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A TRANSFORMAÇÃO HUMANA PRÉ-COLOMBIANA DA PAISAGEM FLORESTAL NO INTERFLÚVIO PURUS-MADEIRA, AMAZÔNIA CENTRAL

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Manaus, AM
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Sinopse:
Estudou-se o impacto da manipulação humana passada sobre a paisagem florestal em um gradiente que parte da margem dos rios Solimões, Purus e Madeira e adentra o interflúvio. A abundância, riqueza e área basal das espécies árboreas úteis, indicadoras de alteração humana passada, a massa de carvão no solo e a quantidade de evidências arqueológicas foram avaliadas.

Palavras-chave: Ecologia histórica, ameríndios, manejo da paisagem, plantas úteis, carvão

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Resumo

A partir de aproximadamente 3000 anos atrás, populações nativas da Amazônia passaram a desenvolver sistemas eficientes de manejo dos recursos florestais, frequentemente criando florestas oligárquicas dominadas por árvores úteis. No entanto, a distribuição espacial e a escala de modificação da floresta permanecem desconhecidas. Estudos recentes propõem que o impacto humano longe dos maiores rios era mínimo, o que sugere que os interflúvios eram relativamente intocados. Este estudo avaliou as variações no grau de manipulação humana passada sobre a vegetação em seis locais ao longo do interflúvio Purus-Madeira, com diferentes distâncias até os rios principais e secundários. Em todos os locais as árvores úteis com DAP $\geq$ 10 cm foram inventariadas em duas parcelas de 1 ha e em cinco parcelas o solo para triagem de carvão foi coletado em três trincheiras até 50 cm de profundidade. Também foram mapeadas evidências arqueológicas nas proximidades dos locais estudados. Foi calculada a menor distância em quilômetros de cada parcela para os rios. Para quantificar a manipulação da floresta foram medidas a riqueza, abundância e área basal relativas de árvores úteis, especialmente frutíferas e palmeiras, e a massa de carvão no solo. Foram testadas as relações entre estes parâmetros e a distância aos rios. Encontramos relações exponenciais negativas fortes entre a manipulação da floresta e a distância dos rios principais. Parcelas localizadas entre 10 a 20 km de um rio principal tiveram 20-40% de espécies arbóreas úteis, parcelas com distâncias entre 20-40 km tiveram 15-25% de árvores úteis, enquanto parcelas a mais de 40 km tiveram menos de 15%. A abundância do carvão foi alta em duas áreas, as mais próximas de rios secundários. A menor distância entre as parcelas e as evidências arqueológicas foi encontrada nos locais mais próximos de rios. Estes resultados sugerem fortemente que a manipulação passada da floresta não se limita aos assentamentos pré-colombianos nas margens dos rios principais, mas se estendeu sobre florestas do interflúvio consideradas primárias atualmente. O uso sustentável e a conservação dos recursos florestais da Amazônia serão mais eficazes se considerar o grau de domesticação da paisagem, já que essas florestas concentram plantas úteis resultantes do enriquecimento humano passado.

Pre-Colombian human transformation of forest landscapes of the Purus-Madeira interfluve, Central Amazonia

Abstract

Starting at least 3000 years before present, Native Amazonian populations expanded to several millions and developed efficient systems for managing forest resources, often creating oligarchic forests dominated by useful trees. The densest human populations were located along the major whitewater rivers. However, the scale and spatial distribution of forest modification is still unknown. Recent studies propose that human impact away from the rivers was minimal, which suggests that interfluves were relatively undisturbed in the past. Our study assessed the variations in the degree of past human manipulation of floristic composition in forests at six sites along the Purus-Madeira interfluve as a function of the distance from the main and secondary rivers. In all sites we inventoried useful trees with DBH ≥ 10 cm in two 1 ha plots and in five plots soil for charcoal analysis was collected in three soil pits. We also mapped archaeological evidence around the study sites. The shortest distance in kilometers from each plot to the rivers was calculated. To quantify forest manipulation, we measured the relative richness, abundance and basal area of useful trees, especially fruit trees and palms. We tested the relationships between these parameters and the plot's distance to the rivers and the difference of soil charcoal mass between the six sites. We found strong negative exponential relationships between forest manipulation and the distance to main and secondary rivers. Plots located from 10 km to 20 km from a main river had 20-40% useful tree species, plots with distances between 20-40 km had 15-25% useful trees, while plots greater than 40 km had less than 15%. Soil charcoal abundance was high in two sites with the shortest distances to secondary rivers. The shortest distance between plots and archaeological evidences was found in sites near rivers. These results strongly suggest that past forest manipulation by humans was not limited to the pre-Columbian settlements at the edges of the main rivers, but extended over interfluvial areas considered to be primary forest today. The sustainable use and conservation of Amazonian forest resources will be most effective if it considers the degree of past landscape domestication, as these landscapes concentrate useful plants related to human management.

Sumário

INTRODUÇÃO

A crença de que os ambientes naturais das Américas foram relativamente intocados por seres humanos antes da conquista europeia não é mais sustentada (Wills *et al.* 2004, Denevan 2011). A partir de aproximadamente 3000 anos atrás, as populações humanas pré-colombianas aumentaram de tamanho, densidade e duração das suas ocupações (Piperno e Pearsall 1998). As paisagens e muitas plantas foram domesticadas em diferentes graus para atender as necessidades dessas sociedades (Clement 1999). Mas, a extensão e o impacto da domesticação na paisagem amazônica são controversos. Enquanto alguns arqueólogos sugerem uma modificação completa da paisagem (Erickson 2008, Heckenberger 2003), ecólogos argumentam o oposto, que a maior extensão da bacia não apresenta sinais de perturbação (Peres *et al*. 2010, Barlow *et al*. 2012). Bush e Silman (2007) e McMichael *et al*. (2012) propõem uma hipótese intermediária, na qual a intensidade da perturbação da floresta decresce exponencialmente com o aumento da distância dos grandes rios da Amazônia e especialmente em florestas não sazonais.

