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Legacies of intensive management in forests around pre-columbian and modern settlements in the Madeira-Tapajós interfluve, Amazonia

Maria Julia Ferreira[1*], Carolina Levis[2], José Iriarte[3] and Charles R. Clement[1]

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ABSTRACT

Amazonian peoples use and manage plant populations in previously domesticated landscapes, but the extent of landscape transformation remains uncertain, especially in interfluvial areas. We tested the hypothesis that useful plant communities vary in richness, abundance and basal area around pre-Columbian and current settlements independent of the distance to a major river. Nine plots were established at different distances from settlements in the Humaitá National Forest and the Jiahui Indigenous Land, where trees and palms with DBH ≥ 10 cm were sampled. Interviews were used to identify species, their uses and management practices. We found high values of richness, abundance and basal area of useful species around settlements both close to and 70 km from the major river. Different use categories presented different responses to current management, which shows that management by current and past populations is selective. We showed that areas of intensive management and landscape transformation are not limited to the margins of major rivers, but also occur in interfluvial areas within a radius of 5 km from pre-Columbian and current settlements. Indigenous people and local communities manage forests around their settlements over time, showing that they are key actors in the sustainable use of Amazonia.

Keywords: Amazonian Dark Earths, ethnobotany, ethnoecology, landscape domestication, local knowledge

Introduction

Pre-Columbian Amazonian societies domesticated the landscapes around their homes and settlements in many ways and in different degrees to make them more productive and familiar (Clement *et al.* 2015; Clement & Cassino 2018). Human activities leave significant traces in the landscape (Balée & Erickson 2006; Roosevelt 2013), which can be observed with archaeological and paleoecological methods (Willis *et al.* 2004; Mayle & Iriarte 2014; Bush *et al.* 2015; Watling *et al.* 2017; Maezumi *et al.* 2018; Robinson *et al.* 2018), with analyses of soil fertility (Fraser *et al.* 2011), as well as with botanical and ecological methods (Balée 1989; Levis *et al.* 2012; 2017; 2018; Clement & Cassino 2018). Recent studies of the human transformation of Amazonian landscapes has questioned the existence of pristine landscapes (Denevan 1992; 2011; Clement *et al.* 2015; Levis *et al.* 2017); however, the heterogeneity of landscape domestication in different environments across Amazonia remains uncertain, especially with respect to areas far from the main rivers. This is because some scholars argue that areas intensely transformed by pre-Columbian peoples are limited to the margins of major rivers (Bush *et al.* 2015; Piperno *et al.* 2015). Piperno *et al.* (2015) claim that less favorable areas for resource capture, such as interfluves, were inhabited and managed, but changes tend to be less pronounced than in more favorable areas, such as along the

1 Programa de Pós-graduação em Botânica, Instituto Nacional de Pesquisas da Amazônia, 69067-375, Manaus, AM, Brazil
2 Programa de Pós-graduação em Ecologia, Instituto Nacional de Pesquisas da Amazônia, 69067-375, Manaus, AM, Brazil
3 Department of Archaeology, College of Humanities, University of Exeter, EX4 4PY, Exeter, UK

* Corresponding author: ferreira.julia2208@gmail.com

margins of major rivers, which facilitate travel and fishing. These margins impressed the first European explorers and were certainly important (Denevan 1996), but smaller tributaries were also occupied, although they are less studied (Levis *et al.* 2014).

Bush *et al.* (2015) affirm that regions between major rivers (interfluves) represent 95 % of Amazonia and that these areas were not intensively transformed. However, Junk *et al.* (2011) show that 30 % of Amazonia are wetlands (major rivers, tributary rivers, streams, lakes, swamps), which provide resources similar to those of major rivers (although in lesser quantity) and also facilitate travel. Although the extent of human manipulation in interfluves is less studied (Levis *et al.* 2014), modern agroextractivist communities and indigenous peoples are known to penetrate these interfluves (Barlow *et al.* 2012), as did indigenous populations in the past (Stahl 2015). These peoples modify these landscapes through their subsistence practices, which include foraging, farming and many other activities (Stahl 2015; Junqueira *et al.* 2017; Levis *et al.* 2018).

Recent discoveries show that the abundance of archaeological sites along smaller rivers is similar to that along major rivers in Central Amazonia (Levis *et al.* 2014), that there are numerous large-scale geometric earthworks in interfluvial regions of southern Amazonia (Schaan 2011; Souza *et al.* 2018), that large, regionally-organized populations had pronounced impacts on the environment in the upper Xingu River (Heckenberger *et al.* 2008), all of which challenge the idea that Pre-Columbian populations were concentrated mostly along the major floodplains. This suggests that the idea that human impacts were infrequent in interfluves is not appropriate.

