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The Phytosociology of Weeds in Agroforestry Systems in Different Types of Amazonian Forest Cover

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Agroforestry systems are examples of soil exploration that is closer to the natural form of the forest, with intercropping of several species within an area, thus being sustainable alternatives. Therefore, the objective of this work was to evaluate the weed community in agroforestry systems in two ecosystems: solid ground and floodplain in the state of Pará. Such collections were made in eight areas, with about one hectare each, cultivated in agroforestry systems, four of which are on dry land and four on floodplains, in the rural area of Cametá-PA. Four plots of one square meter per area were randomly sampled, where the species were identified, counted, and taken to weigh to evaluate the weed community. Among the evaluated environments, the species that stood out the most in the solid ground environment was *Kyllinga brevifolia*, leading most of the evaluated indices. In the lowland ecosystem, the *Brachiaria species purpuracens* were the most relevant.

Keywords: Weed community; agroecosystems; sustainable agriculture; brachiaria purpuracens; Kyllinga brevifolia.

1. INTRODUCTION

The forest cover in the Amazon of Pará is configured in a floodplain forest, whose vegetation occurs along the rivers and floodplains, sheltering animals and plants adapted to seasonal hydrological conditions, and also by solid ground forest, with complexity in the composition, distribution, and density of species [1]. Also used as medicinal plants by the population, many Amazonian plants are intended to treat diseases, due to the extensive and diverse flora. However, the disorderly exploitation, both in floodplain and upland forests, has caused significant damage to the vegetation of these environments [2].

The Agroforestry System emerges as a sustainable alternative for agriculture in degraded environments. In addition to presenting the great potential to reduce soil erosion, it presents potential recovery for soils, increases productivity, and contributes to food security in a scenario of climate change [3].

In agroforestry systems, productive components are allocated to be effective and sustainable, so that they use the production factors with the least competition between them [4,5]. However, the appearance of weeds can compromise the balance of production factors, as they compete with them for growth [6].

Phytosociological analysis has been highlighted in obtaining knowledge about the populations and biology of weed species as an important tool in the technical basis of management recommendations and cultural practices for the implantation and conduction of cultures [7]. Thus, the phytosociological survey results in a list of species distributed hierarchically, depending on their position relative to the others, allowing the quantitative interpretation and the ecological relationships of the weed community [8].

In this context, this study aimed to evaluate the weed community in areas managed in the agroforestry system, in two Amazonian Forest covers: solid-ground forest and lowland forest.

2. MATERIALS AND METHODS

This work was carried out from October to November 2018, in rural areas of the municipality

of Cametá, located in the northeast of Pará, a microregion of the lower Tocantins. Eight agricultural areas conducted in agroforestry systems with an average size of one hectare each were evaluated, four areas of solid ground forest and four of lowland forest.

In each evaluated area, four sample plots of one square meter were randomly admitted for the analysis of the weed community [9]. Then, the weed species contained in the adopted plots were collected by pulling close to the ground and later taken to the laboratory to be quantified and weighed.

The identification of the plants collected in the field was carried out by consulting the specialized literature [10,11]. When identification was not possible, they were sent to the Emilio Goeldi Museum (Belém-PA), for identification.

Based on the data collected from the species present in the analyzed areas, the following phytosociological indices were determined: density (Den), relative density (DenR), frequency (Fre), relative frequency (FreR), abundance (Abu), relative abundance (AbuR), relative fresh mass (MF) importance value index (IVI) and relative importance value index (RI). The Microsoft program, Office Excel®, was used to perform a descriptive analysis and obtain tables and graphs of frequency analysis, referring to the floristic composition of the weed communities. The following formulas were used to calculate the variables according to Cunha et al [12]:

$$Den\ (plantas\ .m^{-2}) = \frac{N^{o}\ \text{total number of individuals per species}}{\text{Total area collected}}$$

$$DenR\ (\%) = \frac{\text{Species density x 100}}{\text{Total density of totas species}}$$

$$Fre = \frac{\text{Number of plots containing the species}}{\text{Total number of samples used}}$$

$$FreR\ (\%) = \frac{\text{Frequency of species x 100}}{\text{Total frequency of totas species}}$$

$$Abu = \frac{\text{Total number of individuals per species}}{\text{Total number of plots containing the species}}$$

$$AbuR\ (\%) = \frac{\text{Species abundance x 100}}{\text{Total abundance of totas species}}$$

$$MF\ (\%) = \frac{\text{Fresh pasta x 100}}{\text{Total fresh mass of totas species}}$$