As manchas de solos antrópicos, chamadas de terra preta de índio (TPI), geralmente estão nas margens dos grandes rios (WinklerPrins e Aldrich 2010). As terras pretas são solos culturais e diferem-se dos solos naturais pelos altos níveis de fósforo (P) e cálcio (Ca), pela presença de artefatos cerâmicos, bem como pela coloração escura causada por altas concentrações de carvão (Woods e McCaan 1999). Esses solos altamente férteis foram criados pelos povos amazônicos desde 5000 a 500 anos atrás (Neves *et al*. 2003), provavelmente pela acumulação de lixo nos assentamentos permanentes e por um longo processo de manejo do solo (Woods e McCaan 1999). Os processos específicos envolvidos na criação desses solos permanecem desconhecidos, mas certamente a vida sedentária e a agricultura extensiva foram essenciais para a sua criação (Neves *et al*. 2003). Essas evidências fizeram com que os antropólogos e arqueólogos assumissem que os povos indígenas preferencialmente residiram em áreas mais elevadas nas margens dos rios de água branca, nos barrancos (Denevan 1996). A preferência pelos barrancos desses rios é explicada pela maior concentração de recursos alimentares e solos mais férteis nas várzeas (Denevan 1996). Estudos recentes sugerem que o impacto humano fora dos locais de alta densidade populacional tenha sido muito limitado (Bush e Silman 2007) e o raio de influência humana na paisagem ao redor do centro de habitação tenha sido restrito (McMichael *et al*. 2012).

Entretanto, centenas de geoglifos foram encontrados no interflúvio do alto Purus-Madeira, distribuídos numa área de 250 km de extensão do norte ao sul, englobando tanto áreas de várzeas como de terra-firme (Pärssinen *et al*. 2009). A existência dessas estruturas sugere a presença de sociedades complexas e populações densas em áreas interfluviais, ambientes anteriormente descritos como incapazes de suportar um número elevado de pessoas (Pärssinen *et al.* 2009). No entanto, a distribuição, extensão e o impacto dos povos pré-colombianos na floresta distante dos grandes rios ainda permanecem desconhecidos. Estudos ecológicos e arqueológicos são escassos nos interflúvios, que constituem a maior proporção da paisagem amazônica (Pitman *et al*. 2011, Barlow *et al*. 2012).

A presença de sociedades humanas bem estruturadas com técnicas avançadas de manejo da paisagem deixou marcas visíveis também na vegetação (Balée 2006, Erickson 2008). Os povos amazônicos identificaram espécies na comunidade florestal de grande utilidade e passaram a construir florestas oligárquicas na Amazônia, ampliando a abundância de certas espécies (Balée 1989, Clement *et al*. 2003). As florestas antropogênicas são florestas dominadas por uma ou mais espécies úteis. Em muitos casos, somente percebemos sinais da manipulação humana na floresta através da distribuição e abundância dessas espécies, e devido à sua alta diversidade são comumente consideradas florestas primárias (Peters 2000). As manchas de castanheiras (*Bertholletia excelsa* Bonpl.), conhecidas como castanhais, e as florestas dominadas por certas palmeiras, como o caiaué (*Elaeis oleifera* (Kunth) Cortés), conhecidas como caiauezais, são exemplos de florestas oligárquicas antropogênicas (Balée 1989, Shepard e Ramirez 2010). Castanheiras com diâmetro maiores que 220 cm são provavelmente mais antigas que a colonização da Amazônia, contando a partir da fundação de Bélem, Pará, em 1616 (Chambers *et al.* 1998). O caiaué é pouco usado atualmente pelas populações tradicionais (Cunha *et al*. 2009); então, sua relação com o homem também está ligada ao período pré-colonial.

Nós examinamos a influência humana passada sobre a floresta, a partir dos rios Solimões, Purus e Madeira, adentrando o interflúvio e considerando o papel dos rios secundários que penetram na região. As condições ambientais desses grandes rios são favoráveis à presença humana; todos abrigam águas ricas em nutrientes dissolvidos e solos férteis nas suas planícies de inundação (Furch e Junk 1997). Os índios da etnia Mura são citados como os principais habitantes do norte da região durante o período pré-colonial (Cunha 1992). No final do século XIX, o rio Madeira foi reocupado para a produção de borracha, proveniente da extração de látex da seringueira (*Hevea brasiliensis* (Willd. ex A.Juss.) Müll. Arg.). Os grandes rios possuem muitas manchas de terra preta em suas margens, especialmente o Solimões e o Madeira (WinklerPrins e Aldrich 2010); já os rios secundários possuem águas pretas e não têm registros arqueológicos até o presente estudo. Em algumas localidades do interflúvio, as florestas são submetidas a solos encharcados na época chuvosa, criando um ambiente inapropriado para ocupação humana sedentária e para a agricultura intensiva durante todo o ano. Mesmo nessas condições, buscamos mostrar que as florestas do interflúvio apresentam sinais de manipulação de acordo com a distância dos rios da região.