The use of the landscape is conceptually divided into zones around settlements, with areas up to 5 km from the village being managed and used more intensively, and areas beyond 5 km receiving less management (Heckenberger *et al.* 2008). McMichael *et al.* (2012) present a similar model, but use the margins of major rivers as a proxy for settlements, while Bush *et al.* (2015) suggest that the changes in landscapes are visible with paleoecological and archaeological techniques up to a maximum of 15 km from the margins. These models have in common the idea that evidence of human manipulation tends to decrease as the distance from settlements increases, depending on the type and size of society living there (Smith 2011). Notice that McMichael *et al.* (2012) and Bush *et al.* (2015) consider the margins of major rivers as proxies for human occupation, while Heckenberger *et al.* (2008) focus directly on the settlements, which expands the focus from major rivers to interfluvial regions.

People manage landscapes around their settlements, which is a part of what is called cultural niche construction (Smith 2011; 2012). Various management practices modify the composition of plant communities, even in mature forests (Levis *et al*. 2018). Plants are important to all peoples, and numerous species with different uses are incorporated into the daily life of small- and large-scale societies (Smith 2011; 2012). It follows that traces of human manipulation observed in modern forests, such as changes in the richness and abundance of useful species in different use categories, allow inferences about the management of forest landscapes in the past (Stahl 2015; Levis *et al.* 2017; 2018). The domestication of plants, including trees, may occur intentionally or not through the selection of desired plants (Zohary 2004), but also through specific management practices that favor certain plants (Rindos 1984) and generate lasting legacies in the local flora (Posey 1985; 1993; Terrell *et al.* 2003; Rival 2007; Levis *et al.* 2012; 2017; 2018; Clement *et al.* 2015).

It is assumed that these changes in the flora were fundamental for the creation of more productive and familiar landscapes capable of sustaining past and current human populations (Clement 1999; Clement *et al.* 2015), as happens worldwide (Boivin *et al.* 2016; Roberts *et al.* 2017). However, in Amazonia, as well as in other biomes, it is necessary to delve into the question of how current and past human manipulations influenced the structure and composition of vegetation in different locations, including areas away from major rivers that are less well-known. Our objective was to test the hypothesis that the richness, abundance and basal area of useful tree and palm species vary with the distance from pre-Columbian and modern settlements. To examine this hypothesis, we concentrate on areas of intensive resource management around a particular type of pre-Columbian settlements called Amazonian Dark Earths (ADE) and traditional and indigenous communities adjacent to a major river (the Madeira) and deep into the interfluvial region between two major rivers (the Madeira and the Tapajós).

Materials and methods

Study area

The study was carried out in the Humaitá National Forest (FLONA Humaitá), situated on the right margin of Madeira River, and in the Jiahui Indigenous Land (TI Jiahui), located along the Transamazon Highway (BR-230), 70 km from the same river. Both locations are in the Madeira-Tapajós interfluve (Fig. 1), which is 529 km wide at the latitude of Humaitá, so 70 km is relatively deep into this interfluve. In this part of Amazonia, the climate is classified as AM, in the Köppen system, with an annual mean temperature of 26.5 °C and annual mean rainfall of 2191 mm (Brasil 1973-1987). The region has pronounced seasonality, with a dry period from May to November (monthly average of 107 mm rainfall) and a rainy period from December to April (monthly average of 287 mm). The predominant vegetation is dense tropical forest, with areas of woody and open savanna (Brasil 1973-1987; Py-Daniel 2007). The soils in the region are predominantly dystrophic yellow Oxisols (Santos *et al.* 2011), with numerous sites with anthropogenic soils (Amazonian Dark Earths - ADE) along the Madeira and its tributaries (Miller 1992a; b). The Madeira River, on the west side of the interfluve, is the largest white-water tributary of the Amazon River (white-water is the common name for rivers rich in sediments, mostly from the Andes) (Junk *et al.* 2011) and the most impacted by gold mining activities (Bastos *et al.* 2015). The Tapajós River, on the east side of the interfluve, is a clear water tributary (rivers with low amounts of suspended sediments) (Junk *et al.* 2011), also with considerable gold mining activity, but on a smaller scale. In the area between these two major rivers there are numerous tributaries of different sizes.

