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BOTANY

Soil nutrient content and plant phytosociology in agroforestry systems of the Rio de Janeiro State highlands, Brazil

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ABSTRACT. This study aimed to evaluate soil fertility and the horizontal structure of three demonstration units of Agroforestry Systems (ASs), Sapucaia, RJ, Brazil. Twenty-four plots (25 m^2) were delineated in each AS. Soil fertility was evaluated through pH, organic carbon, total nitrogen, phosphorus and potassium. The estimated phytosociological parameters were frequency, density, dominance, importance value and the diversity index of Shannon. Magnesium was more pronounced in ASas with more management intensity due to the incorporation of banana biomass (AS 1 and 2). The AS 1 highlights were for banana and coffee (about 45% IV), AS 2 banana and physic nuts (about 50% IV) and AS 3 cassava and 'fumo-bravo' (VI=52.2%). This study suggests that diversity contributes to the maintenance of ecosystem services on a local scale, mainly for the conservation and maintenance of soil fertility, as well as to increase food security in the property. The use of physic nuts has not shown to be a favorable option as a source of energy for the farm studied. However, it can contribute to the increase of local value added. These responses support the importance of ASs for the establishment of more sustainable production models.

Keywords: vegetation horizontal structure; soil fertility; family farming.

Teores de nutrientes do solo e fitossociologia em sistemas agroflorestais na Região Serrana, Estado do Rio de Janeiro, Brasil

RESUMO. Este estudo objetivou avaliar a fertilidade do solo e a estrutura horizontal de três unidades demonstrativas de Sistemas Agroflorestais (SAFs), Sapucaia, RJ, Brasil. Foram demarcadas vinte e quatro parcelas (25 m^2) em cada SAF. A fertilidade do solo foi avaliada através do pH, carbono orgânico, nitrogênio total, fósforo e potássio. Os parâmetros fitossociológicos estimados foram frequência, densidade, dominância, valor de importância e o índice de diversidade de Shannon. O magnésio foi mais pronunciado nos SAFs 1 e 2, com mais intensidade de manejo, devido à incorporação de biomassa da bananeira. Os destaques no SAF 1 foram para banana e café (cerca de 45% do VI); no SAF 2, banana e pinhão-manso (cerca de 50% do VI); e, no SAF 3, mandioca e fumo-bravo (VI=52,2%). Este estudo sugere que a diversidade contribui para a manutenção dos serviços ecossistêmicos em escala local, principalmente para a conservação e manutenção da fertilidade do solo, bem como para aumentar a segurança alimentar. O uso do pinhão-manso não demonstrou uma opção favorável como fonte de energia; no entanto, pode contribuir para o aumento do valor agregado local. Essas respostas sustentam a importância dos SAFs para o estabelecimento de modelos de produção mais sustentáveis.

Palavras-chave: estrutura horizontal da vegetação; fertilidade do solo; agricultura familiar.

Introduction

The long history of occupation of the Atlantic Forest in Rio de Janeiro has resulted in the drastic reduction of its area since the discovery of Brazil (Schmiegelow et al., 2008). Currently, there still about 30% native vegetation in the State, yet under different sucessional stages. From this total, near 33% are composed of forests belonging mainly to Conservation Units and areas of difficult access (Colombo & Joly, 2010; Clemente, Oliveira Junior, & Louzada, 2017). This background is directly associated with biodiversity loss, soil erosion, besides other negative environmental impacts. Based on that, it is of utmost importance to seek for alternatives able to merge different anthropic uses with conservation of natural resources (Campanha, Araújo, Menezes, Silva, & Medeiros, 2009; Assis et al., 2015).

In face of this scenario, Agroforestry Systems (AS) is considered as a sustainable alternative to production (Silva, Lima, Campanha, Gilkes, & Oliveira, 2011). According to Castro, Fraxe, Santiago, Matos, and Pinto (2009); Martins and Ranieri (2014), ASs can be described as a system of land use and occupation with forestry plantations together with farming and livestock activities, within the same local, using a great variety of species and ecological interactions.

