



Comparative herbaceous phytosociology in agroforestry and *Calophyllum brasiliense* monoculture on a river terrace

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Abstract

Invasive forage grasses, especially the *Urochloa* genus, impact reforestation worldwide. The aim of this study was to evaluate management influence on phytosociology of the herbaceous layer, defined as the layer of herbs, sub-shrubs, shrubs and vines, in two agroforestry systems (AFS) (Simple and Biodiverse) in succession to a reforestation of guanandi (*Calophyllum brasiliense*), compared to monoculture of this specie taken as control. The experiment was conducted in Pindamonhangá (SP), Brazil, from 2011 to 2014, in a randomized block design with eight replications and 144.0 m² plots. In Simple SAF area, food crops were grown alongside *C. brasiliense* rows: sweet cassava (*Manihot esculenta*) in rotation with arrowroot (*Maranta arundinacea*), pigeon pea (*Cajanus cajan*), banana shrub (*Musa* sp.), and juçara palm (*Euterpe edulis*). In Biodiverse AFS, fourteen native tree species were also planted alongside the food crops. Altogether 41 herbaceous layer species, 38 genera and 24 botanical families were identified; the most abundant families were: Asteraceae, Poaceae e Cyperaceae. The similarity between the areas diverged after three years of management, with the predominance of *Commelina benghalensis* and *M. arundinacea* in the AFS areas and *Urochloa decumbens* in the monoculture, mainly, due to the shadow gradient established for the three systems.

Keywords: Ecological reforestation; Biodiversity; Spontaneous plants.

Introduction

Inadequate agricultural systems can contribute to soil degradation, resulting in productivity loss and other environmental problems. In the Paraíba do Sul Valley, soil degradation has begun in coffee culture cycle and it has intensified by extensive livestock expansion (DEVIDE et al., 2014; SANTOS et al., 2016). From 1962 to 2011, forest cover increased in the sub-regions of the Paraíba River valley, it had gone up by 133.0% in the middle valley (most industrialized region) and by 77.0% in the high valley, a rural sub-region with a strong exodus, in addition to cattle herd reduction (SILVA et al., 2017). The impacts on the landscape resulted in 82.0% of this remaining natural forest coverage dispersed in small fragmented remnants with 20 hectares or less until 2005 (KRONKA et al., 2005), which is considered too small for biodiversity protection and highly vulnerable to invasive grasses. Currently, the most determining factors for natural forest regeneration are the small size and the large

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distance of those forest remnants that are surrounded by 213 thousand hectares of pasture areas of high potential for ecological self-recovery and 113 thousand hectares of medium ecological self-recovery potential (SECRETARIA DO MEIO AMBIENTE, 2018).

The grasses species belong to the Poaceae family, which comprises approximately 790 genera and 10,000 species. In Brazil, approximately 200 genera and more than 1,350 species of Poaceae have been described (LONDE; SILVA, 2014). Infestation of non-native forage grasses, mainly of the genus *Urochloa* is one of the most important biological barriers for the restoration in tropical forests areas (GARCÍA-ORTH; MARTÍNEZ-RAMOS, 2011; MANTOANI; TOREZAN, 2016). *Urochloa decumbens* (Stapf) R. D. Webster is an exotic grass that has adapted to the tropical environment throughout Latin America as it is quite tolerant to high levels of aluminum prevalent in acidic soils (SEIFFERT, 1980). Forage grasses can increase fire intensity and native species suppression (CABIN et al., 2002; FLORY et al., 2015).

In commercial and regenerative reforestation, grass control is usually carried out by herbicides, to ensure satisfactory conditions for tree growth (CORDELL et al., 2004; PYWELL et al., 2010; MOORE et al., 2011). The large-scale use of chemicals in mountainous relief and in permeable soils can contaminate water resources and reach underground aquifers (BRITO et al., 2001; AGRAWAL et al., 2010; SOARES et al., 2012; MOREIRA et al., 2012; SOARES et al., 2013) and also reduce spontaneous species richness (CÉSAR et al., 2013). In reforestation of slow-growing native species, such as the guanandi tree (*Calophyllum brasiliense* Cambess.), chemical control can become costly and increase the impact on environment and on rural workers. *C. brasiliense* is a climax forest specie (BRENES; MONTAGNINI, 2006; PETIT; MONTAGNINI, 2006) that offers a noble wood; therefore, it is widely used for environmental restoration of flooded areas (DURIGAN, 1990; CARVALHO, 2003; BRENES; MONTAGNINI, 2006).