Of the seven ADE sites found in the study area, five are adjacent to small watercourses, approximately two to six meters wide, and two are on the banks of the Madeira River (Fig. 1A). Three of the seven are located in the TI Jiahui, approximately 70 km from the Madeira River (Fig. 1B), two of which are heavily used for fruit collection and one is currently used for farming by the inhabitants of *Kwaiarí* village. The other four sites are located in the FLONA Humaitá between 0 and 1.7 km from the Madeira River; two of them are part of the Barreira do Tambaqui and Barro Vermelho communities, including their farming areas, and the other two are used for fruit collection and community hunting activities (Fig. 1A).

Ethical aspects

The study received authorizations from the Ethics Committee on Human Research (CEP - INPA) and the National Indian Foundation (FUNAI - CR Madeira): process numbers 1.396.762/2016 and 001/APIJ/2016, respectively. Due to the need to collect and work in a federal conservation unit (FLONA Humaitá), authorization was received from the Biodiversity Authorization and Information System (SISBIO) of the Chico Mendes Institute for Biodiversity Conservation (ICMBio), of the Ministry of the Environment: process number 53041.2/2016. Data collection occurred from April to July 2016; during the first visit, the objectives, methods and consent form (TCLE) were explained to obtain the consent of the residents to carry out the research.

Local populations

In the FLONA Humaitá, the local population is composed of *ribeirinhos,* who are mixed-blood descendants of the indigenous population of the region and of immigrants from other parts of Brazil, predominantly from the Northeast, who migrated to the region during the rubber boom (Adams *et al.* 2005). These communities, with six to 20 families each, subsist on slash-and-burn farming, fishing and hunting, and have as their main sources of income the extraction of timber and non-timber forest products, and, since the 1990s, gold mining with dredges in the riverbed (MMA 2011).

In this region, the main indigenous peoples are the *Torá*, *Parintintim* and *Tenharim*, all of the Tupi-Guarani linguistic family. The *Jiahui* are a subgroup of the *Kagwahiva*, who are *Tenharim*. The Jiahui lands were demarcated in 1999 (Peggion 2002). Their productive activities include slash-and-burn farming, hunting and fishing, mostly for family subsistence. Collecting fruits generates individual income, which integrates them into the regional market (Peggion 2002).

This region has been occupied by pre-Columbian populations since the late Pleistocene, approximately 12,000 BP (Miller 1992a; Roosevelt 2013). Thousands of years later (2,800 BP), the indigenous potters of the Polychrome tradition inhabited the region (Miller 1992a; Hetzel & Negreiros 2007); this tradition is hypothesized to be associated with the expansion of Tupi speaking groups (Barreto *et al.* 2016).

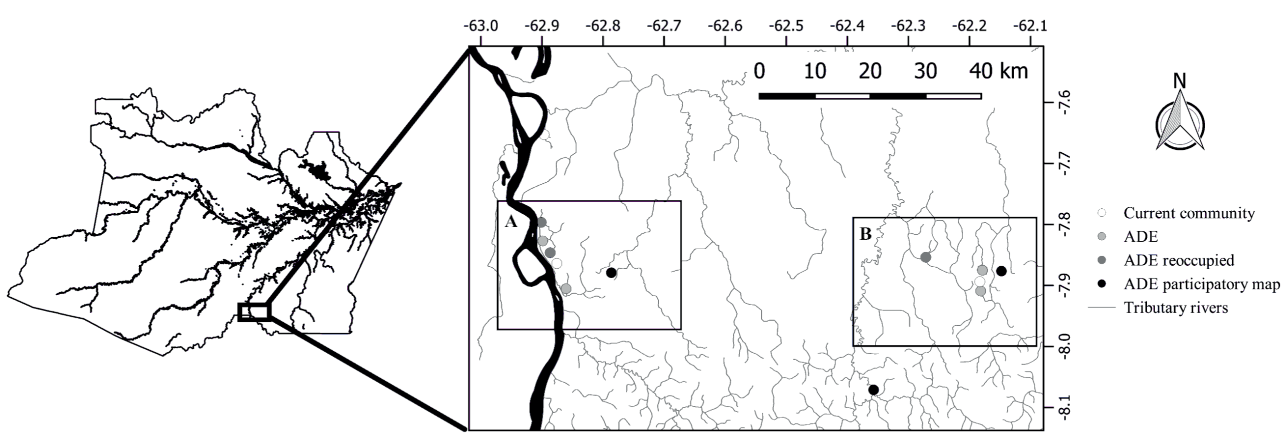

Figure 1. Map of the State of Amazonas, Brazil, with map of the location of Amazonian Dark Earth (ADE) sites and current communities, **A.** representing FLONA Humaitá and **B.** TI Jiahui. White are current settlements located outside ADE sites; Circles in gray differentiate current settlements on ADE sites and ADE sites with no current habitation, not excluding other on-site activities; the black circles indicate sites mentioned in the participatory mapping as ADE, but which were not verified in the field.