3. RESULTS AND DISCUSSION

In the evaluated locations, both in solid ground and floodplain forest areas, 881 plants were found, represented in 48 species, divided into 19 botanical families and 38 genera, shown in (Table 1). The monocots had the highest percentage (52%) with the eudicots, the Poaceae family (monocots) was the most representative, with about (23%) of the weed community found in both ecosystems, followed by the Cyperaceae family with (19%), in addition to the families Arecaceae with five and Melastomataceae with three species present, the families Amaranthaceae, Euphorbiaceae, Lamiaceae, Malvaceae, and Urticaceae presented two species each. And the other families were represented by only one individual.

When analyzing species present in the environments, more than 54% of the species found were present in the areas of solid ground forest, 42% in the lowland environment, and only 4% were species present in both environments, composed of *Rhynchospora species. cephalotes* and *Pennisetum clandestine* (Fig. 1). The solid ground is the most expressive ecosystem and of great complexity in the composition, distribution, and density of species. It is characterized by floristic heterogeneity with the predominance of aggregated species in some formations and random in others [13].

According to Carvalho et al. [14] among the main weeds found in Brazil, the ones that stand out are the grasses (Poaceae) and the sedge plants (Cyperaceae). Which, most were introduced voluntarily by man in Brazil, with economic purposes, mainly for forage purposes, and became major obstacles in agricultural production [15].

Regarding the density (Den) and relative density (DenR) indices, in the solid-ground forest areas, the species that obtained the highest number of individuals was *Rhychospora cephalotes*, with 17 plants.m $^{-2}$, obtaining a DenR index of 19.4 followed by the species, *Kyllynga brevifolia* with 13 plants.m $^{-2}$ and a relative density of 14.4 and *Urochloa plantaginea,* with a density above 9 plantes.m $^{-2}$ and relative density of 10.5, respectively (Fig. 2).

In the same Amazon region of this research, Gonçalves [16] found that the assapê grass (*R. cephalotes)* led all the phytosociological indices evaluated, and the density of plants found was also similar, around 19 plants per square meter. Of the genera of Cyperaceae occurring in Brazil, *Rhynchospora* Vahl is the most representative, with 157 species, of which 40 are endemic and 23 occur in all Brazilian geographic regions [17].

Table 1. Weed community found in areas of solid ground and floodplain agroforestry in the municipality of Cametá-PA

\	Scientific name	Popular name	Group	Occurrence
Amaranthaceae	*Cyathula prostrates* Blume	foxtail burr	eudicot	solid ground
	Amaranthus deflexus L.	Pigweed	eudicot	solid ground
Arecaceae	*Montrichardia linifera* (L.) Schott	Aninga -de -várzea	monocot	floodplain
	Montrichardia arborescens (L.) Schott	Aninga -de – várzea (2)	monocot	floodplain
	Mauritius flexuosa Lf	buriti	monocot	floodplain
	chicken parviflora cav.	buttercup	eudicot	solid ground
	Physalis angulate L.	Camapu	eudicot	solid ground
Brassicaceae	*Lepidium virginicum* L.	Mentruz	eudicot	solid ground
Caryophyllaceae	*Spergula arvensis* L.	spaghetti	eudicot	solid ground
Commelinaceae	*commelina benghalensis* L.	Maria mole	monocot	solid ground
Cucurbitaceae	*Cucumis distress* L.	Gherkin	eudicot	solid ground
Cyperaceae	*Rhynchospora cephalotes* (L.) Vahl	assappe grass	monocot	Terra Firma / Várzea
	Cyperus odorator L.	sweet grass	monocot	solid ground
	Kylinga brevifolia rottb.	Juquinho	monocot	solid ground
	Cyperus rotundus L.	sedge	monocot	solid ground
	Cyperus esculentus L.	yellow sedge	monocot	solid ground
	Cyperus Bravifolius Hassk	One-Headed Grass	monocot	floodplain
	fimbristylis autumnalis (L.) Roem & Schult	beach rosemary	monocot	floodplain
	Cyperus verens michx	Sedge	monocot	floodplain
	Cyperus difformis L.	Marsh sedge	monocot	floodplain
Euphorbiaceae	*Chamaesyce hirta* L.	Santa Luzia herb	eudicot	solid ground
	acalypita arvensis Poepp. & endl	Nettle -large	eudicot	floodplain
Lamiaceae	*Stachys arvensis* L.	stinging nettle	eudicot	solid ground
	hyptis atrorubens point	mint	eudicot	floodplain
Malvaceae	*AIDS planicalis* cav.	broom	eudicot	solid ground
	Spinosa AIDS L.	thorny raccoon	eudicot	floodplain
Melastomataceae	*Myconia guianensis* (Aubl.) Cogn.	Lacrera	eudicot	solid ground
	carapa guianensis Aubl.	andiroba	eudicot	floodplain
	Miconia minutiflora (Bonpl.) DC	white seal	eudicot	floodplain
Myristicaceae	*Virola surinamensis* (Rol.) Ward.	ucuúba	eudicot	floodplain
onagraceae	*ludwigia elegans* (Cambess.) H.Hara	maltese cross	eudicot	floodplain
Phyllantaceae	*phyllanthus amarus* Schumach.	stonebreaker	eudicot	solid ground