The diversification of forest plantations combined with intercropping crops in agroforestry systems (AFS) can be immensely helpful to restore degraded landscapes (DARONCO et al., 2012; MEDEIROS et al., 2015; CÂNDIDO et al., 2016). In the AFS, tree component provides organic residue and shadows the soil under the tree canopy, which improves the efficiency in the control of non-native grasses (CORDELL et al., 2004), thereby reducing the need for chemical management (MOORE et al., 2011). In AFS areas, producers can grow a wide variety of food crops, forage, and forest products, increasing income and minimizing poverty in rural areas (LUEDELING et al., 2014; ALTIERI; NICHOLLS, 2017; FAO, 2017). Among all AFS models, the Simple AFS is suitable for farmers interested in getting maximum yield from annual crops in association with forest species, and the Biodiverse AFS is suitable for farmers who aim to diversify agricultural production and restore the environment through the consortium of forest diversification and agricultural species of short, medium and long cycles occupying different strata of plant succession in space or over time (SECRETARIA DO MEIO AMBIENTE, 2018). These two systems influence differently the community of spontaneous plants, depending on the management intensity and shading.

This study was carried out to evaluate the changes that occurred in the phytosociology of the herbaceous stratum as a result of agroecological management in two agroforestry systems (Simple AFS and Biodiverse AFS), compared to homogeneous reforestation of *C. brasiliense* taken as control. The hypothesis is that at least one AFS has favorable attributes for agroecological management of spontaneous vegetation, especially when considering non-native grass control.

Material and methods

The experimental area (22°53'S; 45°23'O) is located in Pindamonhangaba (SP), Brazil, average altitude of 544 m, in a river terrace toposequence of soils classified by Santos et al. (2013) as Cambisol (Cambissolo), dystrophic in the upper and middle third, and Planosol (Planossolo), dystrophic, in the lower portion of the terrace. They present similar chemical characteristics: pH (H₂O)=5.6; H+Al=3.3 mg dm⁻³; P=60.3 mg dm⁻³; K=18 mg dm⁻³; Ca=1.2 cmol_c dm⁻³; Mg=0.8 cmol_c dm⁻³ and organic matter =22.8 dag kg⁻¹. These soils have uniform appearance and similar hydrological characteristics throughout the series.

Annual rainfall is intense and concentrated in the summer (MATTOS et al., 1998). The local climate is classified as subtropical humid (Cwa) by Köppen and it presents dry winters, with temperatures under 18.0°C, and hot summers with temperatures that exceed 22.0°C. The experimental area is surrounded by the Capituba stream and was flooded due to high rainfall in the Spring/Summer of 2011 (1307 mm) and 2012 (1497 mm); watercourse interrupted its flow during the extreme drought events that took place in 2013 (1158 mm) and in 2014 (619 mm) (TARGA; BATISTA, 2015) (APTA, 2015).

C. brasiliense seedlings were planted at a 3.0 m x 2.0 m spacing in 2008. In 2011, the agroforestry conversion experiment was installed in a randomized block design with eight replications and 144.0 m² plots with four rows of six *C. brasiliense* trees in each line. The treatments were: (T1) monoculture of *C. brasiliense* (control), (T2) Simple AFS and (T3) Biodiverse AFS. In the agroforestry systems, two rows of sweet cassava (*Manihot esculenta* Crantz) were initially grown alongside the lines of the *C. brasiliense*; in 2012-2013 and 2013-2014 cycles, arrowroot (*Maranta arundinacea* L.) was also planted. In the Biodiverse AFS, pigeon pea (*Cajanus cajan* (L.) Huth) was added alongside the lines of cassava in 2012 as well as green manure, banana shrub and seedlings of 15 native forest species spaced one meter apart. Nine of these native species were pioneer successional: *Anadenanthera colubrina* (Vell.) Brenan, *Bixa orellana* L., *Citharexylum myrianthum* Cham., *Croton floribundus* Spreng., *Erythrina verna* Vell., *Inga vera* Willd., *Joannesia princeps* Vell., *Schinus terebinthifolius* Raddi, *Schizolobium parahyba* (Vell.) Blake; and six of these species were non-pioneer species: *Euterpe edulis* Mart., *Handroanthus impetiginosus* (Mart. ex DC.) Mattos, *Handroanthus umbellatus* (Sond.) Mattos, *Magnolia ovata* (A.St.-Hil.) Spreng., *Pseudobombax grandiflorum* (Cav.) A.Robyns e *Zanthoxylum rhoifolium* Lam. All the native species were recommended for riparian forests recovery (TORRES et al., 1992; LORENZI, 1992; LORENZI, 1998). The cultures received organic and mineral fertilization in the agroforestry systems, and the monoculture got limestone in cover.