Sampling of local knowledge

Thirty-six residents were identified as forest experts, those who know the region's forests very well, using the snowball technique (Bailey 1994; Albuquerque *et al.* 2014a). These were invited to participate in semi-structured interviews (Alexiades 1996) and formulate free lists (Thompson & Juan 2006). These methods allowed us to profile the residents (ages, gender, offspring and main activities) and generate lists of species that are, or were, considered useful and important. The interviews also characterized uses and management practices used today and in the recent past (70 to 80 years ago).

From the free lists and interviews, it was possible to group the species into three categories: 1) useful species – those identified as having some use; 2) managed species – useful species that receive some kind of care (Tab. S1 in supplementary material); 3) cultivated species – managed species for which the local residents have knowledge about planting, but did not necessarily plant a given individual. A fourth category was included based on Levis *et al.* (2017): species with populations that show some degree of domestication in some region of Amazonia, but not necessarily in the Madeira-Tapajós interfluve. These categorical groups overlap, that is, the same species can be included in more than one category.

The vernacular names from the free lists were attributed to one or more of eleven use categories (Tab. S2 in supplementary material), defined based on previous studies (Posey 1985; Phillips & Gentry 1993), and also on the uses cited by local residents. The use value (UV) was calculated using the formula proposed by Phillips & Gentry (1993) and modified by Rossato *et al.* (1999), and the cognitive salience index (S) was calculated using the formula proposed by Sutrop (2001).

To validate the names of the plants cited in the interviews and lists, as well as to confirm the management practices mentioned, guided tours were conducted (Albuquerque *et al.* 2014b). There were 9 tours with residents from the FLONA Humaitá and 6 from the TI Jiahui; a total 114 km were covered.

Floristic inventories

Three ADE sites were selected, two in *Ju-í* village (TI Jiahui) and one in Barreira do Tambaqui community (FLONA Humaitá). Around each site we traced a 5 km radius area of intensive management (Heckenberger *et al.* 2008) and randomly placed three 0.5-hectare plots at various distances from each ADE (0-1.5, 1.5-2.5, 2.5-5.0 km), totaling nine plots with 4.5 hectares. Only areas in visually mature forest were selected, thus avoiding recent successional forests that might have recently modified floristic composition.

In each plot, individual trees and palms with DBH ≥ 30 cm were sampled in the full 100 x 50 m plot and individuals with DBH ≥ 10 cm in subplots of 50 x 50 m (Magnusson *et al.* 2005). For analytical purposes, subplot values were multiplied by 2 to have equal areas for individuals ≥ 10 cm and ≥ 30 cm. The physiognomy of the plots was relatively uniform, due to the intentional choice of areas located in mature forest. The canopy height of the plots varied from 15 to 23 m, resulting in low incidence of light in the understory. In all plots, pieces of charcoal were visible to the naked eye in the soil.

All plants sampled received popular names given by local specialists, one from the TI Jiahui and another from the FLONA Humaitá. When possible, at least one plant per species was collected for identification, prioritizing fertile material. Identification was based on the APG IV (Chase *et al.* 2016) and the Species List of the Flora of Brazil (Forzza *et al.* 2010). Fertile material was deposited in the herbarium of the National Institute of Amazonian Research (INPA) and sterile material in the herbarium of the Federal Institute of Amazonas (IFAM), and received voucher numbers (Tab. S3 in supplementary material).

Data analysis

The relationships between richness, abundance and basal area of four groups of species (useful, managed, cultivated, domesticated) and distance from ADE were analyzed with simple regressions, using as independent variables: (1) the straight-line distance from ADE to the inventory plots; (2) the actual distance traveled, considering curves in streams and paths in the forest, from the current communities to the plots. Analyses were made for all use categories together, and for each use category separately. The Visreg package (Breheny & Burchett 2012) was used to graphically represent the analyzes made using R (R Development Core Team 2013).