Examinamos a intervenção humana na vegetação pela abundância, riqueza e área basal das espécies úteis, principalmente frutas comestíveis e palmeiras. Usamos também a massa de carvão no solo para confirmar a presença de atividades humanas passadas nos locais. O fogo é a ferramenta mais poderosa na transformação da paisagem (Erickson 2008) e uma das principais evidências de distúrbios humanos em florestas tropicais (Stanford e Horn 2000, Bush e Silman 2007). Devido à inexistência de dados arqueológicos no interior do interflúvio, mapeamos as evidências arqueológicas, castanhais e caiauezais nas áreas estudadas. Usamos todas essas informações para testar a hipótese de que a intervenção humana passada sobre a comunidade arbórea diminui com o aumento da distância dos rios da região.

OBJETIVOS

Determinar a extensão e o efeito das transformações humanas do passado sobre a paisagem florestal e a composição florística útil em seis áreas do interflúvio Purus-Madeira.

Para avaliar a influência humana na paisagem florestal do interflúvio, pretendemos responder as seguintes questões:

1 – A existência das paisagens domesticadas no interflúvio Purus-Madeira é maior em áreas mais próximas de rios principais e secundários?

2 – O efeito humano sobre a comunidade de árvores úteis diminui com o aumento da distância dos rios da região?

3 – A abundância de carvão no solo da floresta é maior nas áreas mais próximas dos rios?

Capítulo 1

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Pre-Colombian human transformation of forest landscapes of the Purus-Madeira interfluve, Central Amazonia

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Abstract

Native Amazonian populations managed forest resources in numerous ways, often creating oligarchic forests dominated by useful trees. The scale and spatial distribution of forest modification is still unknown, although recent studies propose that human impact away from rivers was minimal. We tested the hypothesis that past human management of the useful tree community decreases with distance from rivers. In six sites, we inventoried trees with DBH ≥ 10 cm and collected soil for charcoal analysis. We also mapped archaeological evidence around the study sites. The shortest distance in kilometers from each plot to rivers wider than 50 m was measured. To quantify forest manipulation, we measured the relative abundance, richness and basal area of useful trees. We found a strong negative exponential relationship between forest manipulation and the distance to large rivers. Plots located form 10 km to 20 km from a main river had 20-40% useful tree species, plots between 20 and 40 km had 15-25%, plots more than 40 km had less than 15%. Soil charcoal abundance was high in the two sites closest to secondary rivers. The shortest distance between archaeological evidence and plots was found in sites near rivers. These results strongly suggest that past forest manipulation by humans was not limited to the pre-Columbian settlements, but extended over interfluvial areas considered to be primary forest today. The sustainable use of the Amazonian forests will be most effective if it considers the degree of past landscape domestication, as human-modified landscapes concentrate useful plants for human use and management today.

Keywords

Historical ecology / landscape modification / interfluve / useful tree community / charcoal

Text

The common belief that natural environments of the Americas were relatively untouched by humans before the European conquest is no longer accepted (1, 2). Starting at least 3000 years before present, pre-Columbian populations increased in size, density and duration of their occupations (3). Landscapes and many plants were domesticated in different degrees to sustain these societies (4). The extent and impact of Amazon landscape domestication, however, are still controversial. While some archaeologists suggest extensive modification of the landscape (5, 6), ecologists often argue the opposite, that most of the Amazon basin shows little sign of disturbance (7, 8). Bush & Silman (9) and McMichael *et al*. (10) suggest an intermediate hypothesis, in which the intensity of human impacts decreases exponentially with increasing distance from the major Amazonian rivers, especially in non-seasonal forests. Human impacts that are easily recognized include changes in soils and relief, such as anthropogenic soils and geoglyphs, as well as changes in forest composition, especially forests dominated by a few useful species, known as oligarchic forests (11).

Anthropogenic soils, called *Terra Preta de Índio* or Amazonian Dark Earths (ADE), are usually found on bluffs along the major rivers (12, 13). Amazonian Dark Earths are cultural deposits and are very different from background soils, having a dark color due to high concentrations of charcoal, high levels of some nutrients, especially calcium (Ca) and phosphorus (P), and the presence of archaeological artifacts (14). These soils were created by Native Amazonians from about 5000-500 years before present (15), by the accumulation of waste around permanent settlements and long-term soil management practices (14). The specific processes that explain their origin remain poorly understood, although a sedentary lifestyle and intensive agriculture were probably crucial for their creation (15). Their frequent occurrence on river bluffs led to the hypothesis that dense pre-Columbian settlement in Amazonia was mostly located on the bluffs of white water rivers (12). The preference for these sites is explained by the high concentration of food resources and more fertile soils in the adjacent floodplains (12).

Nevertheless, hundreds of geoglyphs have been found in the upper Purus-Madeira interfluve distributed over an area 250 km from south to north, encompassing both floodplains and interfluvial upland ecosystems (16). In the Llanos de Mojos in Bolivian Amazonia most of the earthworks are on interfluves in a forest-savanna environmental mosaic with many useful species (17). The occurrence of these earthworks suggests the existence of complex societies and dense populations in interfluvial areas, environments previously described as unable to support large numbers of people (12, 16). The theory that Native Amazonia populations of *terra firme* ecosystems were forced to live as hunter-gatherers with low impact activities due to the limitation of nutrients can no longer be accepted (18). However, aside from the geoglyphs, archaeological studies are few on the interfluves, often thought to constitute the largest proportion of the Amazonian landscape (8). This notion requires careful examination, however, as the Amazonian landscape contains drainage basins of rivers and streams of various magnitudes that extend into the interfluves, especially during the rainy season when all rivers fill significantly. Additionally, wetlands represent more than 30% of the basin (19).