\	Scientific name	Popular name	Group	Occurrence
Poaceae	*Digitaria horizontalis* Willd.	crabgrass	monocot	floodplain
	paspalum maritimum Trin.	ginger grass	monocot	solid ground
	Pennisetum clandestine Hochst. ex Shiov.	grass- kikuio	monocot	Terra Firma / Várzea
	Urochloa plantain (Link) RD Webster	marmalade grass	monocot	solid ground
	Imperata brasiliensis Trin.	thatch grass	monocot	solid ground
	type insularis (L.) Fedde	bitter grass	monocot	solid ground
	digitaria sanguinalis (L.) Scope.	crabgrass	monocot	floodplain
	brachiaria purpurascens (Radd) Henrard	guinea grass	monocot	floodplain
	Cynodon dactylon (L.) Personal	Bermuda grass	monocot	floodplain
	Eleusine Indica (L.) Gaertn	chicken foot grass	monocot	solid ground
	Andropogon bicornes L.	foxtail grass	monocot	floodplain
Pontederiaceae	*Eichhornia crassipes* (CRP Mart)	water hyacinth	monocot	floodplain
Portulacaceae	*portulaca oleraceae* L.	Purslane	eudicot	solid ground
Solanaceae	*Solanum tabacifolium* old	tobacconist	eudicot	solid ground
Urticaceae	*boehmer caudata* sw _	roast fish	eudicot	solid ground
	Cecropia pachystachya Trecul	embaúba	eudicot	solid ground

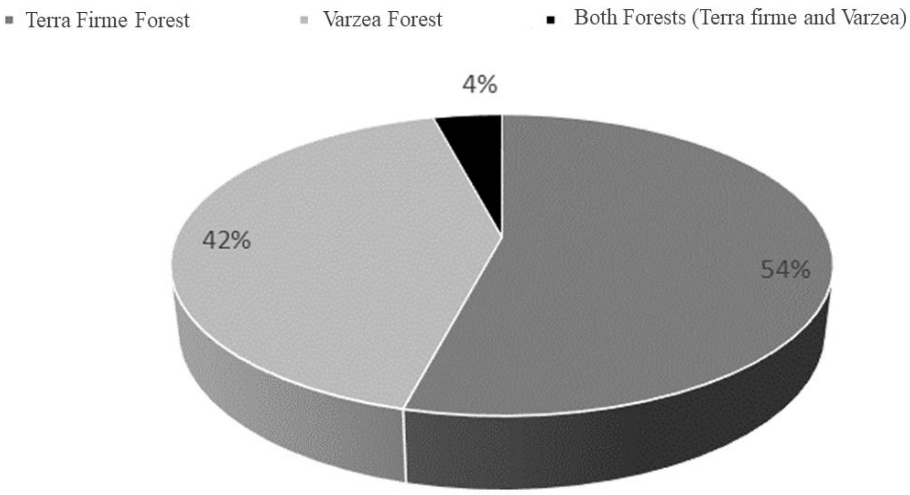
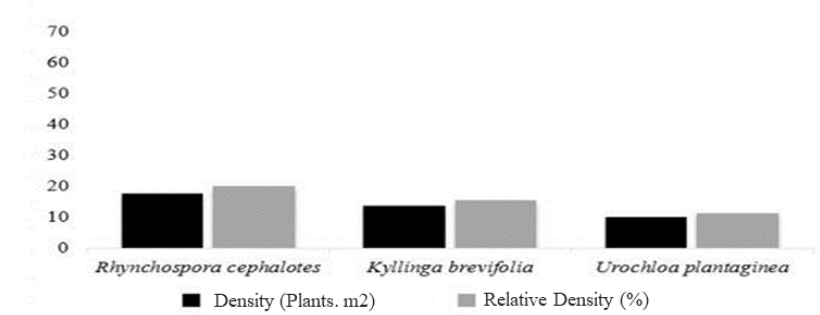


