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PHYTOSOCIOLOGICAL AND DENDROMETRIC PARAMETERS IN CACAO SHADOWING MANAGEMENT: CONTRIBUTIONS TO THE PRODUCTIVE CONSERVATION OF THE CABRUCA AGROFORESTRY SYSTEM

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The high percentage of Atlantic Forest remnants in the Cacau region of Bahia is attributed to the cocoa cabruca agroforestry system, which is still in financial crisis, jeopardizing the conserved ecosystem assets and services. The recovery of cacao farming in the south of Bahia is directly related to the management of the cacao tree and the management of its shading is a determining factor. In order to support the management of shading from the point of view of productive conservation, phytosociological and dendrometric parameters were used to evaluate the structure and interferences in the overgrowth, in a 1.4 ha area of cabruca cocoa, on the Bela farm. Cruz, Municipality of Barro Preto, Bahia, Brazil, In the pre-management period, 30 tree species were inventoried, distributed in 20 families, with basal area (AB) of 17.15 m^2/ha, commercial volume (Vc) of 128.14 m^3 /ha, Margalef Index (MDg) equal to 6.33; after thinning and planting (post-management), 49 tree species remained, distributed in 18 families, with AB = 16.09 m^2/ha, Vc = 112.05 m^3/ha and QM = 1:3.6, DMg = 7 ,03. The results, based on current legislation, allow us to conclude that the area under study is a Cabruca Agroforestry System that can be legally and technically managed; the interference provided environmental gains (QMpre = 1:3.23 and after selective thinning and planting of trees QMpost = 1:3.48) without any loss in species diversity; based on the precepts of productive conservation, there was assertiveness in the proposal to adapt the shading, with an increase in Wealth and Uniformity. The Jentsch Mixing Coefficient (QM), the Margalef (DMg) and Brillouin (HB) indices have adequate characteristics and contribute satisfactorily to decision-making in the management of cabruca cocoa shading.

Key words: Atlantic Forest, native tree, sustainability, cocoa culture.

Parametros fitossociólogicos e dendrométricos no manejo do sombreamento do cacaueiro: contribuições à conservação produtiva do sistema agroflorestal cabruca. O alto percentual de remanescentes de Mata Atlântica na Região Cacaueira da Bahia é atribuído ao sistema agroflorestal cacau cabruca, que ainda hoje está em crise financeira, comprometendo os ativos e serviços ecossistêmicos conservados. A recuperação da cacauicultura sulbaiana está diretamente relacionada ao manejo do cacaueiro e o manejo do seu sombreamento é um fator determinante. Com o objetivo de subsidiar o manejo do sombreamento sob o ponto de vista da conservação produtiva, utilizou-se parâmetros fitossociológicos e dendrométricos para avaliar a estrutura e as interferências no sobreamento, em uma área de cacau cabruca com 1,4 ha, na fazenda Bela Cruz, Município de Barro Preto, Bahia, Brasil, No período pré-manejo foram inventariadas 30 espécies arbóreas distribuídas em 20 famílias, com área basal (AB) de 17,15 m^2/ha, volume comercial (Vc) de 128,14 m^3/ha, Índice de Margalef (DMg) igual a 6,33; após o desbaste e plantio (pós-manejo), remanesceram 49 espécies arbóreas distribuídas em 18 famílias, com AB = 16,09 m^2/ha, Vc = 112,05 m^3/ha e QM = 1:3,6, DMg = 7,03. Os resultados, com base na legislação vigente, permitem concluir que a área em estudo é um Sistema Agroflorestal Cabruca plausível de ser legal e tecnicamente manejada; a interferência proporcionou ganhos ambientais ($QM_{pré}$ = 1:3,23 e após o desbaste seletivo e plantio de árvores $QM_{pós}$ = 1:3,48) não acusando perda na diversidade de espécies; com base nos preceitos da conservação produtiva, houve assertividade na proposta de adequação do sombreamento, com aumento da Riqueza e da Uniformidade. O Coeficiente de Mistura de Jentsch (QM), os Índices de Margalef (DMg) e Brillouin (HB) têm característica adequadas e contribuem satisfatoriamente para a tomada de decisão no manejo do sombreamento do cacau cabruca.

Palavras-chave: Mata Atlântica, árvore nativa, sustentabilidade, cultura do cacau.

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Introduction

The Southern Region of Bahia, inserted in the Atlantic Forest Biome, harbors a high percentage of remaining species, composing an arboreal genetic heritage of inestimable value (Lobão, 2007). According to Setenta and Lobão (2012), the cabruca agroforestry system, a model for planting cacao (*Theobroma cacao*) developed by the peoples of this region, is seen as a great ally in the conservation of all this ecological heritage.

Cabruca is a low impact environmental cultivation system based on the replacement of the understory elements (intermediate strata) of the native Atlantic forest with a crop of economic interest - the cacao tree; implanted under the protection of remaining trees of the original native forest, discontinuously with the natural vegetation, establishing balanced relationships with the associated natural resources; was conceived in a contextualized geographic space, by the direct relationship between man and nature, which served as the basis for the historical and cultural formation of a "genuine territory", the Bahia cacao region (Setenta and Lobão, 2012).

The cabruca system valued the agroecological and agroforestry characteristics of cocoa farming, consolidating a peculiar strategy of implementing extensive tropical agriculture in southern Bahia, without turning it into a plantation (Lobão et al., 1997). Cabruca cocoa is a production system that allows harmonious coexistence between man and nature and maintains good mesological relationships. This gives the system the ability to adapt to different cultures and different soil and climate conditions (Lobão, 2007).