The presence of well-structured human societies with advanced landscape management technologies is believed to have left visible signs in Amazonian forests (5, 20). Upon identifying useful species in the forest community, Native Amazonians often increased their abundance, creating oligarchic forests often associated with ADE (20, 21). These forests, known as anthropogenic oligarchic forests, are dominated by one or more useful species due to human activity (20), but are commonly considered primary forests because of their diversity, stature, and closed canopies. In most cases, the only way to identify signs of past manipulation is by assessing the distribution and abundance of useful species (22). Forest patches dominated by Brazil nut trees (*Bertholletia excelsa*), known as *castanhais*, and by the palm caiaué (*Elaeis oleifera*), known as *caiauezais*, are well-known anthropogenic oligarchic forests (20, 23). Brazil nut trees with diameters greater than 220 cm are probably older than the colonization of Amazonia, counting from the establishment of Belém, Pará, in 1616 (24). As *caiaué* is not frequently used by traditional communities (25), it can be considered pre-colonization also.

In this study, we examined past human modifications of the forest, from the Solimões, Purus and Madeira Rivers to their interfluve, considering also the role of secondary rivers. The environmental conditions of these three major rivers are favorable for human settlement and numerous ADE sites have been found on their bluffs, especially along the Solimões and Madeira Rivers. All of them have nutrient rich waters and fertile floodplain soils (19). In many areas, the interfluvial forests are exposed to flooding during the rainy season (19), creating environments unsuitable for year-round human occupation and intensive agriculture. Even under these conditions, we show that interfluvial forests can have signs of manipulation at different distances from rivers.

We assessed human intervention in the forest by the abundance, richness and basal area of useful tree species, mostly fruit trees and palms, and studied the hydrological conditions of the sites as a possible ecological factor influencing the distribution and abundance of useful palms. We also considered the mass of charcoal in the soil as another indication of past human activities at each site (9, 10). Fire is the most powerful tool for landscape transformation (5) and important evidence of human disturbance in tropical forests (10, 26). Due to the lack of archaeological data on the interfluve, we mapped archaeological evidence (i.e., presence of ADE), and two types of anthropogenic forests, *castanhais* and *caiauezais*, around the study sites. These data were used to test the hypothesis that human intervention in forest landscapes decreases with distance from rivers, as suggested by Bush & Silman (9) and McMichael *et al*. (10).

Results

Archaeological evidence. Archaeological sites and anthropogenic forests were found inside and around the six study sites, far from major rivers (Fig. 1). All sites with ADE were on the banks of secondary rivers (> 50 m wide) and had not previously been identified, e.g., WinklerPrins and Aldrich (13). *Castanhais* and *caiauezais* are mostly near river banks, but also occurred in the interior; they varied considerably in size and density. In the sites closest to rivers, there were shorter distances between the archaeological evidences and the sampling plots, and more evidences in general, as expected from the hypothesis.