Fig. 1. Percentage of species that made up the weed community in the two types of environments evaluated. Cametá-PA, 2018



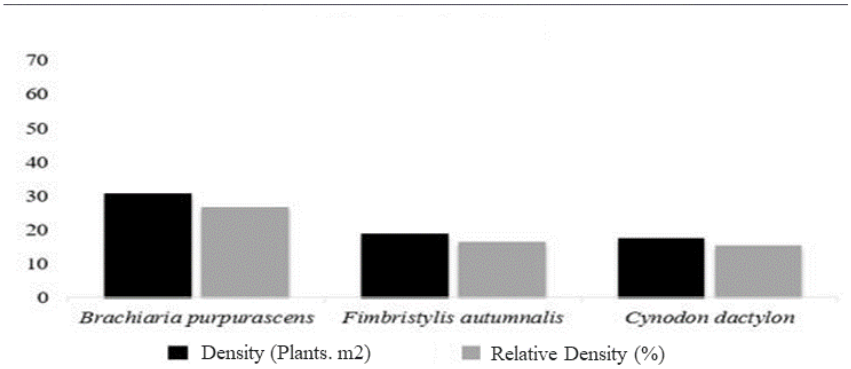


Fig. 2. Density (Den) and relative density (DenR) of the most representative species found in upland and lowland forests. Cametá-PA, 2018

In areas of agroforestry systems present in lowland forests, *Brachiaria purpurarascens*, stood out among the others, having a density of 30 plants.m $^{-2}$ and a relative density index above 25, followed by the species *Fimbristylis autumnalis* and *Cynodon dactylon* with densities of 18 and 15.7 plants.m $^{-2}$ and relative densities of 16.7 plants.m $^{-2}$ and 14.4 respectively (Fig. 2).

The frequency and relative frequency indices were led by the species *R. cephalotes* and *B. purpurascens* in the areas conducted in agroforestry systems in solid ground forest and lowland forest respectively (Fig. 3). In the solid ground environment, the species *Imperata brasiliensis*, presented the second highest frequency index (0.75) and relative frequency (8.33), followed by *K, brevifolia* with indices of 0.5 (Fre) and 5.5 (FreR) (Fig. 3).

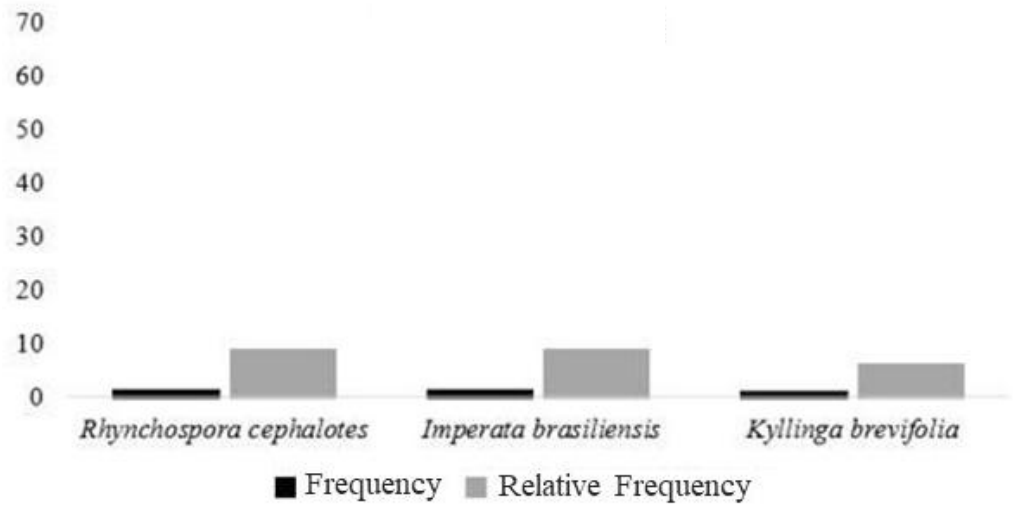
The sapê grass (*I. brasiliensis*) is a very frequent invasive plant, mainly in acidic and dry soils. It infests along roadsides, vacant lots, and annual and perennial crops. Correction of soil acidity and fertility often leads to its eradication [18].