Management in a multiple-use regime, practiced over the years, on cocoa farms in this region, even if empirically, promoted the effective conservation of existing natural resources, as well as the forest heritage inserted in the agricultural production arrangements practiced.

Increasing cocoa production, productivity and profitability is a necessity and is directly related to cocoa management (Müller and Valle, 2012). Among the management practices, the following can be listed: mowing, application of phytosanitary products, fertilization, liming, product improvement, pruning and flowering of the cacao tree, removal of "brooms", cloning and adaptation of shading.

It is necessary to adapt the shading, with the main objective of promoting thermal and environmental comfort for the cocoa tree, aiming at increasing production and productivity; however, this intervention must not compromise the environmental and ecosystem products and services provided by cocoa farming.

Theobroma cacao is a shade-tolerant species, but adequate shade levels can result in relatively high photosynthetic rates, favoring its growth and productivity. Lima et al. (2010), affirm that when the availability of mineral nutrients is not limiting, there is a positive correlation between the production of cocoa beans and the light intensity available and consequently the light interception.

Shading in cabruca has the primary function of promoting the thermal and environmental comfort of the crop, therefore, the silvicultural/phytotechnical management of cocoa shade (raising and/or reducing the canopy, thinning the number of trees and planting), is among the practices that should not be overlooked. It is considered that the use of moderate shading contributes to greater ecological stability, providing adequate conditions, including for the reproduction and development of pollinating insects.

In the adequacy of shading, three basic situations can be worked on: (*i*) heavily shaded areas, where pruning and/or thinning must be carried out to suit them; (*ii*) unprotected areas, where the top protection system must be re-established (recover); and, (*iii*) areas where shading individuals need to be eradicated and/or replaced (inadequate species, dead or diseased trees).

Thinning, a classic silvicultural activity is the first stage of the adaptation process and consists of removing trees to adapt protection to the cacao tree. It aims to adjust the density of the tree population in order to reduce competition by increasing luminosity and providing adequate thermal and environmental comfort to the cacao tree. It is recommended that with each thinning operation performed, the area is reassessed in order to avoid excessive interference (CEPLAC, 2009).

Decisions regarding the intensity and selectivity in thinning must take into account the tree biodiversity of the affected site. Empirical knowledge is generally employed. However, the use of phytosociological descriptors based on species richness, abundance and dominance, can provide subsidies for a more technical decision-making.

Based on the principles of Productive Conservation (Setenta and Lobão, 2012), thinning must be carried out in a way that allows for a diversity that provides an environmental gain (Lobão, 2012).

It is noteworthy that the tree component (tree species of different stages of succession, as well as rare and noble species of commercial value) of the cocoa agroforestry system, most of them are remnants of the primary Atlantic Forest. Therefore, interference must be conducted in a way that adds environmental, social and economic value to the system.

Numerous phytosociological descriptors are generally used to compare different areas and/or populations, estimating the importance of the species in the environment by its frequency, abundance and dominance. The minimum species diversity for the cocoa cabruca system is not technically determined; but there are studies demonstrating the richness of plant diversity in the Southern Atlantic Forest in Bahia and in the shading of the cabruca cocoa system (Lobão, 1993; Lobão et al., 1997).

For the formulation of careful management plans, knowledge of the floristic composition and vegetation structure are very important factors. Silva (2013) and highlight the importance of analyzing the vegetation structure, emphasizing that they function as an essential tool for management.

According to Araújo (2006), the 100% forest inventory (census) aims to determine, with a good degree of precision, the floristic composition, density and real stock of wood in the managed area. It also suggests that trees be mapped and classified according to their quality and use, wood stock and seed production, among others.

Based on the interrelationship between production and shade, Müller and Valle (2012) emphasizes the importance of the work to aim at characterizing the structure, species diversity and tree composition in the pre and post-thinning phases of shade trees in the cabruca system.

Materials and Methods

The study was carried out at Bela Cruz farm (UTM WGS 89: Zona 24L - E - 0443808 N - 8366262), municipality of Barro Preto (BA, BR), which makes up the Vale do Almada cocoa agrosystem in the cocoa region of southern Bahia. The property is part of the Barro Preto Project resulting from the consortium between the Municipality and the Rural Union of Barro Preto, MARS COCOA and CEPLAC.

The Bela Cruz farm has a total area of 11 hectares (ha), of which 09 hectares have an agroforestry system with cocoa cabruca, with an average productivity of 1500 kg ha^{-1} year; 01 ha with pasture and 01 ha with peach palm *(Bactris gasipae).* In the cabruca cocoa area, 1.4 ha was demarcated for study purposes. The area located in the Salgado River microbasin, which makes up the Cachoeira River macro basin, is bathed by the Jussara stream, formed by three springs (two located within the project area) and three other small perennial streams.

This microregion has a hot and humid climate without a dry season, according to the Köppen classification, it is of type Af; with monthly precipitation above 60 mm, relative humidity above 80% and average temperature around 24ºC.

Soils are classified by the Brazilian Soil Classification System (US Soil Taxonomy) with Podzolic (Spodossolo) variation Itabuna Modal, Cepec and Morro Redondo, Latosol (Oxisol) Una and Água Sumida variation and Inceptisol Rio Branco variation.

In the region there are areas with natural vegetation in the initial and medium stages of regeneration (capoeira), as well as areas of humid tropical forests, with primary and secondary characteristics, classified by Veloso et al. (1991) as dense ombrophilous forest, belonging to the neotropical zone. The topography of the region varies from undulating to heavily undulating. The worked area is characterized as wavy.