The *C. brasiliense* monoculture experimental areas are partially covered by grasses since the biotic components of the ecosystem are less resilient and show tendencies of inertial degradation, according to Cortines and Valcarcel (2009). Agroforestry systems are treatments in which the cultivated species can positively influence the biotic and physical components, modifying the levels of homeostatic balance and defining trends for degradation or restoration (FIGURE 1).

Figure 1 – Profile of *C. brasiliense* cultivation systems: A – Single crop with grasses alongside the lines; B – Simple AFS with arrowroot; C – Biodiverse AFS with arrowroot, banana and tree diversity.



Source: Antonio Devide (2013).

The management of spontaneous vegetation in monoculture consisted of annual mowing and selective weeding using hoes around the trees, for the control of vines; agroforestry systems received manual weeding in the management of consortium crops. Prior to management, a phytosociological survey of the herbaceous layer was carried out on September 19, 2011; September 24, 2012; September 28, 2013; and October 09, 2014. An inventory was made by walking alongside the lines of the *C. brasiliense* and randomly throwing the Braun-Blanquet square inventory (0,25 m x 0,25 m) eight times in each plot (BRAUN-BLANQUET, 1979; BOLDRINI et al., 2008). All seedlings and herbaceous plants collected in the interior area of the square were identified and compared to literature (LORENZI; MATOS, 2008; LORENZI, 2000). All plants with aerial and underground vegetative parts were considered as individual plants whether they originated from seed propagation or through branches of structure buried in the soil, as an example, grass clumps. Species classification and nomenclature have been updated by APG IV by checking Flora of Brazil 2020 online databases (under construction) and Reflora - Virtual Herbarium⁵.

Absolute frequency (AF%) and relative frequency (RF%), relative density (RD%) and similarity index (SI%) were determined as follows:

Absolute Frequency:

$$AF(\%) = NSs / NSt * 100$$

at which: *NSs*: the number of samples in which the species occurred; *NSt*: the total number of samples.

⁵ Available in: www.reflora.jbrj.gov.br

Relative Frequency:

$$RF(\%) = AF_s / AF_t * 100$$

at which: *AF_s*: the absolute frequency of a given species; *AF_t*: the absolute frequency of all species.

Relative density:

$$RD(\%) = In / Tn * 100$$

at which: *In*: the number of individuals of a given species in the samples; *Tn*: the total number of individuals sampled.

Jaccard Similarity Index:

$$JSI = (c / (a + b + c)) * 100$$

at which: *a*: the number of species unique to the first community; *b*: the number of species unique to the second community; *c*: the number of species common to both communities (MUELLER-DOMBOIS; ELLENBERG, 1974).

Results

In this study, 41 species, 38 genera, 24 botanical families were identified, and the most abundant were: Asteraceae (nine species), Fabaceae (five species), Poaceae (four species) and Cyperaceae (three species) (TABLE 1). Table 1 lists all species found in the areas, identified with scientific and common names, according to APG IV. The greatest richness of species of herbaceous plants was found in Simple AFS (35 species) followed by Biodiverse AFS (34 species), which were greater than monoculture (25 species); in general, eudicotyledons class prevailed.

Table 1 – Botanical families, scientific name, popular and species richness of the herbaceous layer in *C. brasiliense* planting in river terrace, Pindamonhangaba (SP), Brazil

Family	Scientific name	Popular name	Class ¹	Mono culture	Simple AFS	Biodiverse AFS
ACANTHACEAE	<i>Thunbergia alata</i> Bojer ex Sims	cipó-africano	E	x	-	x
APIACEAE	<i>Bidens pilosa</i> L.	picão	E	x	x	x
ASTERACEAE	<i>Ageratum conyzoides</i> L.	erva-de-são-joão	E	x	x	x
ASTERACEAE	<i>Conyza bonariensis</i> (L.) Cronquist	buva	E	x	x	x
ASTERACEAE	<i>Emilia sonchifolia</i> (L.) DC. ex Wight	serralinha	E	x	x	x
ASTERACEAE	<i>Foeniculum vulgare</i> Mill	funcho	E	-	x	-
ASTERACEAE	<i>Galinsoga parviflora</i> Cav.	botão de ouro	E	-	x	-
ASTERACEAE	<i>Solidago chilensis</i> Meyen	arnica brasileira	E	-	x	-
ASTERACEAE	<i>Sonchus oleraceus</i> L.	serralha	E	-	x	x