In the lowland forest environment, the species *M. arborescens* and *F. autumnalis* presented the same frequency (0.75) and relative frequency (8.11), thus composing the most relevant species, together with *K. brevifolia.* in the frequency rates in this environment (Fig. 3). The genus *Kylinga* rottb*.* It has about 50 species distributed in America and tropical Africa, the region where it presents greater richness. Six species have witnessed material confirming their occurrence in Brazil [19].

The abundance and relative abundance indexes presented different species concerning the previous items, with species *C, dactylon being* very representative in the lowland forest environment with high values of abundance being Abu equal to 67 and AbuR around 21% (Fig. 4). The weed *C. dactylon*, has vegetative propagation, producing a large number of rhizomes and stolons, which makes it a difficult plant to control [20].

The other most relevant species in the abundance indices were the *Andropon bicornis* with an Abu of 36 and an AbuR of 11.54% and *B. purpurascens* with an Abu of 30 and an AbuR of 9.62% (Fig. 4).

Paspalum's plant *maritimun* was the one with the highest abundance in the areas of solid ground forest, having 32 abundance and 13.83% relative abundance, followed by *Digitaria* species. *horizontal* with Abu of 29 and AbuR 12.54% and *K. brevifolia* with Abu 26 and AbuR 11.24% (Fig. 4).



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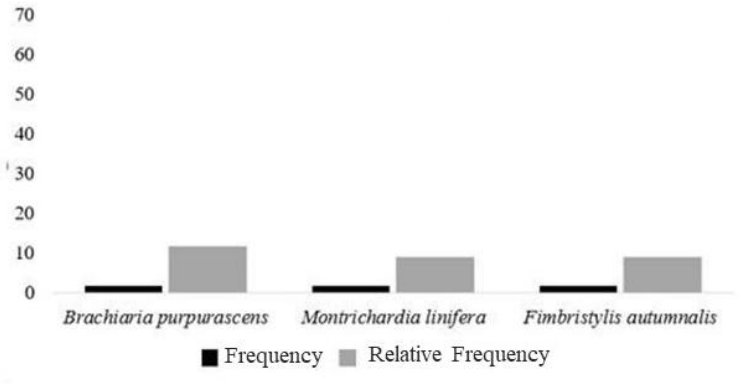

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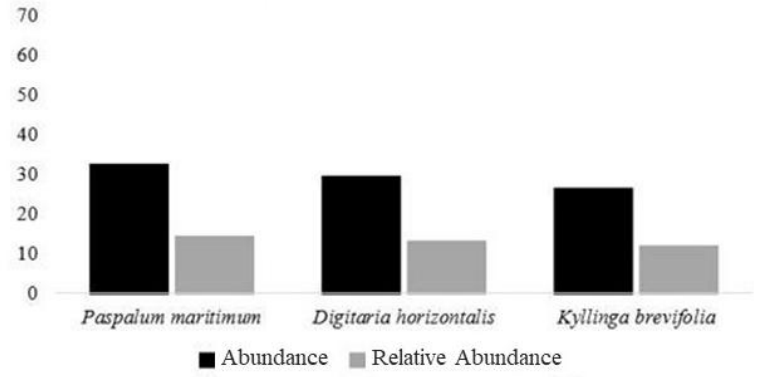
Fig. 3. Frequency (Fre) and relative frequency (FreR) of the most representative species found in upland and lowland forests. Cametá-PA, 2018



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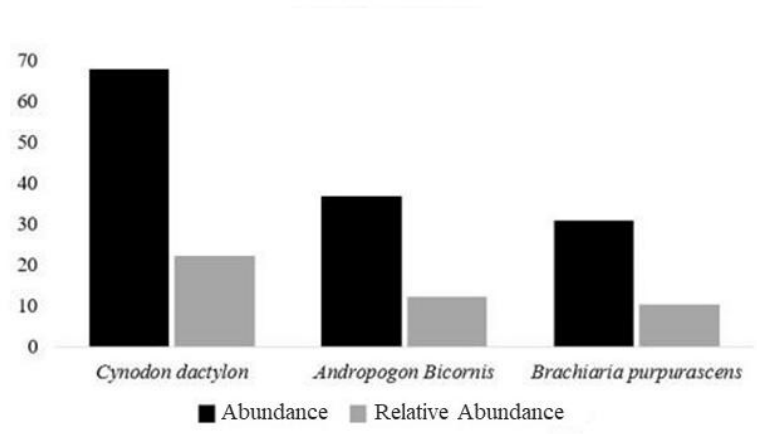