The AS provide a number of benefits for sustainable cropping models and can mitigate impacts from an unsustainable agricultural management. It occurs because such systems promote good soil cover, and increase nutrient cycling, conserving biodiversity and ecosystem services, while providing significant local livelihood (Power, 2010; De Beenhouwer, Aert, & Honnay, 2013; Fernandes et al., 2014). For Jose (2009), Gomes et al., (2016) ASs are also able to reduce significantly carbon levels in the atmosphere through photosynthesis and regulation of soil CO_2. As stated by Jose (2009); Moraes, Xavier, Mendonça, Araújo Filho, and Oliveira (2011), farming sustainability is not only achieved by maintaining soil natural fertility, given the constant exports of nutrients through harvest, which gradually lead to depletion of soil minerals. Concurrent cropping with forest species increases biodiversity, leading to the formation of a floristic structure similar to the native forest. In addition, it may increase the amount of organic matter, microbial biomass and physicochemical properties, such as high reactivity of humic fractions.

Freitas and Magalhães (2012) claimed that phytosociological studies provide detailed information on structure, distribution, and the relationship among species in a plant community, being a tool of great relevance in recovering degraded areas, forest production, and AS designing.

The objective of this study was to evaluate the soil nutrient content and the vegetation horizontal structure in three ASs, held by family farmers, located on a farm, in the city of Sapucaia - RJ, Brazil.

Material and methods

Study area

The study was carried out at the Agroecology Research Station *Arca de Noé* farm, on the Rio-Bahia route (BR 116 road), km 34, in the city of Sapucaia, Rio de Janeiro, Brazil. The area lies on the coordinates 21º 59' 42" S latitude and 42º 54' 52" W longitude, with an average altitude of 800 m above sea level.

The city belongs to the Piabanha River basin. Most part of this area is composed by massifs of highland hills and cliffs. Local vegetation is classified as Dense Ombrophylous Forest. The soil is classified as Yellow Argisol on a sharp slope and hilly surface. A review of land-use history showed a monoculture cropping of brachiaria grass (*Brachiaria decumbens*), over a period of more than 20 years, with direct grazing of dairy cows.

Methodological procedures

Three Demonstration Units (DUs) of AS were installed at the experimental farm. These were composed of As 1 or "coffee system" with six years of planting; AS 2 or "banana system" with 5 years of planting; and AS 3 or "crotalaria system" with 3 years of planting. All of these units had nearly 0.3ha and no irrigation system.

Evaluations of soil nutrient contents and vegetation horizontal structure were carried out in 24 squared plots - 5x5 m (25 m^2). Of these, eight were allocated in each system, totaling an area of 600 m^2, which corresponds to 20% of all implemented DUs.

Soil sampling was performed in August 2015, following protocols of the Handbook for Soil Analysis (Embrapa, 1997), being collected between 0-20 cm depth. From each plot, five simple samples were collected and taken to the laboratory forming a composite sample of each DU. These were conditioned in plastic bags and sent to the Laboratory of Chemical Analysis, *Embrapa Agrobiologia*. There, pH in H_2O, potential acidity, exchangeable aluminum, exchangeable calcium and magnesium, organic carbon, total nitrogen, phosphorus, and exchangeable potassium were assessed.

In each plot, any plant with soil height diameter (DSH) equal to or higher than 2.5 cm was identified and had DSH and total height recorded on field sheets. Botanical material was identified on site; later, identifications were rechecked by means of specialized literature. The plants were classified by the Angiosperm Phylogeny Group System (APG IV, 2016), except for the Fabaceae family which is subdivided into three subfamilies: Caesalpinioideae, Papilionideae, and Mimosoideae according to Magalhães and Freitas (2013).

Three different ways of introducing plant species were set for the three ASs, as follows: cropped (species introduced by farmers), forest remnants (species that had already occurred in the area prior to DU implantation) and spontaneous (species naturally introduced with species found in the vicinity) (Flora Brasil, 2018).

The phytosociological parameters surveyed for horizontal structure analysis were relative frequency (F_r), relative density (D_r), relative dominance (Do_r) coverage value (CV), importance value (IV), and Shannon diversity index (H') (Freitas & Magalhães, 2012). In this study, the basal area (sum of the cross-sectional areas of the individuals, considering the DAS) and its abundance (equivalent to the population size of a species in a community) will also be obtained (Freitas & Magalhães, 2012).