Family	Scientific name	Popular name	Class ¹	Mono culture	Simple AFS	Biodiverse AFS
ASTERACEAE	<i>Synedrellopsis grisebachii</i> Hieron. & Kuntze	agriãozinho	E	x	x	-
ASTERACEAE	<i>Taraxacum officinale</i> Web	dente-de-leão	E	-	x	x
BRASSICACEAE	<i>Coronopus didymus</i> (L.) Sm.	mastruz	E	x	-	x
CALOPHYLLACEAE	<i>Calophyllum brasiliense</i> Cambess.	guanandi	E	-	x	x
COMMELINACEAE	<i>Commelina benghalensis</i> L.	trapoeraba	E	x	x	x
CONVOLVULACEAE	<i>Ipomea purpurea</i> L.	corda-de-viola	E	x	x	x
CUCURBITACEAE	<i>Momordica charantia</i> L.	melão-de-são-caetano	E	x	x	x
CYPERACEAE	<i>Cyperus rotundus</i> L.	tiririca	M	x	x	x
CYPERACEAE	<i>Eleocharis</i> R.Br.	capim fino	M	x	x	x
CYPERACEAE	<i>Rhynchospora alba</i> (L.) Vahl	cebolinha	M	x	x	x
FABACEAE	<i>Arachis pintoi</i> Krapov. & W.C.Greg.	amendoim forrageiro	E	-	x	x
FABACEAE	<i>Centrosema plumieri</i> (Turpin ex Pers.) Benth.	cipó bravo	E	x	x	x
FABACEAE	<i>Centrosema virginianum</i> (L.) Benth.	feijão bravo	E	x	x	x
FABACEAE	<i>Mimosa pudica</i> L.	dormideira	E	-	x	x
FABACEAE	<i>Senna obtusifolia</i> (L.) H.S.Irwin & Barneby	fedegoso	E	x	-	x
HYPOXIDACEAE	<i>Hypoxis decumbens</i> L.	tiririca-de-flor-amarela	M	-	x	-
LYTHRACEAE	<i>Cuphea carthagenensis</i> (Jacq.) J.F. Macbr.	sete sangria	E	-	x	-
MALVACEAE	<i>Malvastrum coromandelianum</i> Garcke	guanxuma	E	x	x	x
MARANTACEAE	<i>Maranta arundinacea</i> L.	araruta	M	x	x	x
ONAGRACEAE	<i>Ludwigia longifolia</i> (DC.) H.Hara.	cruz-de-malta	E	x	x	x
ORCHIDACEAE	<i>Oceoclades maculata</i> (Lindley) Lindley	orquídea	M	x	x	X
OXALIDACEAE	<i>Oxalis latifolia</i> Kunth	trevo	E	-	x	X
PHYLLANTHACEA	<i>Phyllanthus tenellus</i> Roxb.	quebra-pedra	E	x	x	X

Family	Scientific name	Popular name	Class ¹	Mono culture	Simple AFS	Biodiverse AFS
POACEAE	<i>Cenchrus echinatus</i> L.	capim carrapicho	M	-	x	X
POACEAE	<i>Cynodon dactylon</i> (L.) Pers.	grama seda	M	x	x	X
POACEAE	<i>Eleusine indica</i> (L.) Gaertn.	capim-pé-de-galinha	M	x	x	X
POACEAE	<i>Urochloa decumbens</i> (Stapf) R.D.Webster	brachiaria	M	x	x	X
PORTULACACEAE	<i>Portulaca oleracea</i> L.	beldroega	E	-	-	X
SOLANACEAE	<i>Solanum americanum</i> Mill.	maria-pretinha	E	x	x	X
SOLANACEAE	<i>Solanum sisymbriifolium</i> Lam.	joá-mata-cavalo	E	x	-	X
TALINACEAE	<i>Talinum paniculatum</i> (Jacq.) Gaertn.	major-gomes	E	-	x	X
Total				26	35	34

¹E – eudicotyledons; M – Monocotyledons

Source: Elaborated by the authors (2014).