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Fig. 4. Abundance and relative abundance (%) of the most representative species found in upland and lowland forests; Cametá-PA, 2018

It is noted that again the species *K. brevifolia* composed the three most relevant species in the agroforestry system of solid ground. The rush grass (K. *brevifolia)* is usually associated with humid and shady environments, being easily found in rice crops [21].

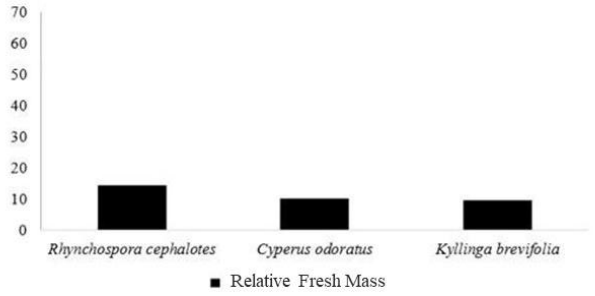
The species *R. cephalotes* and *Montrichardia arborescens* had the highest mass found in both environments, consequently reaching the highest relative fresh mass indices in the solid ground forest (17.4%) and lowland forest (14.4%), respectively (Fig. 5). In the Tocantins Amazon region, researchers Gonçalves [16], and Souza et al [6] also found that the species *R. cephalotes* was the one with the highest value in this phytosociological index.

Belonging to the Araceae family, the *Montrichardia* species *linifera*, popularly known as aninga, is an amphibious aquatic macrophyte widely distributed in the Amazonian floodplains and also found in several flooded ecosystems such as igapós, river banks, holes, and streams [22].

On dry land, the *Cyperus species odoratu* s was the second most relevant with an index of 10.1, being preceded by the species *K. brevifolia* with a fresh mass index of 9.6, which again appeared in the weed community with high values. Very important in East Africa and Madagascar the genus *Kyllinga* has many species, forming part of the vegetation cover of these regions [23].

In the lowland forest environment, the second relevant species was *Eichhornia crassipes* (11.7%), followed by *B. purpurascens* (11.9%) in the fresh mass index (Fig. 5).

When verifying the importance value index and the relative importance of the species that made up the weed community, in which this index relates to all the previous indices analyzed, it was verified that the species *R. cepholotes* (IVI of 52.01 and RI of 13. 01%) and *B. purpurascens* (IVI of 54.72 and RI of 13.69%) were the most important in the solid ground forest and lowland forest environments, respectively. (Fig. 6).



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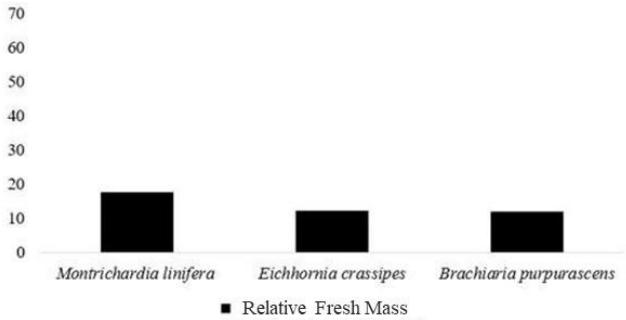

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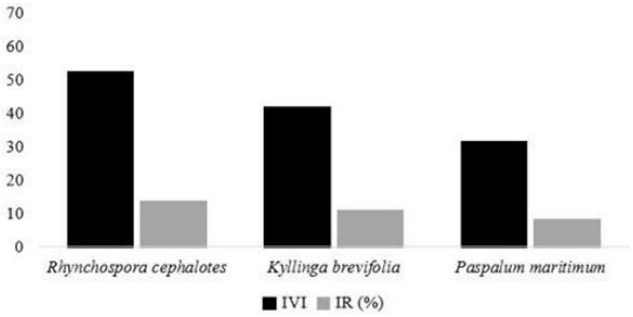
Fig. 5. Relative fresh mass (%) of the most representative species found in upland and lowland forests. Cametá-PA, 2018