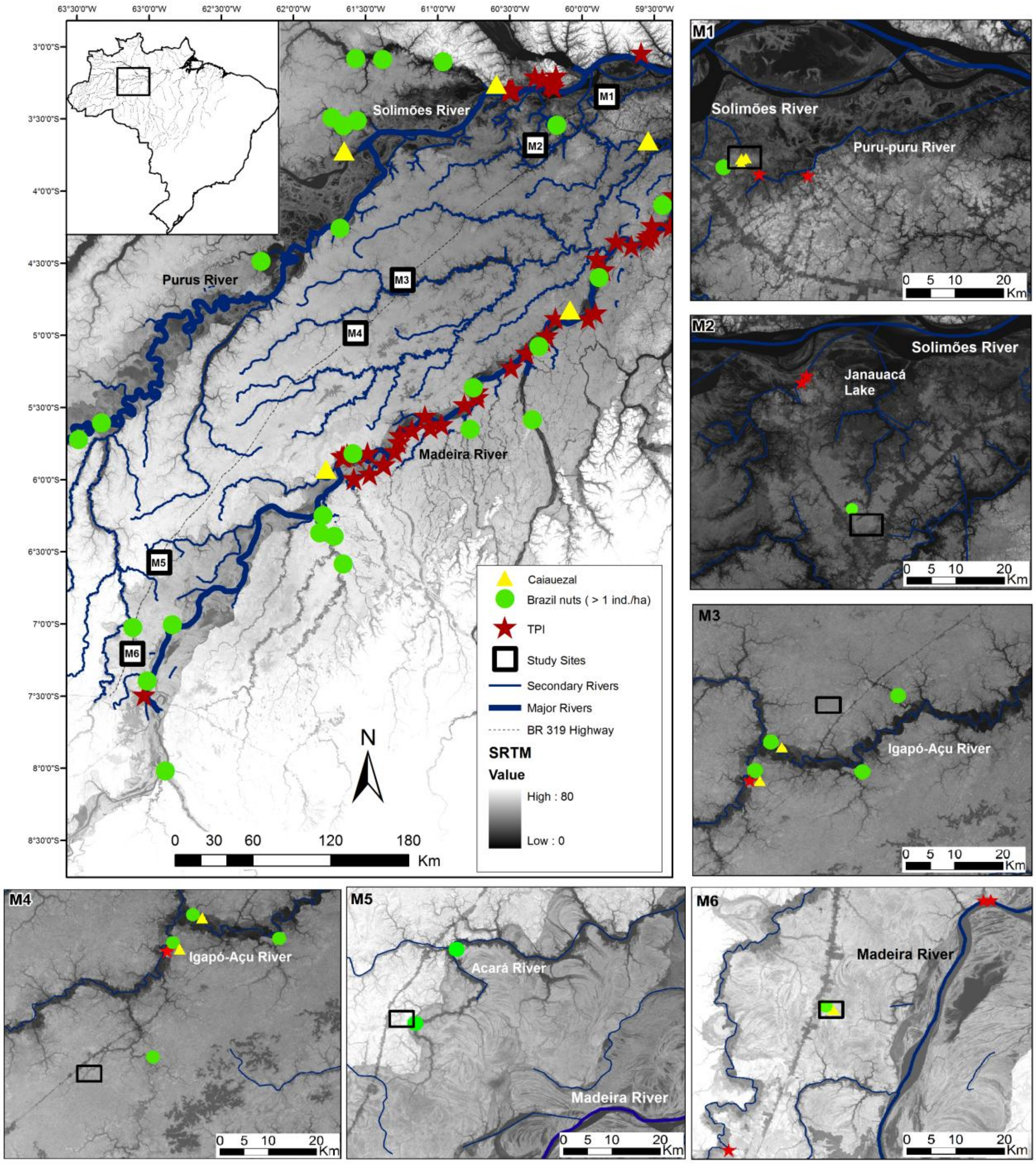

Fig. 1.The large map shows the central-northern Purus-Madeira interfluve. The empty squares are the six sampling sites at different distances from major rivers. In each site, two plots were sampled for floristic analysis and five for charcoal analysis. Yelow triangles are *caiauezais*, green circles are *castanhais* (Brazil nuts > 1 individual/hectare) and red stars are ADE (*terra preta* sites). ADE data from WinklerPrins and Aldrich (13), *castanhais* from RADAMBRASIL (27) and *caiauezais* from Moretzsohn *et al*. (28). The other six maps show

the newly identified *terra preta* sites (ADE) and anthropogenic forests in the vicinity of each site, identified by interviews with local residents or by observation.

Charcoal in the soil. Macroscopic charcoal particles were recorded in all areas and in all soil layers down to 50 cm (Fig. 2). Only in the 30-40 cm layer at site 6 was charcoal absent. Higher values of charcoal were detected in the sites closest to secondary rivers. At M1 the charcoal mass was high in the top 20 cm soil depth. Charcoal particles were abundant in all layers at M2, 36 km from the main river, and the mean was much higher than the median value observed by Piperno and Becker (29) in upland forest soils 90 km north of Manaus in Central Amazonia, which is thought to be the value expected in soils without past human activities. All other sites had charcoal close to the median value.

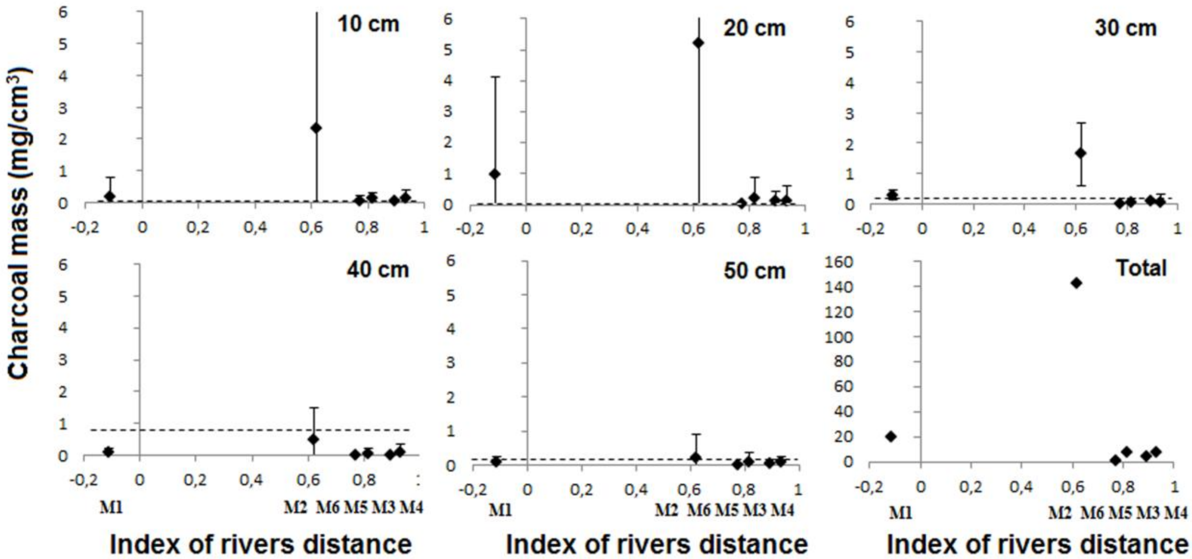

Fig. 2. Mass of charcoal in the soil (mg/cm^3) for each soil layer from 10 cm to 50 cm in depth. The plots are in order of increasing distance from the sites to the rivers, expressed by the index of rivers distance. Each point is the average mass of charcoal in the soil from 14-15 samples in each area. The vertical lines represent the standard deviation. The dotted line represents the median value of the mass of charcoal found at each depth in the soil of forests north of Manaus in Central Amazonia, which is the value expected in soils without past human activities (29).