Table 2 shows the most abundant species and the largest number of individuals after three years of management. In the monoculture, *U. decumbens*, *C. rotundus* and *C. benghalensis* predominate; in Simple AFS, *C. benghalensis*, *B. pilosa*, *M. arundinacea* predominate, and in Biodiverse AFS, *C. brasiliense*, *M. arundinacea* and *C. benghalensis* predominate.

Table 2 – Absolute frequency (AF), relative frequency (RF), relative density (RD) of 15 species of herbaceous strata abundant on a river terrace, in monoculture (T1), Simple AFS (T2) and Biodiverse AFS (T3).

Species	AF			RF			RD		
	T1	T2	T3	T1	T2	T3	T1	T2	T3
<i>U. decumbens</i>	25	2	0	62	4	0	64	2	0
<i>C. rotundus</i>	5	4	0	13	7	0	14	5	0
<i>C. benghalensis</i>	3	15	3	8	25	19	6	36	22
<i>P. tenellus</i>	3	5	1	6	8	3	6	8	2
<i>R. alba</i>	2	2	0	4	3	0	3	2	0
<i>C. virginianum</i>	1	1	0	3	1	0	2	1	0
<i>O. latifolia</i>	1	2	0	1	4	0	2	2	0
<i>Amaranthus sp.</i>	1	2	0	1	3	0	1	2	0
<i>C. bonariensis</i>	1	5	0	1	8	0	2	14	0
<i>B. pilosa</i>	0	7	0	0	12	0	0	12	0
<i>S. oleraceae</i>	0	2	0	0	3	0	0	2	0
<i>T. alata</i>	0	2	0	0	4	0	0	2	0
<i>T. paniculatum</i>	0	2	0	0	4	0	0	3	0
<i>M. arundinacea</i>	0	6	5	0	10	31	0	7	26
<i>C. brasiliense</i>	0	1	6	0	2	37	0	1	41

Source: Elaborated by the authors (2014).

After three years of management, the phytosociological similarity of the Biodiverse AFS herbaceous plant community diverged from other cultivation systems (TABLE 3).

Table 3 – Jaccard Similarity Index (SI%) of spontaneous plants in *C. brasiliense* monoculture (T1), Simple AFS (T2) and Biodiverse AFS (T3) on a river terrace

Treatments	2011	2012	2013	2014
T1/T2	54	58	60	50
T1/T3	80	60	69	14
T2/T3	52	71	67	18
Average	62	63	65	27

Source: Elaborated by the authors (2014).

Discussion

In the present research, forage grasses were the most abundant species in monoculture, showing that mowing and weeding around the *C. brasiliense* trees were inefficient practices to control *Urochloa*. This species is one of the most important problem for forest natural regeneration once it competes for nutrients and water, preventing the establishment of native species (VIEIRA et al., 1994; NEPSTAD et al., 1996; SOUZA; BATISTA, 2004; CORTINES; VALCARCEL, 2009). In another study, about a silvopastoral system installation with the pequizeiro (*Caryocar brasiliense* Cambess.), the grasses *Panicum* L. and *Urochloa* P.Beauv. presented a high vegetative development and productivity of dry matter, causing the suppression of styling (*Stylosanthes capitata* Vogel and *Stylosanthes macrocephala* M. B. Ferreira & Sousa Costa) in the consortium (FAVARE et al., 2018). Grasses are C4 plants adapted to full sun that occupy open areas, which can reduce the diversity of herbaceous (RIBEIRO et al., 2005) and woody species from natural regeneration and they can also increase the vulnerability of those areas to fire (CABIN et al., 2002; CORTINES; VALCARCEL, 2009; MOORE et al., 2011; FLORY et al., 2015; MANTOANI; TOREZAN, 2016). Areas infested by grasses have less resilient biotic components of the ecosystem and tend to inertial degradation, by ruderal herbaceous species, with intense cycles of plant growth and senescence, producing a highly flammable dry biomass in hot and dry periods, which inhibits the growth of woody species, whereas in the forest environment there is a natural tendency towards restoration (CORDELL et al., 2004; CORTINES; VALCARCEL, 2009; MOORE et al., 2011). Infestation of non-native grasses can cause damage to crops and forest species, with decreases in productivity, either by direct competition for natural resources or for allelopathic compounds released (SOUSA et al., 2003).