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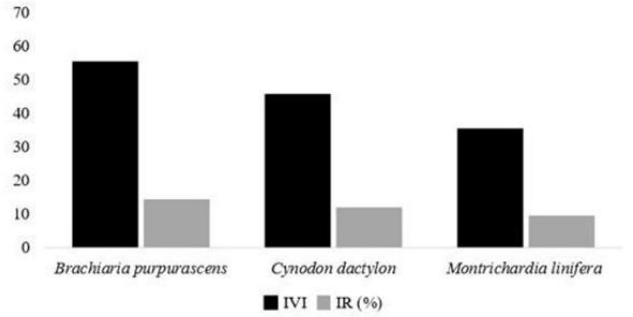

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Fig. 6. Importance value index (IVI) and relative importance index (RI) of the most representative species found in solid ground and floodplain forests. Cametá-PA, 2018

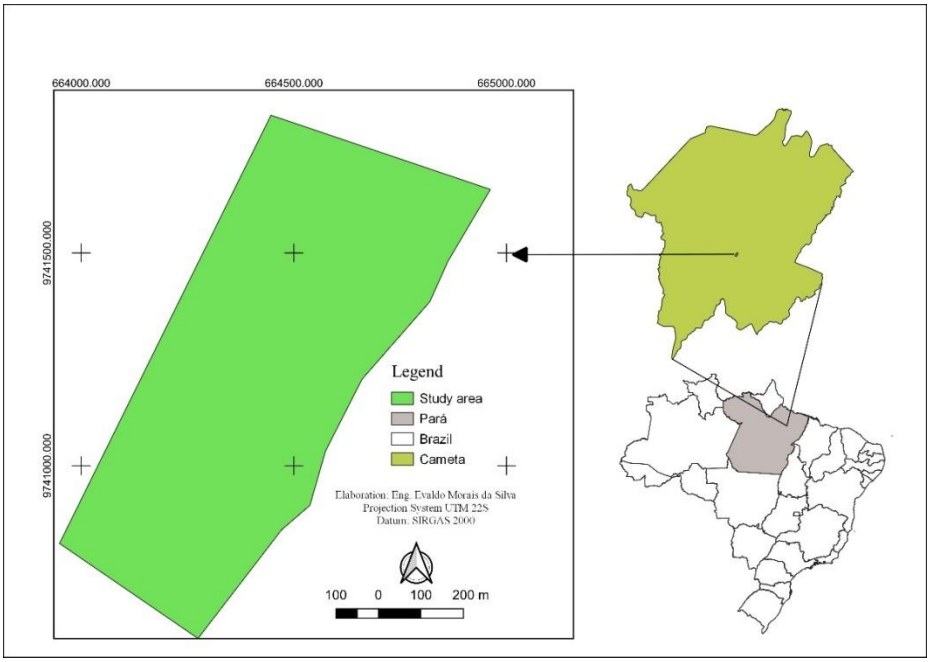

Fig. 7. Location of the study area

In the solid ground forest environment, the other two most important species were K. *brevifolia (*IVI of 41.23 and RI of 10.31%) followed by *P. maritimum* (IVI of 30.97 and IR of 7.74%). In the lowland forest environment, the other two most important species were *C. dactylon*, (IVI of 45.01 and RI of 11.25% and *M. linifera* (IVI of 34.68 and RI of 8.67%) (Fig. 6).

All the plants found in both environments are considered therapeutic by the local populations, in which home remedies are prepared with a single or several plants to achieve the expected effect. There are several formulations made from the species found that can be used alone or associated with allopathic medicines, which indicates a vast knowledge of local populations on the use of natural resources with phytotherapeutic potential.

The advantages of using the plants found would be easy access, low cost, ease of preparation, and uses [24] evidencing that the medicinal flora in the Brazilian Amazon plays an important role in the public health of communities in the region.

4. CONCLUSION

In areas managed in agroforestry systems, *K. brevifolia* and *R. cepholotes* in solid-ground forests and *B. purpuracens* and *M. linifera* in floodplain forests were the most expressive species in the weed community, being present with high values in most phytosociological indices, with the species *K. brevifoli* a and *B. purpuracens* were present in all indices in the solid ground and lowland forest environment respectively.

CONSENT AND ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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