The study area had the arboreal component of the shading inventoried at 100% (census), where the inclusion factor adopted to measure the trees was the diameter at breast height (DBH) $\geq$ 8 cm, as determined by the Sema-Inema Ordinance 03 /2019.

The André Maurício de Carvalho Herbarium - CEPLAC was used as a reference and the botanical classification system adopted was the Angiosperm Phylogeny Group II (APG II, 2003). Tree management was based on the ethics of productive conservation (Setenta and Lobão, 2012 and the ordinances of the Forestry Decree of Bahia 15.180/2014 and Sema-Inema Decree 03/2019). The cocoa trees, as they are not the object of study, were not inventoried.

The inventoried trees were recorded: species, circumference at breast height (CAP), basal area (AB), commercial height (Hc), total height (Ht), crown branch height (He) and its georeferenced location.

In the analysis of the horizontal structure, the tree species were evaluated by phytosociological indicators of Absolute Frequency (FA) and Relative Frequency (FR), Absolute Density (DA) and Relative Density (DR), Absolute Dominance (DoA) and Relative Value of Dominance (DoR), Importance Value Index (IVI) and Coverage Value Index (ICV), calculated in Microsoft Excel.

The diversity of tree species in the shading of cacao in the study area was recorded by Wealth (number of individuals per species) and by Uniformity (distribution of individuals among the inventoried species). Diversity was estimated based on Shannon Index (H'), Brillouin Index (HB), Pielou Equability (J''), Margalef Index (MDg), Menhinick Index (MDn). To express the floristic composition, the Jentsch Mixing Coefficient (QM), calculated from the analysis of the total number of inventoried individuals, and the Sørensen Similarity Index (S) were used (Pielou, 1984; Ricklefs, 2001; Lobão. 2007; Lima, Souza and Pederassi, 2016).

Results and Discussion

Decisions regarding the agroforestry management to be adopted in the recovery of the cocoa plantation involve important phytotechnical aspects that are not adherent to the objective of this study. Only the analysis regarding the use of phytosociological and dendrometric descriptors and the effect of interference on cocoa shading will be addressed.

In the forest census of the area (1.4 ha), 136 adult trees were identified, belonging to 30 species, distributed in 20 botanical families, making a total average Density of 97 ind ha^{-1} (Figure 1).

The estimates of the parameters related to the phytosociology of the area before and after the management intervention are presented in Table 1. The total Basal Area (AB) was estimated at 17.15 m^2 ha^{-1}. The native tree species with the largest Basal Area (3.6 m^2 ha^{-1}) was *P. foliolosa* (21%) and *A. heterophyllus*,

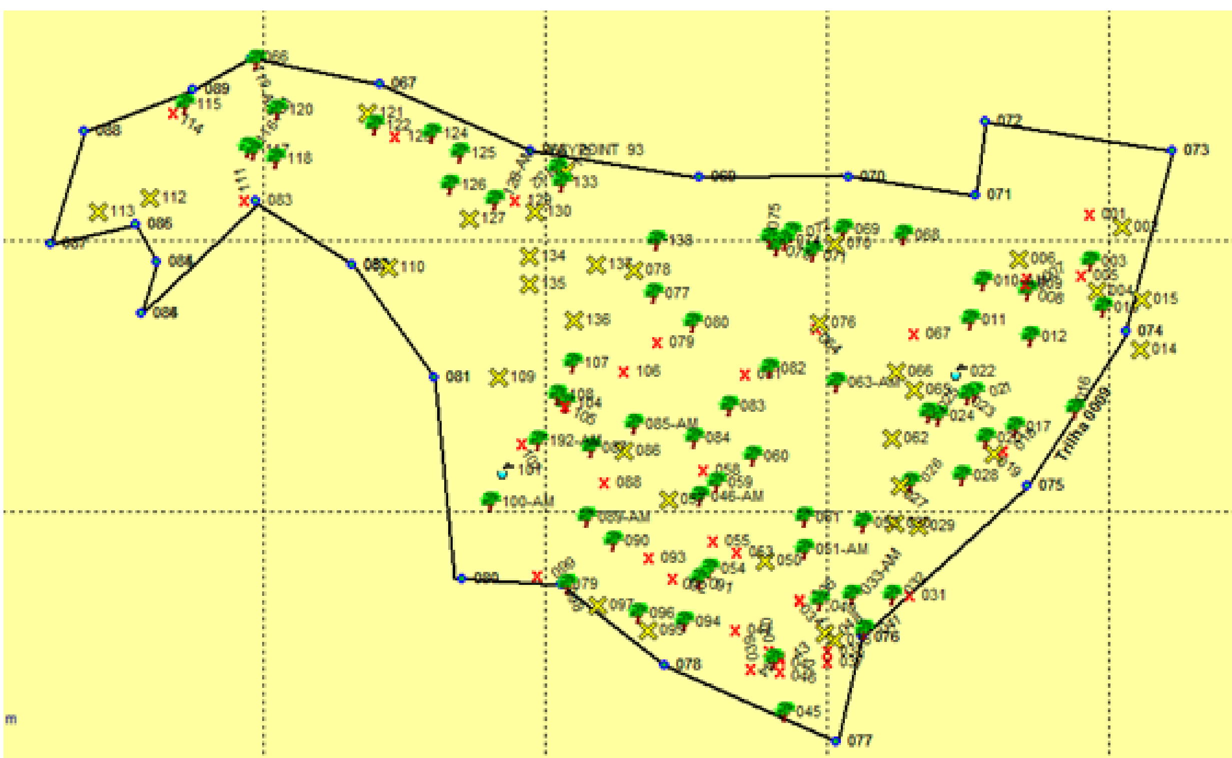

Figure 1 - Bela Cruz Farm, map of the inventoried area (qualification and demonstration unit - UDQ). Remaining trees without interference (φ); Remaining trees with pruning interference (pruning and/or canopy reduction) ( ); Trees to be thinned (X).