Results and discussion

Soil fertility

Table 1 demonstrates AS 1 had a higher content of exchangeable calcium e lower of aluminum whether compared to the other sampled areas.

Table 1. Soil chemical analysis results for calcium, magnesium, exchangeable aluminum and potential acidity, in $cmol_c$ dm^{-3}, organic carbon and total nitrogen, in percentage, and phosphorus and potassium, in $mg.dm^{-3}$, sampled from each AS at a depth range of 0-20 cm.

	Ca	Mg	H+Al	Al	pH water	Corg	P	K	N
		$Cmol_c$ dm^{-3}			1:2.5	%	$Cmol_c$ dm^3	mg dm^{-3}	%
AS1	3.1	0.9	6.3	0.1	5.62	1.90	0.0125	153	0.21
AS2	2.3	0.8	7.3	0.2	5.31	1.99	0.0164	143	0.25
AS3	2.1	0.7	6.8	0.2	5.41	1.93	0.0064	75	0.20

The pH values in the sampled DUs ranged from 5.3 to 5.6 and showed few restraints in the analyzed soil.

Calcium is an important component in the sum of exchangeable bases in the soil and a key plant nutrient, being essential in cell division and formation of new tissues and it is a major (Pinheiro, Pozza, Pozza, Moreira, & Alves, 2011; Waraich, Ahmad, & Ashraf, 2011). Its higher contents in AS 1 might have been related to the longer implantation time (6 years), besides the quality of the woody material deposited on the ground, which, insofar as it is mineralized, promotes an increase thereof in the soil.

Gonçalves, Fonseca, and Figueiredo (2013) verified that wood residues from selective logging caused increases in nutrient availability in the soil (by decomposition), mainly for the exchangeable bases K, Ca, and Mg, during the rainy season. The reason for those increases in relation to the total stocks of nutrients in the raw wood material is that nutrient concentrations in this fraction are much higher (especially Ca and Mg) than are those of dead wood with larger diameters.

Litter is one of the main sources of nutrient in Agroforestry system, mainly nitrogen, calcium, and phosphorus. Litter deposition and decomposition, under the influence of weather, soil fauna, and crop management are considered key processes for maintaining an ecosystem quality and stability, especially in soils with low natural fertility under alternative cropping production (Jose, 2009; Souza et al., 2012; Palma, Blanco-Canqui, DeClerckc, Gaterea, & Grace, 2013).

Pioneer tree species have great differentials in nutrient content and decomposition rates, since they are characterized by rapid growth and have greater investment in leaf production and roots instead of woody material (Vendrami, Jurinitz, Castanho, Lorenzo, & Oliveira, 2012).

Potassium content of the soil in this area was also superior to the other two sampled units. These findings point to a greater deposition of organic material or even an improved temporal stability of the management system. Within each AS, a selective pruning management provided a higher content of exchangeable potassium in the soil of ASs 1 and 2. In these places, banana trees were predominant, so that a greater amount of this element could be accumulated in the biomass and, consequently, being mostly recycled in the soil through biomass mineralization (Moreira & Fageria, 2009). Furthermore, potassium is easily leached from the canopy, being absorbed in increased quantities by plants. It constitutes a rapid cycling nutrient and readily available for the following crop. According to Silveira, Pereira, Polidoro, Tavares, and Mello (2007), this element is found in larger concentration in banana tree leaves and fruit. These authors also reported that V% contents (K, Ca, Mg and Na) in a Latosol (Oxisol) planted with banana trees were higher than were those in areas with forest and cassava cultivation.

Nutrient recycling by litter decomposition in Agroforestry system is one of the main contributions to an efficient nutrient use and sustainable farming (Lima, Leite, Aquino, Oliveira, & Castro, 2010). As stated Gonçalves et al. (2013), a large part of the organic matter and nutrients remain in the soil and sediments during the cold season in temperate regions, being only released to the soil solution in spring-summer. Yet, in tropical ecosystems, most of the nutrients remain in the biomass, being thus recycled within system organic structures throughout the year (Odum, 1988). Therefore, carbon and nutrient recycling is fundamental in biogeochemical cycles, mainly for tropical areas and in poor soils (Dawud et al., 2016). On the other hand, soil fertility management and its self-regulating mechanism of chemical, physical, and biological properties are essential for proper crop management and productivity over time.