Relationship between the useful tree and palms community and the distance from rivers. The relative abundance, basal area and richness of useful trees decreased with distance from major rivers (Fig. 3). The relationship between these variables was a highly significant negative exponential curve. Plots located from 10 to 20 km from a major river had 20-40% useful tree species, plots with distances between 20 and 40 km had 15-25%, plots more than 40 km had less than 15%. In the first 20 km from major rivers there was a rapid decrease in useful tree species and individuals. Beyond 40 km, the proportions of useful individuals and species decreased slowly. The sites with higher concentrations of useful plants (M1, M2 and M6) were on *paleo-várzeas*, pre-Holocene floodplains (27, 30) (Table S1).

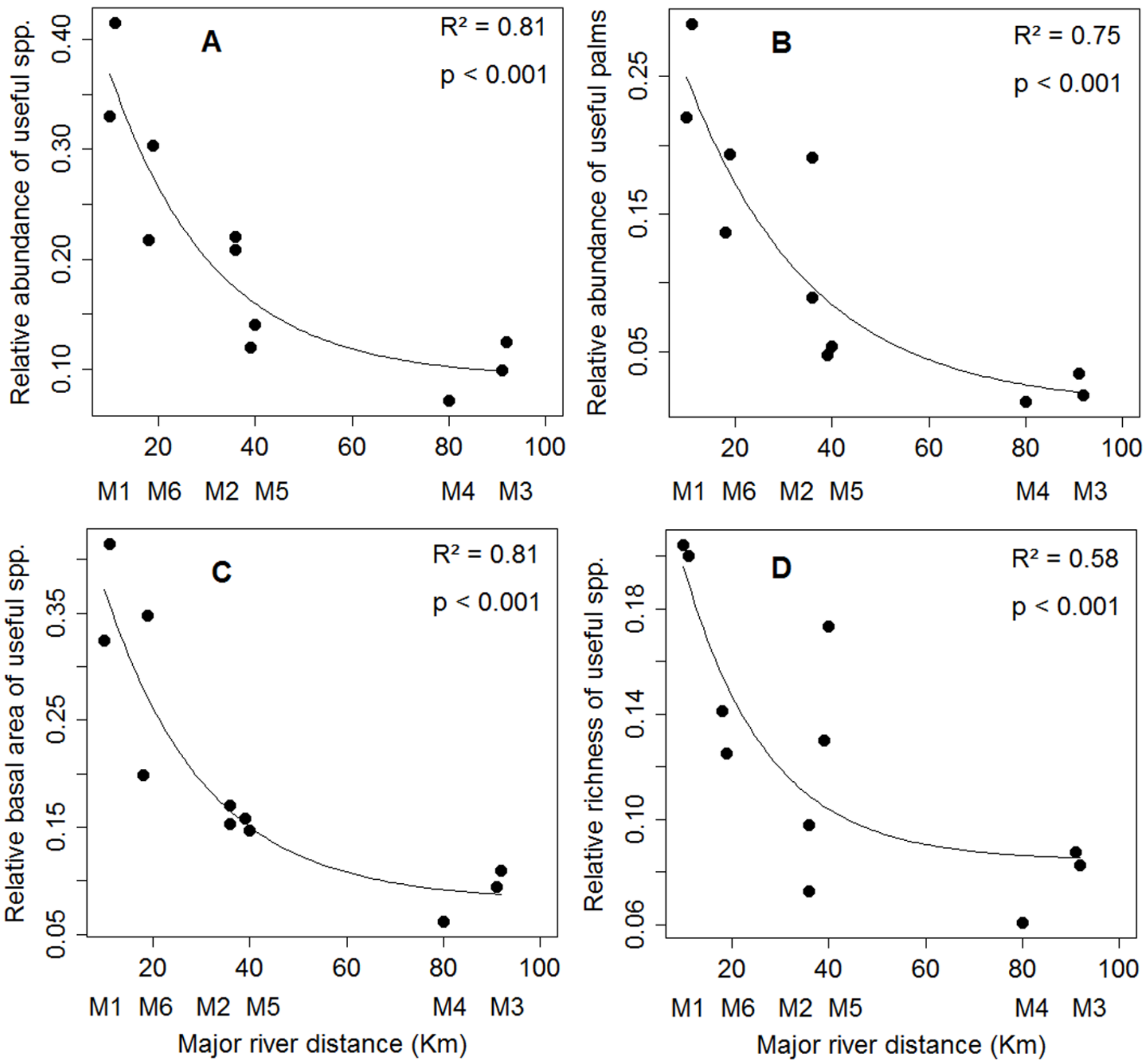

Fig. 3. Relationships between the relative abundance of useful species per plot (A), the relative abundance of useful palms per plot (B), the relative basal area of useful species per plot (C) and the relative richness of useful species per plot (D), with the distances from major rivers. Points are the plots of all sites, totaling 11 plots. The shortest straight line distance in km from the plot to the Solimões, Purus or Madeira River was evaluated.

We also observed a negative relationship between abundance, basal area and richness of useful trees and the index of distance from secondary rivers crossing the interfluve. This relationship was linear and less significant, although it still explained ≥ 50 % of the variance (Fig. S1). Since we couldn't sample sites with a high variation in distances from secondary rivers, there were two plots in site 1 (M1) with very high index values and the other plots with much lower values (Table S1). The landscape of site 1 is characterized by numerous

Amazonian Dark Earth sites and anthropogenic forests, as well as by rivers and lakes (Fig. 1) that were and still are waterways used for movement and fishing.