Table 1- Phytosociological descriptors of the trees inventoried in the cabruca of the Bela Cruz farm in Southeastern Bahia

Scientific name	Comum name	Pre-intervention area management							post-intervention area management						
		N	AB	DR	DoR	IVC	IVI	Vc(m^3)	N_r	Vc_d(m^3)	Vc_r(m^3)	IVI_d	IVI_r	AB_d	AB_r
Aegiphila sellowiana	fumo-bravo	2	0,151	2,21	0,88	3,09	5,3	1,11	0	1,11	0	4,18	1,11	0,01	0,14
Aleurites moluccana	Nogueira	1	0,017	0,74	0,1	6,58	1,54	0,13	0	0,13	0	1,41	0,13	0	0,01
Annona silvestres	pinha-do-mato	2	0,066	2,21	0,38	2,59	4,8	0,43	2	0	0,43	4,8	0	0	0,07
Apeiba tibourbou	jangada-branca	1	0,192	1,43	1,12	2,59	4,06	1,07	1	0	1,07	4,06	0	0	0,19
Arthorcarpus heterophyllus	Jaqueira	21	3,227	22,09	18,81	40,9	62,99	19,61	12	7,98	11,63	55,01	7,98	0,06	3,16
Bauhiniafus conervis	unha-de-vaca	1	0,035	1,47	0,2	1,67	3,15	0,26	1	0	0,26	3,15	0	0	0,03
Bertholletia excelsa	castanha-do-pará	1	0,014	0,74	0,08	0,82	1,56	0,13	1	0	0,13	1,56	0	0	0,01
Cedrela odorata	cedro-rosa	11	2,176	11,78	12,69	24,47	36,25	16,41	9	0,52	15,89	35,73	0,52	0,01	2,17
Centrolobium sp.	Putumuju	1	0,512	0,74	2,98	2,87	3,6	4,25	1	0	4,25	3,6	0	0	0,37
Cordia trichotoma	Claraíba	4	0,822	3,68	4,79	8,47	12,16	7,82	3	1,14	6,69	11,02	1,14	0,01	0,82
Croton sp.	Velame	4	0,371	4,42	2,16	6,58	11	3,05	1	2,2	0,85	8,79	2,2	0,02	0,36
Erythrina poeppigiana	eritrina-de-alta	1	0,104	0,74	0,6	1,34	2,08	0,71	1	0	0,71	2,08	0	0	0,1
Ficus sp.	Gameleira	4	2,107	4,42	12,28	16,7	21,12	13,7	4	0	13,7	21,12	0	0	2,11
Genipa americana	Jenipapeiro	1	0,109	1,47	0,63	2,11	3,58	1,12	1	0	1,12	3,58	0	0	0,11
Jaracatia sp.	mamão-de-veado	1	0,128	0,74	0,75	1,27	2,01	0,42	1	0	0,42	2,01	0	0	0,09
Lonchocarpus sp.	Cabelouro	7	1,384	7,36	8,07	15,43	22,8	8,08	5	1,57	6,52	21,23	1,57	0,02	1,36
Molinedia sp.	farinha-seca (Una)	1	0,032	0,74	0,19	0,92	1,66	0,21	1	0	0,21	1,66	0	0	0,03
Myrciaria cauliflora	Jaboticaba	1	0,098	1,47	0,57	2,04	3,52	0,42	1	0	0,42	3,52	0	0	0,1
Nectrandra sp.	Louro	6	0,642	6,63	3,75	7,4	14,03	5,16	5	0,59	4,58	13,44	0,59	0	0,13
Persea americana	Abacateiro	2	0,179	2,21	1,04	3,25	5,46	0,71	2	0	0,71	5,46	0	0	0,18
Plathymenia foliolosa	Vinhático	9	3,602	9,57	21	30,57	40,14	35,41	9	0	35,41	40,14	0	0	3,6
Pouteria sp.	Bapeba	1	0,082	0,74	0,48	1,21	1,95	0,3	1	0	0,3	1,95	0	0	0,08
Roupala sp.	Aderno	1	0,024	0,74	0,14	0,88	1,61	0,21	1	0	0,21	1,61	0	0	0,02
Sparattosperma leucanthum	Carobussu	2	0,31	2,21	1,81	4,02	6,23	2,03	1	0,5	1,53	5,73	0,5	0	0,31
Spondias venulosa	Cajarana	1	0,063	0,74	0,37	1,1	1,84	0,46	1	0	0,46	1,84	0	0	0,06
Swartzia macrostachya	grão-de-burro	3	0,345	2,86	2,01	4,95	7,9	1,85	2	0,23	1,63	7,67	0,23	0	0,34
Tabebuia serratifolia	pau-d'arco-amarelo	4	0,219	3,68	1,27	4,96	8,64	2,06	4	0	2,06	8,64	0	0	0,22
Trema micranta	Corindiba	1	0,024	0,74	0,14	0,88	1,61	0,17	0	0,12	0,05	1,49	0,12	0	0,02
Trichilia pallida	rosa-branca	1	0,082	0,74	0,48	1,08	1,81	0,52	1	0	0,52	1,81	0	0	0,06
Unknown	Unknown	1	0,041	0,74	0,24	0,98	1,71	0,3	1	0	0,3	1,71	0	0	0,04
TOTALS		**97**	**17,11**	**99,3**	**99,8**	**201,7**	**294,4**	**128,1**	**74**	**16,09**	**112,05**	**280**	**16,09**	**0,13**	**16,3**

N = número de árvores, AB = área basal; DR = densidade relativa; DoR = dominância relativa; IVC = índice de valor de cobertura; IVI = índice de valor de importância; Vc(m^3) = volume comercial; Vc_d(m^3) = Vc desbastado; Vc_r(m^3) = Vc remanescente após desbaste; IVI_d = desbastado; IVI_r = remanescente pós desaste; AB_d = desbastado; AB_r = remanescente pós desaste.

an exotic species, with 3.22 m^2 ha^{-1} of total Basal Area, equivalent to 18.78% of the studied area.

