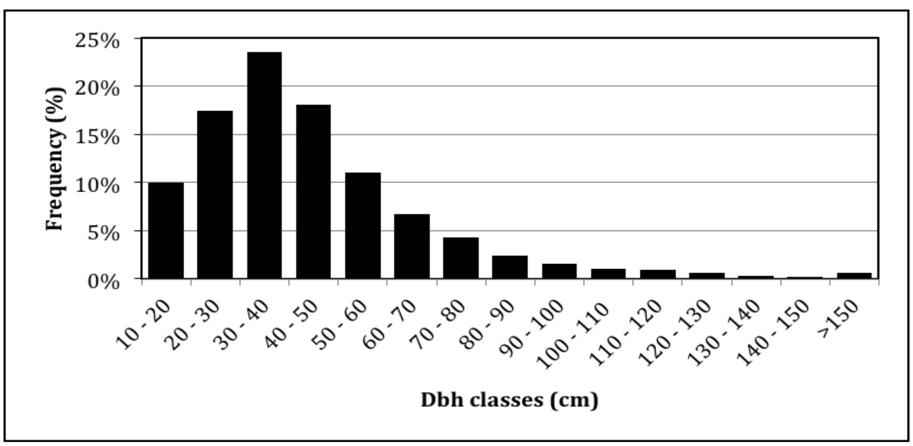

Figure 1. Frequency distribution (%) of diameters at breast height (in cm) of dispersed trees in pastures (n = 5,896 trees) of cattle farms in a dry tropical ecosystem.

Table 1 Mean crown area and structural characteristics of the main individual tree species (n = 11) found dispersed in pastures of cattle farms in a dry tropical ecosystem.

Tree species	n	Crown area (m^2)		dbh (cm)		tree height (m)		Density ($n\ ha^{-1}$)	CCP
Enterolobium cyclocarpum (Jacq.) Griseb	29	481.7 g	(78.0)	92.6 g	(9.8)	15.9 h	(1.1)	0.03	2.6
Samanea saman (Jacq.) Merr.	41	295.7 f	(40.7)	57.3 ef	(6.2)	14.2 g	(0.9)	0.05	2.3
Guazuma ulmifolia Lam.	337	141.6 e	(4.3)	58.9 ef	(1.6)	10.3 cd	(0.1)	0.40	8.9
Andira inermis (W. Wright) Kunth ex DC	107	139.5 e	(7.5)	59.5 f	(2.2)	9.9 cd	(0.3)	0.13	2.8
Pachira quinata (Jacq.) W.S. Alverson	51	117.5 d	(13.3)	53.7 de	(3.7)	12.1 e	(0.6)	0.06	1.1
Byrsonima crassifolia (L.) Kunth in Humb,; Bonpl. & Kunth.	192	99.2 cd	(3.9)	50.1 d	(1.4)	8.6 b	(0.1)	0.23	3.5
Tabebuia ochracea (A.H. Gentry) A.H. Gentry	144	94.6 c	(5.1)	33.5 ab	(1.3)	10.9 d	(0.3)	0.17	2.5
Cordia alliodora (Ruiz & Pav.) Oken	316	89.0 c	(3.1)	42.8 c	(0.9)	13.1 f	(0.2)	0.38	5.2
Tabebuia rosea (Bertol.) DC. In A. DC.	467	61.7 b	(1.9)	36.5 b	(0.7)	10.6 cd	(0.2)	0.56	5.4
Bursera simaruba (L.) Sarg.	22	43.0 b	(9.1)	30.2 a	(2.9)	6.7 a	(0.4)	0.03	0.2
Acrocomia aculeata (Jacq.) Lodd. ex Mart.	400	21.1 a	(1.0)	36.4 b	(0.6)	9.9 c	(0.2)	0.48	1.6

Density = Calculated as the number of individuals of the particular tree species divided by total farm pasture area. Dbh= Diameter at breast height. CCP = crown cover expressed as percentage of total crown cover (Total crown cover = 53.6 ha). Means (standard errors) within a column with different letters are significantly different ($P < 0.05$) using Duncan test.