Phytosociological survey

AS 1 is the oldest unit and had been under the highest management intensity, according to the farmers' own information, mainly due to the ease of access. Conversely, the newest unit, AS 3, is still intended to the restoration of the original processes of ecological succession, holding the poorest floristic richness (Table 2).

Both AS 1 and AS 2 had similar values of diversity and evenness (Table 2). Magalhães and Freitas (2013) evaluated the floristic composition of six forest fragments of different ages in the mountainous region of Rio de Janeiro State; after five and seven years of fallow, these authors found similar values of diversity, which were 1.59 and 1.82 nats ind^{-1}, respectively. This outcome suggests that both of the mentioned DUs might have high diversification because of a spontaneous recruitment of autochthonous species from Atlantic Rainforest, which are typical of early stages of succession, such as *Vernonia polyanthes, V. polycephala, Trema micrantha*, and *Solanum mauritianum* (Magalhães & Freitas, 2013).

Table 2. Floristic richness of the three ASs installed in *Arca de Noé* farm, Sapucaia, state Rio de Janeiro.

Floristic richness	AS 1	AS 2	AS 3
Individuals	338	167	141
Stems	418	202	219
Species	28	25	13
Family	20	18	9
Diversity index(H')	2.34	2.58	1.68
Equability index (J)	0.70	0.80	0.65
Density (ind hd^{-1})	16.900	8.350	7.050
Basal Area (m^2 ha^{-1})	3.4390	10.4130	0.0470

The density and basal area showed that AS 1 and 2 contributed majorly to the woody flora, being comparable with forest fragments in the early stages of ecological succession of the Atlantic Rainforest. According to the Conama's resolution number 06/94, for the state of Rio de Janeiro, forest fragments in the early stages of succession have to present a herbaceous shrub physiognomy with an average basal area of up to $10m^2.ha^{-1}$. In addition, there must be a prevalence of heliophytes, mainly represented by rosemary (*Rosmarinus officinalis*), "assa-peixe" (*Vernonia polyanthes*), "trema" (*Trema micrantha*), "embaúba" (*Cecropia* spp.), and guava (*Psidium guayava*) (Brasil, 1994).

The largest number of exclusive species (*Coffea arabica, Psidium guajava, Myrciaria glazioviana, Hymenaea courbaril,* among others) was found in AS 1, containing several species in common with AS 2 (*Mangifera indica, Euterpe edulis, Jatropha curcas, Carica papaya, Musa* sp., etc.). Four species present in the three DUs (*Vernonia polyanthes, V. polycephala, Trema micranta*, and *Solanum mauritianum*) are pioneers, typical of initial stages of the Atlantic Forest (Magalhães & Freitas, 2013) (Figure 1 and Table 3).

AS 1 is characterized by strong integration, in the medium term, for banana (*Musa* sp.) with coffee (*Coffea arabica)*, staggered with short-term cultivations, such as: *Carica papaya* and *Morus nigra* (fruit) and others of medium and long terms, such as: *Euterpe edulis* (peach palm), *Eugenia uniflora* (fruit), *Inga edulis* (fruit), *Myrciaria glazioviana* (fruit), *Malpighia glabra* (fruit), *Persea americana* (fruit), *Mangifera indica* (fruit), *Psidium guajava* (fruit), *Eriobotrya japonica* (fruit), *Hymenaea courbaril* (wood), and *Jatropha curcas* (energy), plus species proving ecosystem services, such as: *Tithonia diversifolia* (biomass incorporation), *Solanum mauritianum, Trema micranthus, Sapium glandulatum* (brightness adjustment and biomass incorporation), and *Vernonia polycephala* (pollination). With this, the system shows the major potential of continuous production, supporting family farmers and increasing income, besides enhancing the successional evolution of the ecosystem

In Costa Rica, ASs contributed to the growth and weight of coffee (Souza et al., 2012). According to Pezzopane, Souza, Rolim, and Gallo (2011) AFs promote shading for the coffee crop, that brings benefits such as protection against frost, excess radiation, winds and high temperatures, which contribute to increase the sustainability of the crop. For Alves, Silva, Oliveira Neto, Barrella, and Santos (2015), financial indicators showed positive values in agroforestry systems for coffee and bananas.