The survey made it possible to quantify the number of individuals per species, the species considered abundant (*A. heterophyllus* – DA = 22; *C. odorata* – DA = 12; and *P. foliolosa* – DA = 10) represented 43.5% of DR of all of them; while *Nectandra* sp. (DA = 7) and *Lonchocarpus* sp. (DA = 7) made up DR of 14% of the total. The vast majority of species presented low abundance with DR of 43.7% and 12% of these species presented only one individual in the area. As for the abundance index, *A. heterophyllus*, introduced many years ago and disseminated along with cocoa, confirms that it is ecologically, culturally and socially integrated and adapted (Table 1).

The one with the highest Relative Density (DR) among the species was *A. heterophyllus* (exotic species) with an occurrence of 22.1%, followed by *C. odorata* (11.4%), *P. foliolosa* (9.3%), *Lonchocarpus* sp. (7.1%) and *Nectandra* sp. (6.4%) representing DR of 56.3%. Sambuichi (2002) observed that these species were among the four most abundant in an area of cocoa-cabruca in the municipality of Ilhéus - BA.

This density points to a regional preference for these species, suggesting the intrinsic social and economic value related. They are easily recognized by the rural community and spared from slaughter, demonstrating the importance of qualifying the manager to identify young individuals of species of interest to cocoa farming in order to contribute to the regeneration of other shade species.

Relative dominance (DoR) expresses the physical occupancy rate of a given species in relation to the sampled species. Among those inventoried, those with the highest representation were *P. foliolosa* (21%), *A. heterophyllus* (18.8%), *C. odorata* (12.6%) and *Ficus* sp. (12.2%). In shading management, this DoR Index helps the manager to prevent species of low interest for productive conservation from dominating, such as *Ficus* sp. which competes aggressively with the cocoa tree. The other three species, *P. foliolosa*, *A. heterophyllus* (18.8%) and *C. odorata* (12.6%) are species of high value interest in the timber market. However, *C. odorata* is considered an endangered species and is therefore legally immune from cutting.

These 4 species presented, respectively, a commercial volume of 35.4 m^3, 19.6 m^3, 16.4 m^3 and 13.7 m^3, totaling 85.1 m^3 (66.4%) of the total commercial volume (128.14 m^3) of the studied area (Table 2).

The values estimated by the Coverage Value Index (IVC) showed that the species with the highest ecological efficiency in terms of horizontal distribution,

Table 2 - Species to be used on the mitigation

Scientific name	Comum name	Family	CI	G ECO	Origen
Astronium urundeuva	aroeira	Anacardiaceae	BM	SI	Native
Virola bicuhyba	bicuiba-vermelha	Myristicaceae	DR	C	Native
Melanoxilon brauna	brauna	Fabaceae	IC	C	Native
Pradosia glycyphloea	buranhem	Sapotaceae	BS	ST	Native
Astronium sp.*	gonçalo-alves*	Anacardiaceae	NR	ST	Native
Eschweilera ovata	biriba	Lecythidaceae	DM	SI	Native
Dalbergia nigra	jacarandá-da-bahia	Fabaceae	NR	ST	Native
Cariniana legalis	jetiquibá-rosa	Lecythidaceae	NR	C	Native
Euterpe edulis	Jussara	Arecaceae	BM	C	Native
Manilkara elata.	maçaranduba	Sapotaceae	DR	C	Native
Paubrasilia echinata	pau-brasil	Fabaceae	IC	C	Native
Tabebuia impetiginosa	pau-d'arco-roxo	Bignoniaceae	NR	C	Native
Copaifera langsdorfii	pau-óleo-copaiba	Fabaceae	BR	C	Native
Aspidosperma discolor	peroba	Apocynaceae	NR	C	Native
Caryocar barbinerve	piqui-amarelo	Caryocaraceae	DM	C	Native
Caryocar edule	piqui-preto	Caryocaraceae	IC	C	Native
Centrolobium robustum	putumuju-gigante	Fabaceae	NR	ST	Native
Lecythis pisonis	sapucaya	Lecythidaceae	DM	C	Native
Bowdichia virgilioides	sucupira-pele-de-sapo	Fabaceae	NR	ST	Native
Plathymenia foliolosa	vinhático	Fabaceae	NV	ST	Native
Virola bicuhyba	bicuiba-vermelha	Myristicaceae	DR	C	Native

Subtitle: * to be confirmed botanically; commercial importance (CI) => NR = noble wood for use in joinery; BR = white wood used in joinery; BM = white wood for use in posts and fences; DR = hard wood used in joinery; BS = white wood for boards (taipá); NV = white wood used in furniture making. Ecological succeeding (GECO) => SI = initial secondary; ST = late secondary; C = Climax.

in terms of relative density and dominance were *P. foliolosa* (30.6%), *Lonchocarpus* sp. (15.4%), *A. heterophyllus* (40.9%), *Ficus* sp. (16.7%) and *C. odorata* (24.4%) belonging to Fabaceae, Moraceae and Meliaceae families, respectively. It can be seen that five of these species with the highest IVC, in the analysis of the horizontal structure of the area, were the same that showed the highest Dominance.