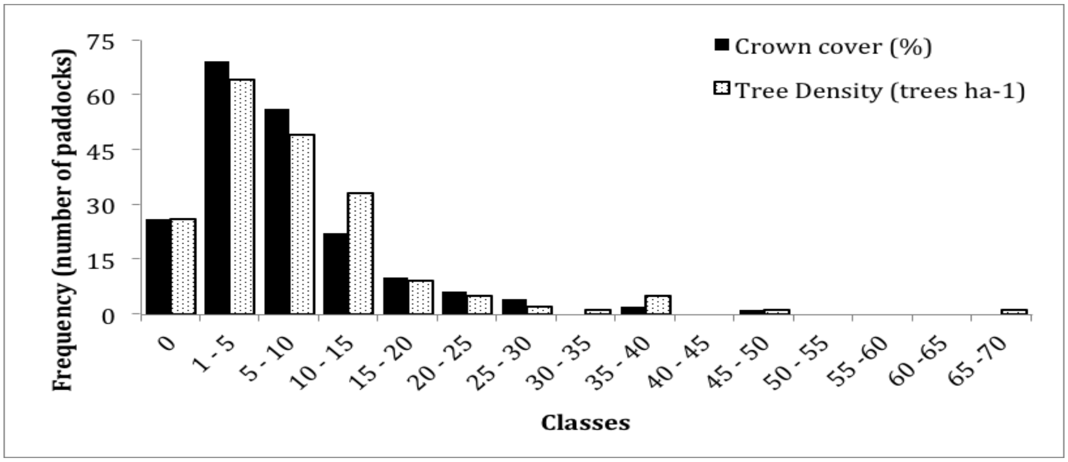

Figure 2. Frequency distribution of crown cover (%; black bars) and tree density (trees ha^{-1}; dotted bars) of dispersed trees in pastures (n = 196) of cattle farms inventoried in a dry tropical ecosystem.

Multiple regression analysis (Table 2) were statistically significant ($P < 0.0001$; $r^2 > 0.25$) for both, crown cover (%) and tree density (tress ha^{-1}) models. Pasture crown cover (%) was influenced positively ($P < 0.05$) by paddock slope (%) and mean height (m) of dispersed trees within the paddock. On the other hand, tree density (trees ha^{-1}) was positively affected ($P < 0.05$) by paddock slope (%), mean height (m) of dispersed trees within the paddock and by the shortest distance (m) to internal farm roads and negatively by paddock size (ha) and mean dbh (cm) of dispersed trees in paddock.

The Jaccard similarity index for biodiversity divided the farms into two groups; one including the three types of beef cattle farms which had comparable similarity index among them (65%) regardless of their different sizes and the mixed farm type which had 44% of the same species as beef cattle farms. No statistical differences were found among farm types ($P > 0.24$) in mean values of species richness neither for the Simpson nor Shannon diversity indices.

DISCUSSION

The study showed a low pattern of tree richness, abundance and density dispersed in paddocks of cattle farms. These findings can be associated to farmer's decision to maintain or remove particular tree species and individuals. Commonly, farmers prefer to maintain trees species based on the dependence on products and services that particular tree species provide to cattle farms (Augusseau *et al*., 2005; Kosaka *et al*., 2006; Harvey *et al*., 2011). The most abundant tree species found dispersed in paddocks were *T. rosea*, *C. alliodora, B. crassifolia*, *A. aculeate, G. ulmifolia* from which farmers obtain timber, as an additional farm income (Beer *et al*., 2000) as well as forage (both leaves and pods) for cattle (Cajas-Giron and Sinclair, 2001), results that are consistent with the findings from other studies conducted in dairy farms (Souza de Abreu *et al*., 2000), dual purpose and beef cattle farms. Farmer's decision to maintain or remove particular tree species dispersed in paddocks has a major impact on tree pattern observed. Local knowledge studies in the study zone (Stokes, 2001; Muñoz *et al*., 2003; Harvey *et al*., 2011) showed that livestock farmers had a wealth of knowledge regarding how large crown multipurpose tree species provide shade and fodder to cattle (Thapa *et al*., 1997) and how they affect the growth of pasture. However, they did not have a good understanding of the improvements in cattle productivity by keeping large crown trees in pastures. In this manner, farmers prefer to maintain tree species with large crown cover, such as *E. cyclocarpum, S. saman, Ficus spp and Mangifera indica*, at low densities avoiding interference with pasture production. Thus, policy and management strategies that conserve, enhance and increase tree species diversity and density in paddocks through tree natural regeneration should be directed through participatory research with farmers about the positive contribution that large crown trees provide to farm productivity irrespective of a decrease in grass productivity. In addition to this, generally, many cattle farms had small areas with secondary re-growth and large fence sections in which less abundant tree species may be planted. This implies that, strategy for tree conservation on a farm level would have to include a mixture of tree species in different habitats such as trees in pastures, live fences, riparian and secondary forests. Thus, maintaining and increasing trees within cattle farm systems may represent a great opportunity to conserve diversity because of the large amount of pasturelands existing worldwide.