In order to focus on the influence of the secondary rivers, we reanalyzed the relationship between the distance to secondary rivers and useful tree parameters, excluding plots from the two sites closest to the main rivers, M1 and M6 (Fig. 4). This analysis showed that the abundance and the basal area of useful species in areas away from major rivers is closely related to their distance to secondary rivers, suggesting that the secondary rivers were also occupied by pre-Columbian populations.

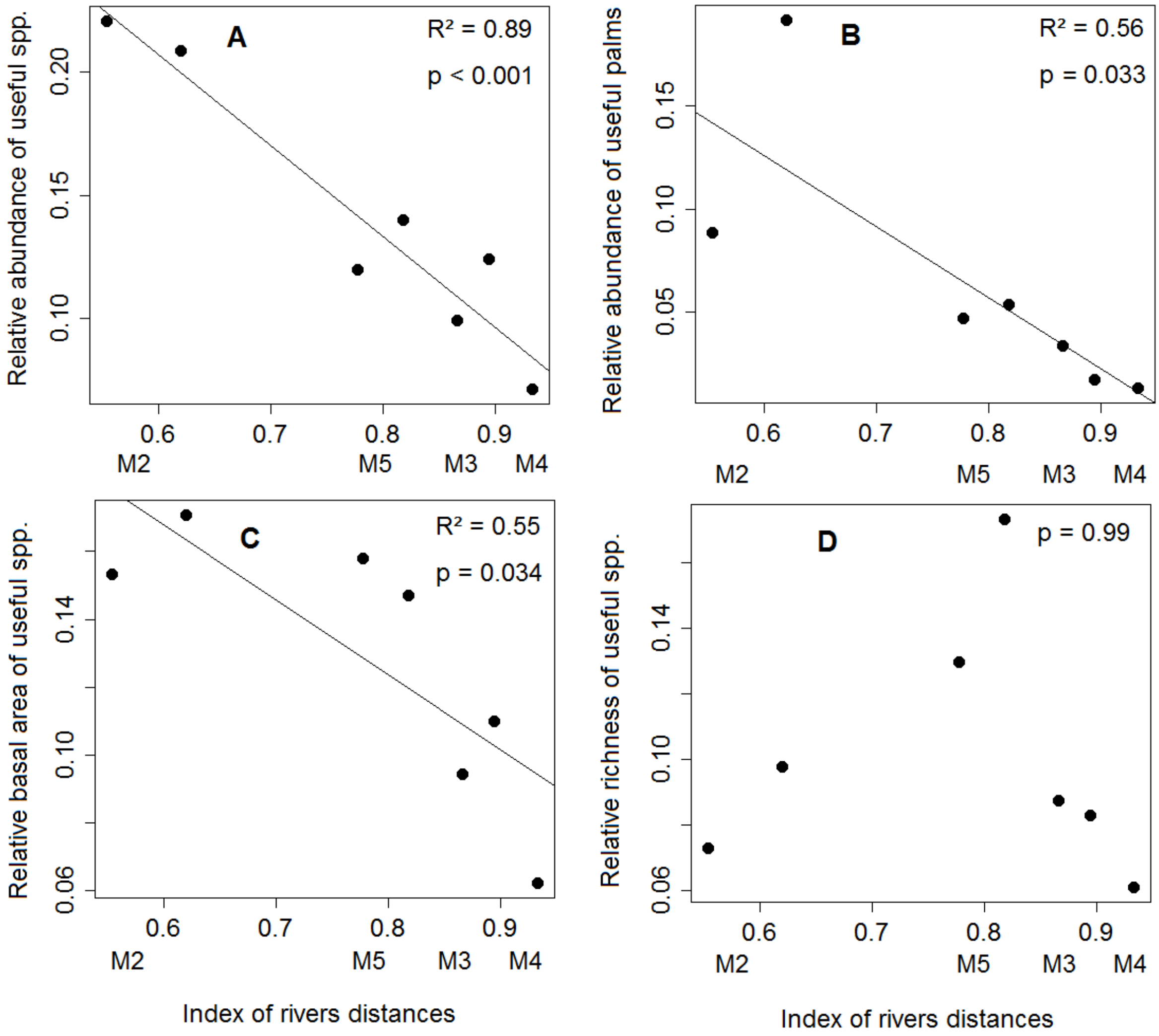

Fig. 4. Relationships between the relative abundance of useful species per plot (A), the relative abundance of useful palms per plot (B), the relative basal area of useful species per plot (C) and the relative richness of useful species per plot (D), with the distances from rivers. Points are the plots of sites M2, M3, M4, M5, totaling seven plots. The index of rivers distances is the sum of the inverse distances from each plot to all perennial rivers greater than 50 m wide in a 25 km diameter zone around the sites.

Palms. Arecaceae were the most abundant useful family in all plots (Table S1). The relationship between the relative abundance of palms and the distance to rivers was as strong as the relationship for all useful species together (Fig. 3*B* and 4*B*). Excluding the useful palms, the relationship between the abundance of dicotyledonous trees and the distance to major rivers was less significant (p = 0.05). A multiple regression analysis of the relationship between the relative abundance of useful palms with the distance from rivers and the hydrologic gradient indicated a strong effect of the distance from rivers (p = 0.001, Fig. 5) and a significant effect of the hydrologic gradient on the abundance of useful palms (p = 0.05, Fig. 5). The hydrologic gradient was not the major determinant of useful palm abundance in the interfluve, and a large fraction of variance is attributable to distance per se, which is our proxy for anthropogenic effects.