Results and discussion

Forest composition around pre-Columbian settlements

In the nine plots, we sampled 2381 trees and palms in 383 species in 55 botanical families (Tab. S3 in supplementary material). The values of relative richness, abundance and basal area of useful, managed, cultivated and domesticated tree and palm species (Tab. 1) around pre-Columbian settlements were high both in the FLONA Humaitá and in the TI Jiahui, suggesting similar human manipulation of the landscape near the major river and deep in the interfluve. The absolute values of richness, abundance and basal area of the species did not increase or decrease with distance from ADE near the margin of the Madeira or deep in the interfluve (Fig. 2), showing that intensity of management is high and constant in forests up to 5 km from ADE sites independent of the distance from a major river.

Floristic composition and its relationship with human management was also evaluated in the study of Levis *et al.* (2012), who observed a different pattern because they used the margin of major rivers as proxies of greater intensity of human manipulation. Also, they assumed that settlements are more abundant along the margin of the major rivers than in interfluvial areas, following McMichael *et al.* (2012) and Bush *et al.* (2015), without considering that many settlements also occur along smaller rivers present in the interfluves. Human legacies due to management decreased with distance from the Purus and the Madeira rivers (west and north of our area); useful species represented 6 to 14 % of the richness (versus 45 to 62 % here), 10 to 40 % of the abundance (versus 39 to 67 %) and 5 to 35 % of the basal area (versus 48 to 77 %) in plots that varied from 10 to 100 km from the main rivers, always with the highest values near the rivers. Moraes (2016) analyzed the human legacy in interfluvial forests of the Içana River basin, a tributary of the Negro River, at different distances (0 to 12 km) from that river, and observed that the species managed by the Baniwa people accounted for 4 to 20 % of the richness (versus 38 to 55 % here), 2 to 50 % of the abundance (versus 38 to 50 %) and 2 to 72 % of the basal area (versus 32 to 70 %) in plots. Both studies found lower relative values of richness, abundance and basal area (for useful and managed species, respectively) than found here, principally because our study concentrated on intensively managed areas in a 5 km radius around ADE sites.

High values of richness and abundance of species of interest suggest a favoring of these in relation to other plants in the landscape (Clement & Cassino 2018). Junqueira *et al.* (2010) sampled secondary forests along the middle Madeira River and found that the values of richness and abundance of domesticated species on ADE sites were significantly

Table 1. Summary of relative values of richness, abundance and basal area of nine inventory plots in the Madeira-Tapajós interfluve. The prefix rib identifies plots in the FLONA Humaitá, and the prefixes tia and tip identify plots in the TI Jiahui – they are different because they are associated with different ADE sites; the numbers order the plots from the nearest (1) to the farthest (3) from ADE. The rib1 plot is the only one located on an ADE site. The columns show total number of plants sampled in the plots (T) and the relative values for useful, managed (Man), cultivated (Cult) and domesticated (Dom) species. These categories sum to more than 100 %, because they are subsets of Useful and are not exclusive, i.e., only useful species are managed, and techniques to cultivate some of them are often known.

Plots	Abundance (nº individuals)					Richness (nº ssp.)					Basal area (m^2)				
	T	%				T	%				T	%			
		Useful	Man	Cult	Dom		Useful	Man	Cult	Dom		Useful	Man	Cult	Dom
rib1	279	39.8	38.0	18.3	33.3	55	54.6	52.7	18.2	10.9	24.24	67.0	65.9	56.1	11.0
rib2	329	60.5	54.7	9.4	1.5	80	61.3	55.0	11.3	2.5	12.55	48.3	41.9	11.4	3.6
rib3	304	62.5	47.7	9.2	5.3	76	50.0	42.1	9.2	3.9	12.63	49.3	32.4	6.0	2.4
tia1	255	51.0	44.3	20.8	3.5	64	46.9	42.2	12.5	3.1	13.47	60.3	47.4	20.1	2.2
tia2	250	66.8	51.2	14.0	5.2	62	62.9	50.0	19.4	9.7	10.79	61.7	47.7	22.0	8.8
tia3	260	63.1	60.8	23.5	10.0	57	57.9	50.9	17.5	5.3	13.10	60.5	47.2	24.4	11.2
tip1	256	58.2	50.0	26.6	7.4	75	45.3	38.7	12.0	1.3	13.47	60.1	53.1	35.2	12.6
tip2	239	54.0	52.3	22.2	4.2	73	49.3	46.6	17.8	4.1	16.80	66.2	64.3	28.7	1.7
tip3	209	67.0	60.8	23.4	9.1	64	59.4	53.1	15.6	6.3	11.94	77.5	70.7	40.7	22.8
Mean	264.6	58.1	51.1	18.6	8.8	67.3	54.2	47.9	14.8	5.2	14.3	61.2	52.3	27.2	8.5
SD	33.4	8.2	6.9	6.0	9.0	8.4	6.2	5.4	3.4	3.1	3.8	8.4	11.8	14.4	6.5