Table 2. Regression for crown cover (%) and tree density (tree ha^{-1}) of disperse tree species in pastures of cattle farms in a dry tropical ecosystem.

Estimated variable	Linear model	r^2	P < value
Crown cover (CC, %)	CC = 3.2 (3.7) + 0.27 (0.11) S + 0.86 (0.17) h	0.29	0.0001
Tree density (TD, n ha^{-1})	TD =9.15 (4.6) – 0.35 (0.17) Sz + 0.26 (0.13) S + 0.01 (0.002) D + 1.10 (0.21) h – 0.13 (0.04)dbh	0.26	0.0001

S = paddock slope (%); h = mean tree height (m); Sz = paddock size (ha); D = distance to farm internal road; dbh = diameter at breast height (cm). Standard errors of regression parameters are shown in parenthesis.

The small number of individuals in the lowest dbh category (10–20 cm) found indicated a low rate of natural regeneration, which may be associate with grass species sown and paddock management practice, particularly weed control (Bautista-Tolentino *et al*., 2011). Recent studies in dry tropical areas (Villacis *et al*., 2003; Villanueva *et al*., 2003) reported lower tree cover in pastures sown with improved grass species compared to pastures sown with naturalized grass specie and in paddocks in which weeds was controlled with the use of herbicides compared to paddocks in which weeds were manually controlled (Camargo *et al*., 2000). In the same sense, larger tree seedling damage caused by cattle trampling, defoliation, and damage of young trees occurred in paddocks managed in a very intensively manner (high stocking rates and heavy grazing regimens) than those paddocks less intensively managed (Camargo *et al*., 2000). Thus, the fact that paddocks in the study area have been largely used for cattle grazing and that large areas of pastures were established with the aggressive improved *B. brizantha* grass species, may have caused competition between grass, cattle and tree seedlings resulting in high sapling mortality lowering natural regeneration rates of trees in pastures. Hence, temporary cattle exclusion from paddocks as well as selective weed control management programs are some tree conservation strategies that is urgent to work with farmers to adapt current management practices which would favor tree seedling establishment and survival in pastures (Spooner *et al*., 2002; Guevara *et al*., 2004; Fischer *et al*., 2009; Harvey *et al*., 2011).

The large range in tree density and cover among paddocks observed can be explained by the particular site and on agro-ecological conditions. Regression analysis showed that less sloping paddocks were associated with lower tree densities and cover. These findings suggest that farmers were using their acquired knowledge to manage the tree cover to protect the hilly areas against soil depletion and erosion. It may be also due to that flatter areas of this study were dominated with more fertile soil (vertisols) such that livestock production is more intensively managed on the more fertile flat areas were grasses may also maintain better cover suppressing natural regeneration of trees.

CONCLUSION

Dispersed trees in pastures are common in cattle farm systems but the current tree cover indicates that farmers are managing a low tree diversity, abundance, cover and density. Therefore, policy incentive schemes along with participatory research with farmers that explain the positive contribution that trees in pastures provides to livestock farms are necessary in order to enhance tree cover on pastures.

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