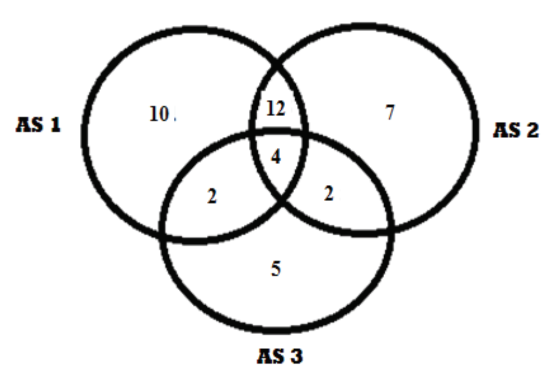

Figure 1. Venn diagram for the three UDs of Agroforestry system at *Arca de Noé* farm, Sapucaia, Rio de Janeiro state, Brazil, with the number of exclusive and mutual species.

Table 3. Floristic List, given in alphabetical order by family, ways of plant species introduction for the three DUs of Agroforestry system, at *Arca de Noé* farm, Sapucaia, Rio de Janeiro state, Brazil.

Families	Cientific Names	Common Names	Introduction
Anacardiaceae	*Mangifera indica* L.	mango	cultivated
Annonaceae	undetermined 1	undetermined 1	spontaneous
Arecaceae	*Euterpe edulis* Mart.	peach palm	cultivated
Asteraceae	*Tithonia diversifolia* (Hemsl.) A. Gray	mexican-sunflower	cultivated
	Vernonia polyanthes Less.	"assa-peixe"*	spontaneous
	Vernonia polycephala A. DC.	"assa-peixe"*	spontaneous
Cannabaceae	*Trema micrantha* (L.) Blume	"trema"†	spontaneous
Caricaceae	*Carica papaya* L.	papaya	cultivated
Erythroxylaceae	*Erythroxylum pulchrum* A. St.-Hil.	"fruta-de-pombo"*	spontaneous
Euphorbiaceae	*Jatropha curcas* L.	physic nut	cultivated
	Manihot sp	cassava	cultivated
	Ricinus communis L	castor bean	cultivated
	Sapium glandulatum (Vell.) Pax	"burra-leiteira"*	spontaneous
Fabaceae	*Crotalaria juncea* L.	sunn hemp	cultivated
	Erythrina sp	"eritrina"*	remainig
	Hymenaea courbaril L.	"jatobá"*	cultivated
	Inga edulis Mart.	"ingá-de-metro"*	cultivated
	Piptadenia gonoacantha (Mart.) J. F. Macbr.	"pau-jacaré"*	spontaneous
	Stryphnodendron adstringens (Mart.) Coville	"barbatimão"*	spontaneous
	Undetermined 5	undetermined 5	spontaneous
Lamiaceae	*Rosmarinus officinalis* L.	rosemary	spontaneous
Lauraceae	*Persea americana* Mill.	avocado	cultivated
Malpighiaceae	*Malpighia glabra* L.	"acerola"*	cultivated
Malvaceae	*Luehea grandiflora* Mart.	whips horse	remaning
Moraceae	*Artocarpus heterophyllus* Lam	jack fruit	cultivated
	Morus nigra L.	black mulbarry	cultivated
Musaceae	*Musa* spp.	banana	cultivated
Myrtaceae	*Eugenia uniflora* L.	cherry	cultivated
	Myrciaria glazioviana (Kiaersk.) G. M. Barroso ex Sobral	"cabeludinha"*	cultivated
	Psidium guajava L.	guava	remainig
Piperaceae	*Piper aduncum* L.	"aperta-ruão"*	spontaneous
	Piper crassinervium Kunth	"jaguarandi"*	spontaneous
	Piper hispidum M. Martens & Galeotti	"jaborandi"*	spontaneous
Rosaceae	*Eriobotrya japonica* (Thunb.) Lindl.	"nêspera"*	cultivated
Rubiaceae	*Coffea arabica* L.	coffee	cultivated
	Coutarea hexandra (Jacq.) K. Schum.	"quina"*	cultivated
Rutaceae	*Citrus* sp.	cravo lemon	cultivated
Sapindaceae	Undetermined 2	undetermined 2	spontaneous
Solanaceae	*Solanum mauritianum* Scop	"fumo-bravo"*	remainig
Urticaceae	*Cecropia hololeuca* Miq.	"embaúba-branca"*	spontaneous
Undetermined	Undetermined 3	undetermined 3	spontaneous
	Undetermined 4	undetermined 4	spontaneous