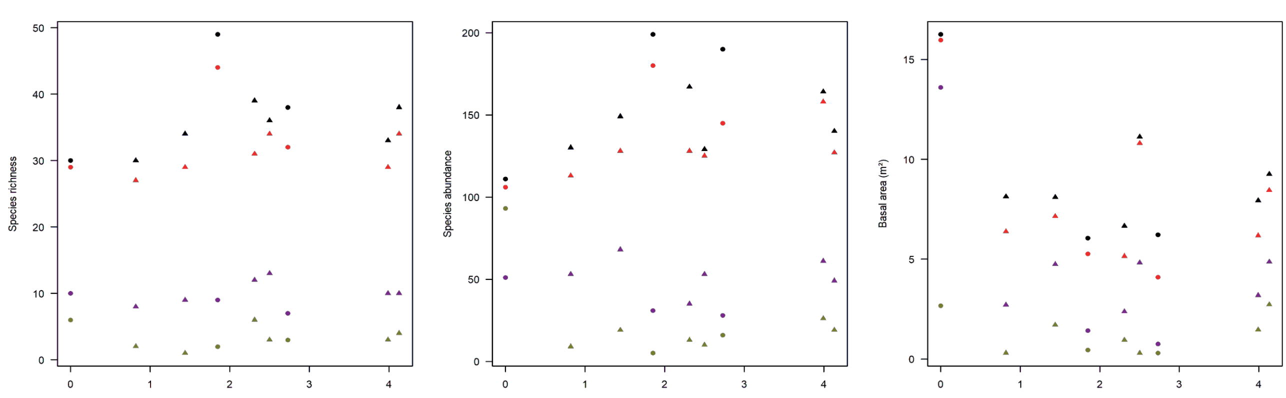

Figure 2. Variation of the values of absolute richness, abundance and basal area of the species as a function of the distance from ADE; all regressions presented non-significant values (Tab. S5 in supplementary material). The triangles represent plots located in the TI Jiahui and the circles represent plots in the FLONA Humaitá, Amazonas. The colors represent the different categories of species: useful (black), managed (red), cultivated (blue) and domesticated (green).

higher than on soils adjacent to these sites, due to long-term human activity. Our plot located on an ADE site (rib1) agreed with the observations of Junqueira *et al*. (2010), because it had a higher abundance of domesticated species than the other plots (Tab. 1).

Balée & Erickson (2006) affirm that every site with confirmed human presence has been altered and Clement *et al*. (2015) argue that these changes occurred with different intensities in different places. Bush *et al*. (2015) and Piperno *et al*. (2015) agree, but affirm that changes occurring in interfluvial areas are less intensive than in areas close to major rivers. Our data from the Madeira-Tapajós interfluve suggest that pre-Columbian societies managed forests located 70 km from the major river and their legacies persist in forests up to at least 5 km from ADE sites, which agrees with the association between these sites and domesticated forests (Levis *et al*. 2017).

Current use of the landscape

The communities used the landscapes around their settlements for different activities and with different intensities (Fig. S1 in supplementary material). Throughout the study it was possible to observe that nearby areas are also more commonly used (Text S1 in supplementary material). The floristic inventory plots are used in different ways (Tab. S4 in supplementary material) and the closer ones are used more intensively, which agrees with the ideas of Smith (2011), who states that the time and energy expended to perform activities in forests are limiting factors for humans, generally reducing the distance travelled. However, we observed low variation and high values of richness and abundance of useful and managed species as a function of distance (Fig. 3) when compared to other studies in Amazonia, similar to the pattern around ADE. Again, this is certainly due to our focus on the areas of intensive management.

Selectivity in management

The free lists and interviews identified 167 ethno-species in 11 use categories (Tab. S7 in supplementary material); of these, 126 received some management practice. Among the popular names of the free list, 40 % was considered useful for both groups of residents. Fifty-five names were cited only by residents of the FLONA Humaitá, of which 34 are used for construction and only four are used as food. Forty-four names were cited only by residents of the TI Jiahui, of which 16 are used for construction and 12 as food. Although free lists have limits (Alexiades 1996), this suggests that residents of the FLONA are less aware of food species and are more aware of species used for construction of homes and boats, including mining rafts.