However, many grasses are planted in alleys in AFS aiming to provide phytomass and accelerate the restoration of degraded soils (MICCOLIS et al., 2016). Management is carried out by frequent cut, according to César et al. (2013). Depending on the intensity of management and the location of phytomass in the surroundings or in the cultivation lines of commercial species, grasses form a layer of organic matter that recycles nutrients and maintains soil moisture (MICCOLIS et al., 2016).

In the present research, in agroforestry management, the number of dicotyledonous plants has increased while the number of monocotyledonous plants had decreased due to shading conditions. The Biodiverse AFS with higher density of plants and higher species diversity had greater shading, which resulted in efficient grass control, compared to the Simple AFS. This corroborates the results

of other authors who reported that shading is the best mechanism for invasive non-native grasses control (CORTINES; VALCARCEL, 2009), as verified in the ecological restoration of riparian forests (MOORE et al., 2011), and also in dry forests (CODELL et al., 2004) and in AFS with suppression of guinea grass (*Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs) by canopy cover of native tree vegetation (MANTOANI; TOREZAN, 2016).

In all commercial reforestations (PYWELL et al., 2010), regenerative reforestation (MOORE et al., 2011) and AFS, the tree component, improves efficiency in controlling non-native grasses through shading. The input of organic matter from the tree component improves soil fertility, controls erosion, reduces nutrient leaching (WEZEL et al., 2014), increases soil water availability and resilience to extreme drought conditions (BASCHÉ; EDELSON, 2017), which occurs frequently in tropical regions (TARGA; BATISTA, 2015).

In tropical agrosystems, dominant invasive plant communities are made up of native and cosmopolitan species and agricultural practices such as soil and crop management, significantly, influence the floristic composition and the size of invasive plant communities (SOUSA et al., 2003) in addition to soil attributes (MENEZES et al., 2008).

The Jaccard similarity index, applied on the species of all treatments, can indicate trends for spontaneous regeneration (MAGURRAN, 1988; CORTINES; VALCARCEL, 2009) and demonstrates the sustainability of restoration treatments. While the density of *Urochloa* remained high in monoculture, in AFS, the spaces alongside the lines of *C. brasiliense* were occupied by crop consortium. The areas of monoculture and Simple AFS were more similar in species composition, varying from 54.0% to 60.0% over the years (TABLE 3). Cortines and Valcarcel (2009) found the terrestrial orchid *O. maculata* in forest areas. In the present study, the occurrence of this species in the Biodiverse AFS characterizes an attribute of spontaneous regeneration of mature forest (CORTINES; VALCARCEL, 2009) with favorable conditions for the recruitment of other species in the advanced stage of natural regeneration. With species similarity between 14.0% and 18.0%, Biodiverse AFS was the system that differed from the others. By intercepting the light energy in the different strata and adding organic matter to the soil, Biodiverse AFS provided the biggest changes in the environment, favorable to the recruitment of shade-tolerant species, such as *C. benghalensis* and *M. arundinacea*.

The introduction of *M. arundinacea* as a cultivated plant turned this species into a bioindicator of environmental resilience in AFS. Due to its rusticity and natural occurrence in the forests of Rio de Janeiro, *M. arundinacea* tolerates shading (MONTEIRO; PERESSIN, 2002; FELTRAN; PERESSIN, 2014), produces rhizomes and abundant aerial biomass (ODEKU, 2013; SWADIJA et al. 2013; SHINTU et al., 2015; ROHANDI et al., 2017) enabling its perennial establishment under favorable conditions. Bianchi et al. (2016) consider geophyte plants that use carbohydrates stored in rhizomes to regenerate as the most adapted to water stress. Grown in the *C. brasiliense* reforestation understorey, *M. arundinacea* was an important native species for ecological restoration work, especially in riparian areas susceptible to flooding, due to its ability to regenerate itself from parts of rhizomes buried in the soil, even in severe water restriction conditions, *M. arundinacea* started to occupy the sites previously colonized by *Urochloa* in the shaded environment of Biodiverse AFS. As a native spontaneous plant of high mycorrhizal activity, *M. arundinacea* can benefit the *C. brasiliense* in addition to rhizomes production in a low environmental impact exploitation model by dispensing soil preparation and turnover for replanting in the AFS.