The species that presented the highest Importance Value Index (IVI) were *A. heterophyllus* (63%), *P. foliolosa* (40%), *C. odorata* (36%), *Lonchocarpus* sp. (23%), *Nectrandra* sp. (14%) and *C. trichotoma* (12%). The analysis of Table 1 indicates that, in most cases, the parameter that most contributed to the determination of the importance of a species was the relative density; sometimes, Relative Dominance appeared as the most influential parameter, as in the case of the species *A. heterophyllus*, *P. foliolosa, C. odorata*, which present individuals with greater basal area.

Silva (2005) apud Martins (1991) used the IVI among the possibilities to estimate the importance of each species for the phytosociological structure of an area. According to the author, there are some drawbacks in using IVI; almost always due to the use of parameters related to its definition, as it limits the power of information about the area under study, making it possible to obtain identical IVIs in completely different vegetation.

To analyze the proportional abundance of the area, the Shannon Heterogeneity Index (H') was estimated at 2.82 nats ind^{-1} indicating the number of species that would be expected in the community if all species had the same abundance. This estimated value is lower than those found by Sambuichi (2003) both in new cabrucas (3.54 and 4.22) and in older ones (3.31, 3.34 and 3.99). Likewise, Lobão (2007) found 3.29, 3.24 and 3.97 for the Shannon diversity index, which can be considered high, especially as they are distinct areas of entropized secondary fragments. According to Martini and Prado (2010), the higher the H' values, the greater the floristic diversity of the area; they usually range from 1.5 to 3.5 (rarely above 5.0). In the study area with census inventory, the Shannon Index is not the best estimator of richness diversity.

The evenness index (J) or area uniformity was estimated from the H'/Hmax ratio (maximum evenness) at 0.83. As in the literature, equability is directly proportional to density and antagonistic to dominance, the closer to 01, the greater the diversity. This value may indicate that there was no dominance of one or a few species in the studied area, if analyzed in isolation. However, Ricklefs (2001) warned that, in both the calculation of H' and J', the rarest species contribute less than the more common species of greater abundance.

The Brillouin Index (HB) is a descriptor that demonstrates the uniformity in the distribution of the abundance of the species in the studied area, it requires that the community be fully known, so it is rarely used; for this reason, it is the most suitable for inventory in a single plot or in the total area, not requiring statistical tests.

However, the greatest difficulty found in its use is in obtaining the natural logarithm of the factorial of values above 69. At the Bela Cruz farm, the Brillouin value was 3.4, demonstrating the uniformity in the distribution of species abundance in the studied area.

Considering that the study area was inventoried by census (at 100%), a recommended richness index to assess the similarity between areas is the Margalef Index (DMg), which presented a value of 6.3, which means that 6.3 individuals for each species in comparable areas. After carrying out the proposed interferences in the area (thinning and compensatory planting) the estimated DMg was 7.03, showing a gain in floristic richness. The Menhinick index, equivalent to the Margalef Index, is at 3.0 and will change to 2.9 after the interference, indicating the conservation of the original richness.

The Jentsch Mixing Coefficient (QM) showed a ratio of 1:3.23 for the species and or 1:4.85 for families. In the Southeast region of Bahia, the QM of areas with cocoa-cabruca ranged from 1:3 to 1:8 for species and from 1:8 to 1:12 for the botanical family, that is, every 3 to 8 tree individuals there was a new species and between 8 - 12 individuals a new family (Lobão et al., 1997; Lobão, 2001; Lobão et al., 2004).

During the census, according to their location, 14 individuals with potential for reproduction were pre-selected and demarcated, being four *C. odorata* trees (DoR = 12.7%), four *C. trichotoma* (DoR = 4.79%), three *P. foliolosa* (DoR = 21%), two *Nectrandra* sp. (DoR = 0.78%) and one *Centrolobium* sp. (DoR = 2.13).

According to Silva (2009), the choice of species for seed production depends on the interest and purpose of use, whether for personal consumption or for commercialization, whether for forest recovery, commercial planting or other uses. Different areas can be used for seed production, as described in specific legislation for the production of seeds and native forest seedlings, always seeking the genetic diversity of plants of the same species (variability), also taking into account the vigor and phenotypic qualities of the arboreal individual.

The evaluation carried out in the field to promote the environmental suitability and the thermal comfort of the area for the cultivation of cocoa, indicates that of the 136 trees inventoried, 97 were alive; of these, 33 trees of 11 species were selected to be suppressed (thinning), corresponding to 24% of the total number of inventoried trees. There were 14 species classified as exotic and 19 as native, regarding their origin. It should be noted that 49 individuals (30%) were technically classified as devitalized or perishing trees due to their vegetative state (Figure 2).

Daniel (2007) emphasizes that the sociological position of the trees and their vigor are outstanding characteristics of the competition between them and help in the decision of which ones should be thinned and which ones will be favored. The expected result with thinning is to obtain a stand with a stock of quality trees, as Daniel (2007) points out that thinned stands present a greater increase in volume than non-thinned stands, in addition to the remaining individuals presenting with characteristics superior phenotypes.