Of the 10 common names with highest Use Values (UV), eight are among the 10 names with the highest cognitive salience index (S) (Tab. S8 in supplementary material), which is an index that infers importance (Sutrop 2001). This overlap allows us to say that there is a strong relationship between the plants that are most used and the plants considered most important. All are managed species that receive some care that favors them in the landscape at different stages of growth.

All plots had intense regeneration of *Euterpe precatoria* (12 individuals) and/or *Attalea speciosa* (49 individuals), that is, individuals who have not yet reached the specified DBH (> 10 cm). This suggests the non-suppression of individuals of human interest, a practice cited by the residents interviewed, or simply that there are many adult individuals of reproductive age nearby. The presence of these species, which are important for food and medicine, suggests possible enrichment. Domestication of the landscape can occur through the enrichment of forests with species of interest (Clement 1999; Smith 2011; Clement & Cassino 2018; Levis *et al*. 2018) and is expected in societies that depend partly on the forest to obtain their subsistence (Stahl 2015).

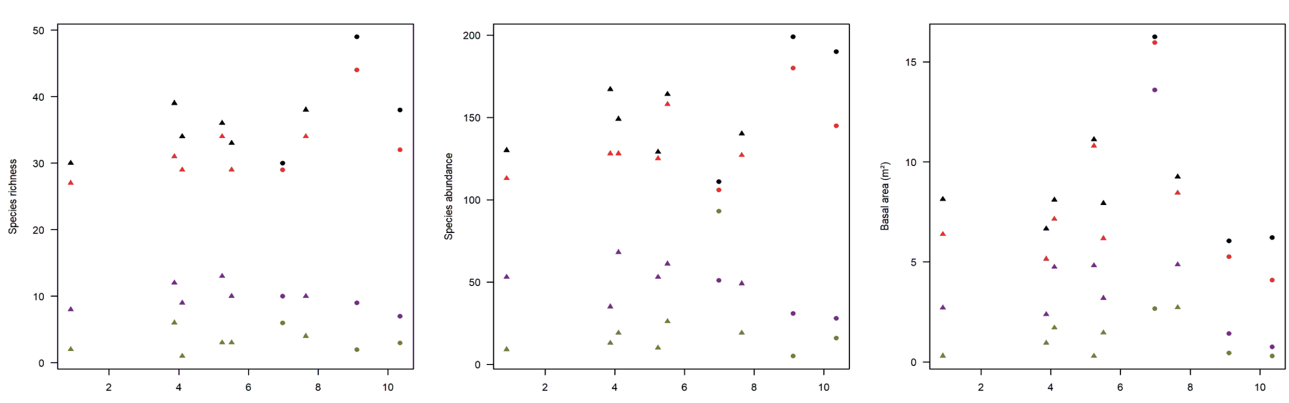

Figure 3. Variation of the absolute values of richness, abundance and basal area of the species as a function of the actual distance traveled from the current community; all regressions presented non-significant values (Tab. S6 in supplementary material). The triangles represent plots located in the TI Jiahui and the circles represent plots in the FLONA Humaitá. The colors represent the different groups of species: useful (black), managed (red), cultivated (blue) and domesticated (green).

In the nine plots, species in eight use categories were identified. The food category stood out in richness and abundance of species (Tab. S9 in supplementary material). Among the managed species, the most abundant categories did not present significant correlations (Tab. S10 in supplementary material) with the distance from current settlements (Fig. 4). The food category of managed species showed a tendency to maintain richness and abundance with distance. The food species were the most cited in the interviews, highlighting their importance to these communities, especially to the residents of the TI Jiahui. Many human societies develop simple strategies for food acquisition, such as concentrating fruit trees in the forest (Stahl 2015; Levis *et al.* 2018). In this study, it can be inferred that the maintenance of food species in areas around the communities provides greater availability of food for the families that depend on the forest, thus requiring less collection effort (Smith 2011).

The managed species in the construction and manufacturing categories, whose use often involves the suppression of individuals, showed a tendency to be less abundant in places closer to settlements (Fig. 4). This contrasts with the medicinal category, whose species tend to be conserved or even propagated in the plots. These differences between use categories show that human management occurs selectively, depending on the use category and the human group. According to Stahl (2015), the current vegetation allows inferences about changes that occurred in the past, and it can be expected that the selectivity observed in this study was also practiced in the pre-Columbian period. However, studies integrating modern botanical data with archaeology and palaeoecology can further test the hypothesis that there was selectivity of plant management in the pre-Columbian period. One such study, Maezumi *et al.* (2018), compared pollen, phytoliths and modern inventories of edible and non-edible plants before, during and after pre-Columbian occupation in the lower Tapajós region, and identified changes in floristic composition that agree with our observations.