*Species that have common names in portuguese.

Likewise, AS 2 has a production potential in the medium term for banana (*Musa* sp.) and energy (*Jatropha curcas*), besides for fruit supply (*Morus nigra, Artocarpus heterophyllus, Inga edulis, Eriobotrya japonica, Carica papaya, Mangifera indica, Eugenia uniflora, Citrus* sp) heart of peach palm (*Euterpe edulis*) and ecosystem services (*Solanum mauritianum, Vernonia ferruginea, Trema micrantha, Erythroxylum pulchrum, Vernonia polycephala, Ricinus communis, Coutarea hexandra*, and others). These characteristics confer on this unit, the same social, economic, and environmental benefits of the previous one.

Banana exploitation by family farmers is a reality identified in other Brazilian agricultural areas, being considered as the fourth most important crops on the representing the fourth source of energy after corn, rice and wheat (Borges, Pereira, & Lucena, 2009). Banana cultivation under shade is considered a suitable mean of overcome losses caused by *Sigatoka* (fungus), besides ensuring profitability of the business (Beltrán-Garcia et al., 2014).

AS 3 still presents characteristics of a forest under formation. This DU can be described by the forest succession theory proposed by Ernest Göesth to Agroforestry system (Götsch, 1996). According to this author an agroforestry system can be understood as an organism. From the understanding of the dynamics of the successional process are identified some groups of species that serve to set up the Agroforestry intercropping over time. The cassava is a very important crop in Agroforestry system; it is of easy cultivation, has high resistance and, above all, plays an important role in food security for family farmers (Vieira et al., 2007).

The cassava (*Manihot* sp.) can be produced properly under drought conditions making it the ideal food security crop in family farming (Henkel & Amaral, 2008; Saraiva, Silva, Sousa, Cerqueira, Chagas, & Toral, 2013), while already established species as *Solanum mauritianum, Erythrina* sp., *Luehea grandiflora, Piptadenia gonoacantha*, *Ricinus communis*, *Rosmarinus officinalis*, *Trema micranth*, *Vernonia* *polyanthes,* and *V. polycephala* may provide ecosystem services (nitrogen biological fixation, light control, phytomass incorporation, pollination, among others), in the long- and mid-terms. The herbaceous species *Crotalaria juncea* promote within a short-term nitrogen biological fixation, soil covering (against erosion and to increase water retention) (Madhaiyana, Poonguzhalia, Senthilkumar, Sundaram, & Sa, 2009), besides biomass incorporation. Thus, this unit can shortly reach similar characteristics to the previous ones.

In short, all three ASs (DUs) are characterized as shrubby vegetation in both structure and composition. According to May et al. (2008), this model has potential to conserve biodiversity, especially in the early stages of ecological succession, allowing solar radiation penetration as well as in the cocoa-cabruca system, shaded coffee plantations with great diversity, and banana trees shaded by other trees (agro-silvicultural banana systems).

The phytosociological analysis showed that AS 1 had dominance of a banana + coffee system, accounting for over 40% of IV. It most likely has happened because of farmers' expectations about the trading of these products. Nevertheless, the heart of palm and papaya represented approximately 15% of IV. Again, farmers, for commercial reasons, might have driven it (Table 4).