Thirty-three species from 10 botanical families were indicated for thinning, being the Moraceae family the most important, directly related to the relative dominance of the species *A. heterophyllus*. After thinning, the species *A. heterophyllus, C. odorata, Ficus* sp., *P. foliolosa* and *Lonchocarpus* sp., represented 12.4 m^2 of the basal area, equivalent to 76% of the total, with 83.1 m^3 of commercial volume. In the intervention, two pioneer species at the end of their life cycle (*T. micrantha* and *A. sellowiana*) of the Ulmaceae and Vernaceae families were eradicated.

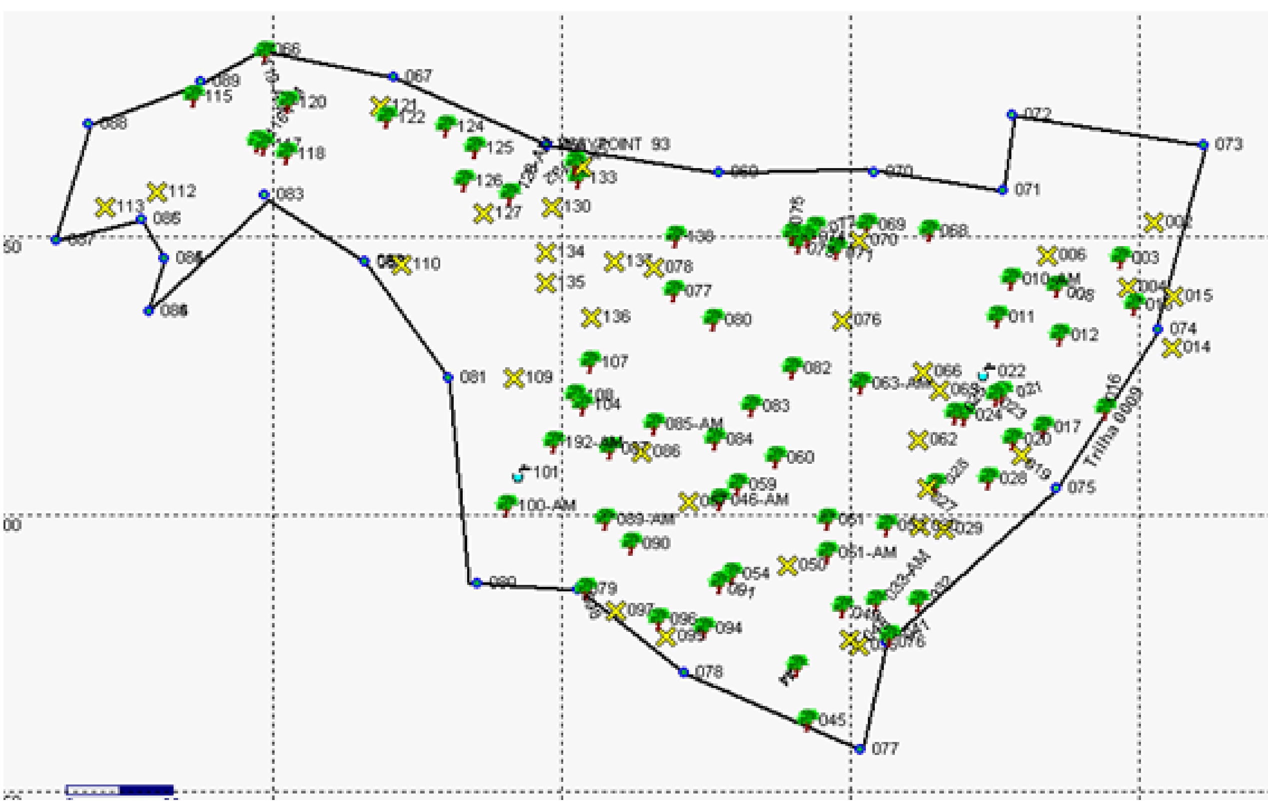

Figure 2 - Map of the inventoried area of Bela Cruz farm, Barro Preto/BA. Area without suppressed tree individuals - (φ) Remaining trees without interference; (✕) Remaining trees with pruning interference (pruning and/or canopy reduction.

The proposed interventions were the target of compensatory actions, with the planting of 100 tree individuals distributed in 13 species (Table 2), under the guidance of Ceplac and the legislation in force (planting of 3 for each native tree with cut shade, preferably threatened of extinction).

This intervention provided ecological gains, the QM of the area originally with 1:3.23, after a selective thinning of trees of species with higher density, decreased to 1:2.74; and, after reimbursement planting, it evolved to 1:3.48, a value close to that found in the regional Atlantic forest (Lobão, 2007; Silva, 2013). It is possible to observe that at the time of thinning, despite the undeniable negative impact provided by the selective felling of trees, there were gains as recorded by QM after compensation planting.

Conclusion

The results obtained in the management for the adequacy of shading of cabruca cocoa allow us to conclude that:

- The studied area, based on current legislation, is a cabruca agroforestry system that can be technically managed.
- The phytosociological analysis, based on the assumptions of conservation, showed that there was efficiency, effectiveness and environmental assertiveness in the proposal to adapt the shading; and that the thinning and planting of compensation (compensation) promoted environmental gains in diversity (richness and uniformity) of tree species.
- The presence of rare and noble native species in the studied area contributes to the conservation of the genetic and ecological heritage, highlighting the potential of SAF cabruca to conserve ecosystem assets.
- Due to the characteristics of the cocoa cabruca agroforestry system and the legal regulations governing the elaboration of the PTMC (Cabruca Technical Management Project), it is recommended to apply and use the Jentsch Mixing Coefficient (QM), and the Margalef (DMg) and Brillouin (HB), to support the shading management of cabruca cocoa.