In the present study, it was shown that changes in the forest landscape around pre-Columbian and modern settlements, regardless of the proximity of the major river, are intense and selective, contrasting with expectations of less modified interfluvial regions (McMichael *et al.* 2012; Bush *et al.* 2015; Piperno *et al.* 2015). However, this is also a methodological question (Hecht 2017), as the studies that identified less modified interfluvial areas used only charcoal and mostly crop phytoliths as indicative of changes in the landscape, rather than floristic information, which can provide a wider range of species in more use categories (Clement & Cassino 2018).

Conclusions

We conclude that there are areas of intensive management around pre-Columbian and current settlements within a radius of 5 km, irrespective of the distance from a major river. This is confirmed by the high values of richness,

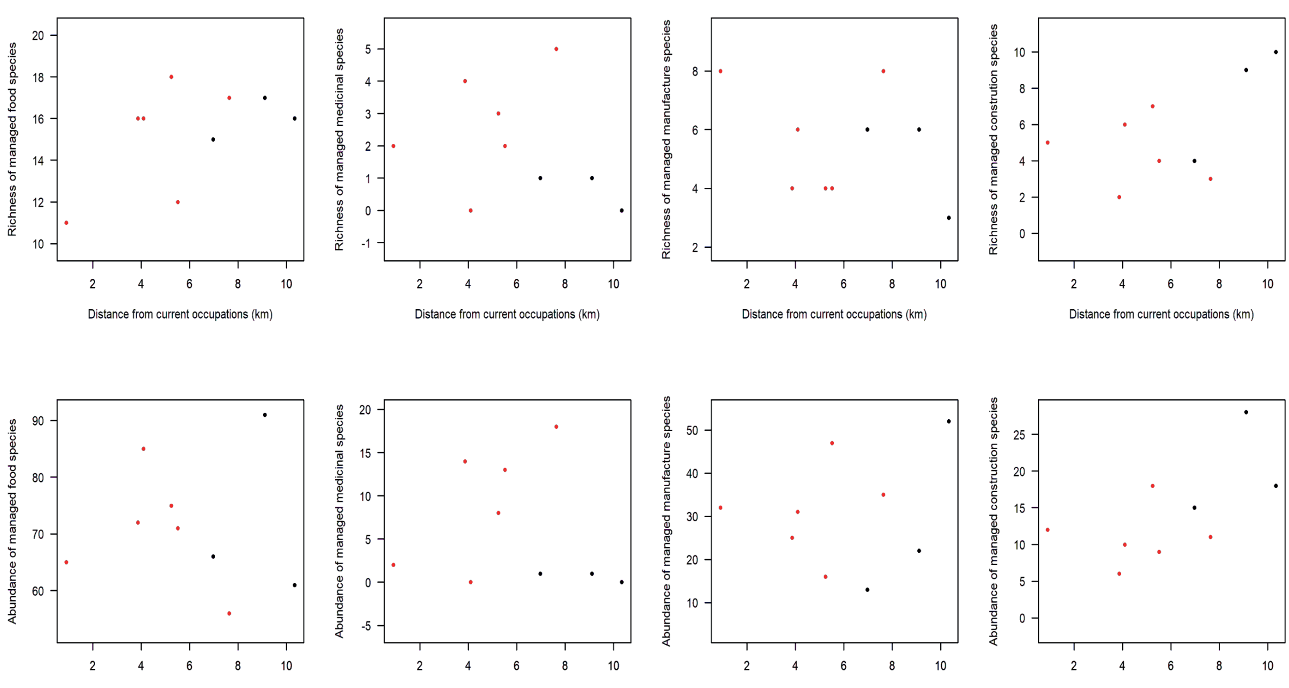

Figure 4. Relations between the values of richness and abundance of managed species of different use categories (Y axis) and the distance from current settlements to the plots (X axis). Red dots represent plots located in the TI Jiahui and black dots represent plots in the FLONA Humaitá.

abundance and basal area of useful, managed and cultivated tree species, when compared to other studies in Amazonia. As current indigenous communities inhabit the vicinities of small rivers with ADE sites in the interfluves and manage extensive areas around their settlements, similar zones of intensive management can be expected around other pre-Columbian and current settlements in other interfluvial regions of Amazonia. The study also identified different trends in different use categories, which suggests that current and past management occurred selectively.

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