The origin of the *C. brasiliense* seedlings in the Biodiverse AFS also indicates that there is no barrier to tree colonization; partly due to the presence of litter inherent to agroforestry management

and the presence of natural perches for dispersing bats, which were positioned on the underside face of banana leaves. In addition, grasses form a dense vegetation cover that prevents seeds from reaching the soil (WHELAN et al., 1991; AIDE et al., 1995), or harm its viability due to its high competition (CORTINES; VALCARCEL, 2009), which are justifications for low natural resilience in the areas of monoculture and Simple AFS.

Among the beneficial effects of AFS, in addition to shading, it is worth mentioning the improvement in soil fertility, especially due to the expressive accumulation of organic residues from banana shrubs, which can reach 55.0 t ha^{-1} (DEVIDE et al., 2019). The improvement in soil fertility makes the plants of interest more competitive and able to maintain growth and overlap spontaneous vegetation, even in restricted drought conditions. Sousa et al. (2003) also attributed the reduction of monocots number in AFS with cupuaçuzeiro tree (*Theobroma grandiflorum* (Willd. ex Spreng.) Schum.), banana shrub (*Musa* sp), pupunha palm (*Bactris gasipaes* Kunth) and ingá tree (*Inga edulis* Mart.) in different soil management systems after adding fertilizers and organic matter.

In the present study, the agroecological management of spontaneous vegetation in the AFS strengthens the conservation of soil and water resources. Chemical grass control is not desirable in this environment due to the toposseque slope, soil permeability and proximity to the watercourse. Cultivation between the lines of reforestation is an efficient technique for controlling non-native invasive grasses and can generate extra income from food production (CÉSAR et al., 2013; CÂNDIDO et al., 2016). Promoting multi-purpose forestry is a sustainable alternative to generate income, strengthen food production, and increase soil, water volume, and biodiversity conservation on rural properties (MONTAGNINI, 2012; ARÉVALO-GARDINI et al., 2015; DEVIDE et al., 2014). In this context, agroforestry cultivation of food species with native trees can control undesirable spontaneous plants (OLIVEIRA et al., 2016; CÉSAR et al., 2013) and favors environmental restoration.

Conclusions

Biodiverse AFS reduces the density of spontaneous plants, due to the shading of the species that occupy different strata alongside the lines of *C. brasiliense*.

The similarity of spontaneous vegetation diverged after three years of agroforestry management, with the selection of eudicotyledonous species in the areas of AFS and predominance of *Urochloa* in monoculture.

Acknowledgments

To the Postgraduate Course in Phytotechnics, Area of Concentration in Agroecology, at the Federal Rural University of Rio de Janeiro (UFRRJ) and the Agricultural Research Support Foundation (FUNDAG), for supporting this research within the scope of the first author's PhD.

Fitossociologia herbácea comparada em sistemas agroflorestais e monocultivo de guanandi em terraço fluvial

Resumo

Gramíneas forrageiras invasivas, principalmente do gênero *Urochloa*, impactam os reflorestamentos no mundo todo. O objetivo deste estudo foi avaliar alterações na fitossociologia do estrato her-

báceo, definido como a camada de ervas, subarbustos, arbustos e trepadeiras, em função do manejo de dois sistemas agroflorestais (SAF Simples e SAF Biodiverso) na conversão de reflorestamento de guanandi (*Calophyllum brasiliense*), comparado ao monocultivo (testemunha). O experimento foi conduzido entre os anos de 2011-2014 em delineamento em blocos ao acaso com oito repetições e parcelas de 144,0 m². Nos sistemas agroflorestais foram cultivadas culturas alimentares de mandioca (*Manihot esculenta*) e rotação com araruta (*Maranta arundinacea*) nas entrelinhas do guanandi, acrescidas de guandu (*Cajanus cajan*), bananeira (*Musa* sp.), palmeira juçara (*Euterpe edulis*) e 14 espécies arbóreas nativas no SAF Biodiverso. Ao todo foram identificadas 41 espécies no estrato herbáceo, 38 gêneros e 24 famílias botânicas, sendo Asteraceae, Poaceae e Cyperaceae as mais abundantes. A similaridade entre as áreas divergiu após três anos de manejo, com o predomínio de *Commelina benghalensis* e *M. arundinacea* nos SAF e *Urochloa decumbens* no monocultivo, principalmente, em função do gradiente de sombra estabelecido entre os três sistemas.

Palavras-chave: Reflorestamento ecológico; Biodiversidade; Plantas espontâneas.

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Received in: April 9, 2019

Accepted in: July 31, 2019