Table 4. Abundance (N), Basal Area (B), Relative Frequency (F_r), Relative Density (D_r), Relative Dominance (Do_r), in descending order of Importance Value (IV), for three Agroforestry system (ASs) represented in three Demonstration Units (DUs), installed at *Arca de Noé* farm, city of Sapucaia, Rio de Janeiro state, Brazil.

Plots	Cientific Names	N (ind ha^{-1})	B (m^2 ha^{-1})	Fr (%)	D_r (%)	Do_r (%)	IV (%)
AS 1	*Musa* spp.	370	23.58	8.16	10.95	68.55	29.22
	Coffea arabica	121	0.21	8.16	35.8	0.60	14.85
	Solanum mauritianum	90	7.35	5.10	2.66	21.36	9.71
	Euterpe edulis	430	0.29	8.16	12.72	0.85	7.24
	Carica papaya	150	2.03	7.14	4.44	5.89	5.82
	Others	113	0.96	63.24	33.47	2.77	33.14
	Total	1247	34.39	100	100	100	100
AS 2	*Musa* spp.	470	98.64	10.26	28.14	94.73	44.38
	Jatropha curcas	210	0.74	8.97	12.57	0.71	7.42
	Morus nigra	140	0.13	10.26	8.38	0.13	6.26
	Solanum mauritianum	90	4.37	6.41	5.39	4.20	5.33
	Artocarpus heterophyllus	110	0.02	6.41	6.59	0.02	4.34
	Others	650	104.11	57.67	38.95	0.21	32.28
	Total	1670	104.13	100	100	100	100
AS 3	*Manihot* sp	660	0.14	19.44	46.81	30.06	32.11
	Solanum mauritianum	170	0.15	16.67	12.06	31.58	20.10
	Crotalaria juncea	300	0.06	22.22	21.28	12.57	18.69
	Vernonia polycephala	70	0.05	8.33	4.96	10.99	8.10
	Trema micrantha	50	0.02	5.56	3.55	3.22	4.11
	Others	160	0.04	27.8	11.36	11.59	16.89
	Total	1410	0.47	100	100	100	100

Physic nut (*J. curcas*) ranked second in importance of value for the AS 2, well below bananas (*Musa* sp.), accounting for over 40% of IV (Table 4).

Physic nut may be being gradually removed from the systems since there is a low market expectation for oil extraction from its fruit, for biodiesel production. According to Spinelli, Dias, Rocha, and Resende (2014), the physic nut culture is not yet a reality in Brazil, because in addition to low grain yield and fruit maturity, the lack of high yield genotypes limits the competitiveness of this crop. Perhaps, this scenario has discouraged the maintenance of this species in AS 2. However, the use of physic nut should not be discarded, being a species with potential for multiple use, e.g. pharmatical industry (Silva, Hisatugo, & Souza, 2016). Another fact is, according to Queiroz et al. (2013), the development of this species in monocultures presents many problems, mainly due to the attack of acari (*Polyphagotarsonemus latus* e *Tetranychus desertorum*), stink bug (*Pachycoris torridus*), cigarrinha-verde (*Empoasca kraemeri*) e ants (*Atta* spp.), which can be prevented when it is produced in a system with greater biodiversity.

In AS 3, we could clearly observe the role of *Crotalaria juncea* as fertilizer, as well as the relevance of cassava (*Manihot* sp.) as a high added-value crop, at the beginning of the cycle. These facts make these crops responsible for more than 50% of IV (Table 4).

Conclusion

This study demonstrated that:

Nutrient contents, especially Ca and Mg, in AS 1 and 2 were favored by species diversification, incorporation of banana in the soil and, also, the incorporation of woody residues of DUs with greater management intensity.

Diversification of species contributes to the maintenance of ecosystem services on a local scale (conservation and maintenance of soil fertility, etc.) and food security.

Jatropha curcas was seen as an unfavorable option as energy, given the low value of importance in the system (IV = 7.42%). However, this species can be considered with possible aggregation of local value (ege.g., cosmeceuticals).

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conservation and subsistence agriculture in family farming areas, by means of analysis of economic-financial feasibility.

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