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Literature Cited

ARAÚJO, H. J. B. 2006. Inventário florestal a 100% em pequenas áreas sob manejo florestal madeireiro. Acta Amazônica (Brasil) 36(4):447-464. ISSN 0044-5967.

COMISSÃO EXECUTIVA DO PLANO DA LAVOURA CACAUEIRA - CEPLAC. 2009. Adequação do sombreamento do cacaueiro. Nota Técnica. Ilhéus, BA, DIRET/CEPLAC. 11p.

DANIEL, O. 2007. Silvicultura. Universidade Federal da Grande Dourados, Faculdade de Ciências Agrárias Dourados – MS.

LIMA, M. A. O. et al. 2010. Crescimento e plasticidade fenotípica de três espécies arbóreas com uso potencial em sistemas agroflorestais. Science Forum (Brasil) 38(87):527-534.

LIMA, M. S. C. S.; SOUZA, C. A. dos S.; PEDERASSI, J. 2016. Qual Índice de Diversidade Usar? Cadernos UniFOA (Volta Redonda) 30:129-138.

LOBÃO, D. E. et al. 2012. Cacau Cabruca – Sistema Agrossilvicultural Tropical. In: Valle, R. R. (ed.). Ciência, Tecnologia e Manejo do Cacaueiro, CEPLAC/CEPEC/SEFIS. 2º ed. Gráfica e Editora Vital. Itabuna, BA. pp.467-506.

LOBÃO, D. E. 1993. Emprego do método de quadrantes na análise fitossociológica de um fragmento de Mata Atlântica, no Sudeste da Bahia. Dissertação de Mestrado. UFV, Viçosa, MG. 121p.

LOBÃO, D. E. et al. 1997. Cacau-Cabruca: um modelo sustentável de agricultura tropical. Indícios Veementes. FNDPF, São Paulo, SP. Ano III. pp.10-24.

LOBÃO, D. E. V. P. 2007. Agroecossistema Cacaueiro da Bahia: cacau cabruca e fragmentos florestais na conservação de espécies arbóreas. Tese Doutorado. Universidade Estadual Paulista Júlio de Mesquita Filho, Jaboticabal, SP. 98p.

LOBÃO, D. E.; SETENTA, W. C.; VALLE, R. R. 2004. Sistema Agros-silvicultural Cacaueiro - Lobão, Silva and Lobão Modelo de agricultura sustentável. Revista da Sociedade Brasileira de Agrossilvilcultura (SBAG) 1(2):163-173.

LOBÃO, D. E. 2001. Classificação e seleção de espécies florestais nativas para o sistema agrossilvicultural (SAGS) cacaueiro. CEPLAC/ CEPEC/SERAM. Ilhéus, BA. (Datilografado - Documento interno). 20p.

MARTINI, A. M. Z.; PRADO, P. I. K. L. 2010. Índices de diversidade de espécies. PPGECB, UESC. Disponível em: www.ecologia.ib.usp/let/lib/exe/fetch.php.

MARTINS, F. R. 1991. Estrutura de uma floresta mesófila. Campinas, SP, Editora da UNICAMP. 246p.

MÜLLER M. W.; VALLE R. R. M. 2012. Ecofisiologia do cultivo do cacaueiro. In: Valle, R. R. (Ed.). Ciência, tecnologia e manejo do Cacaueiro. CEPLAC/CEPEC/SEFIS. 2 ed. Gráfica e Editora Vital. Itabuna, BA. pp.31-66.

PIELOU, E. C. 1984. The interpretation of ecological data. New York. Wiley-Interscience. 263p.

RICKLEFS, E. R. 2001. A Economia da natureza. Rio de Janeiro, RJ, Guanabara Koogan. 503p.

SAMBUICHI, R. H. R. 2002. Fitossociologia e diversidade de espécies arbóreas em Cabruca (Mata Atlântica raleada sobre plantações de cacau) na região sul da Bahia, Brasil. Acta Botânica Brasilica 16:89-101.

SAMBUICHI, R. H. R. 2003. Ecologia da vegetação arbórea de cabruca - Mata atlântica raleada utilizada para cultivo de cacau - na região sul da Bahia. Tese Doutorado. UnB, Brasília, DF. 161p.

SETENTA, W.; LOBÃO, D. E. 2012. Conservação Produtiva: cacau por mais 250 anos por Wallace Setenta e Dan Érico Lobão. Itabuna, BA. 190p.

SILVA, A. G.; GUEDES-BRUNI, R. R. 2005. Uma abordagem quantitativa para a importância de recursos florais em comunidades vegetais. Natureza online 3(1):3-6. [online] http://www.naturezaonline.com.br. Publicado pela ESFA.

SILVA, L. A. M.; PAIXÃO, J. L.; PEREIRA, C. E. 2009. Marcação e seleção de matrizes e colheita de sementes. In: Sambuichi, R. H. R.; Mielke, M. S.; Pereira, C. E. Nossas Árvores: conservação, uso e manejo de árvores nativas no sul da Bahia. Editus. Ilhéus, BA. pp.125-149.

SILVA, M. A. S. 2013. Conservação Produtiva: manejo do sombreamento no sistema cabruca, região cacaueira da Bahia. Dissertação Mestrado. IPÊ-Instituto de Pesquisas Ecológicas, Uruçuca, BA. 88p.

VELOSO, H. P.; RANGEL-FILHO, A. L.; LIMA, J. C. A. 1991. Classificação da vegetação brasileira, adaptada a um sistema universal. IBGE, Rio de Janeiro, RJ. 124p.

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