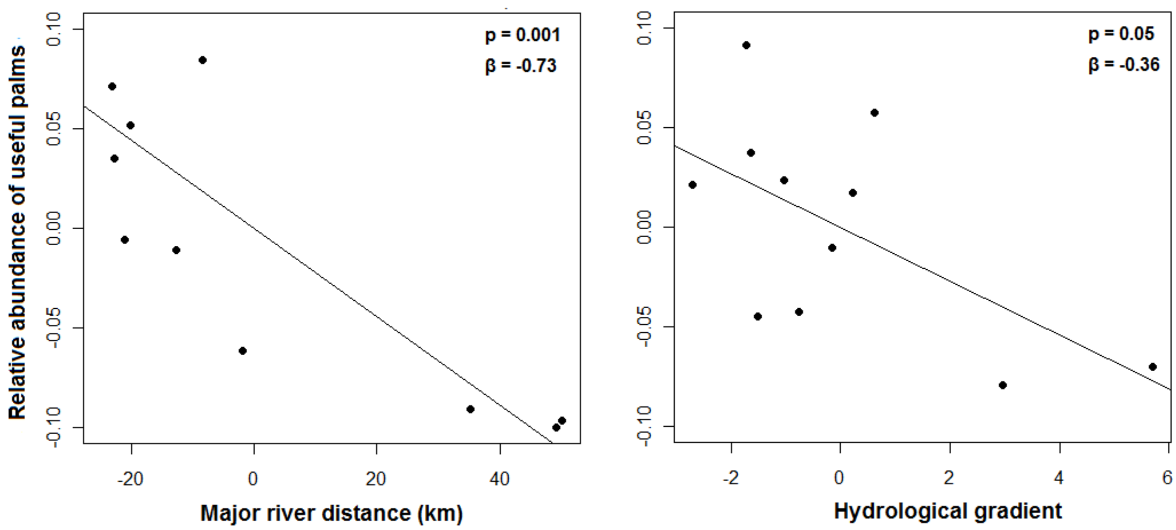

Fig. 5. Partial regressions between the relative abundance of useful palms and the distance of each plot to the Solimões, Purus and Madeira Rivers (left) and the hydrologic gradient (right). The full multiple regression model has an R^2 = 0.73.

Discussion

Human intervention in the landscape decreases with distance from rivers. Our data confirm McMichael *et al*. (10) hypothesis and the expectations of Bush & Silman (9) that human intervention in the landscape decreases with distance from major and secondary rivers. However, the extent of human impact in the forest observed in our study is much greater than expected by these authors and the assumptions of Peres *et al*. (7) and Barlow *et al*. (8). We found high abundances of useful tree species up to 20 km into the interfluve, and also the presence of anthropogenic forests and Amazonian Dark Earths far from the major rivers, but close to secondary rivers. Studies that only assessed past human disturbance in terms of charcoal, pollen and phytoliths of cultivated plants (9, 10) failed to detect signals of less intensive interventions in the landscape, such as forest enrichment through extractive activities and hunting. Less intensive activities also caused changes in the concentration of useful plants in the past (22, 31) and even today contribute to increases in the concentration of certain plants, such as Brazil nut, along trails (32, 33).

Archaeological evidence and useful species composition found at M1, the site closest to the major rivers, indicate forest management practices by different groups in different historical moments in the past. The existence of ADE, *castanhais* and *caiauezais* near plots are evidence of landscape domestication by indigenous groups before European conquest. On the other hand, all inventoried individuals of the rubber tree (*Hevea brasiliensis*) had marks of extraction. Rubber is usually rare in the forest (34); however, we found 30 individuals in a one ha inventory (Table S2), the density of a very common species. Hence, some of these forests were reoccupied, exploited and transformed by rubber tappers in the early twentieth century, resulting in the increased abundance of rubber trees (and possibly other useful species) in the forest.

Distinguishing between pre-Columbian and post-conquest management events requires more historical and ethnographic studies in each locality. Except at M1, we didn't find signs of rubber tapper impacts. However, in 1970 the BR-319 Highway was constructed, allowing a movement of migrants into the interfluve. Most local residents in the vicinity of the study sites have been there since this period. Current management practices in mature forest performed by these recent arrivals probably wouldn't impact the tree community with DBH > 10 cm.

Considering the extent of Amazonian forests, we need more systematic studies, particularly in regions devoid of information (35). It is too early to make basin-wide projections, such as Barlow *et al.*'s (8, p.4) suggestion of "a largely imperceptible footprint from subsistence hunting and resource extraction across vast tracts of Amazonian forests". This caution is especially true for the interfluves, all of which are insufficiently sampled (10, 36). Only the Tapajós-Xingu interfluve has a large number of ADE records (13, 37), but the others have not been adequately surveyes. In the Purus-Madeira interfluve, we detected ADEs on black water secondary rivers and in places susceptible to flooding in anomalous years. Geoglyphs were found in the upper Purus-Madeira interfluve (16), indicating that this region is unique and may not be representative of other interfluves. On the other hand, all of these observations suggest that if we look, we will find more and more evidence of past human activities on the interfluves.

We expect that the footprints of past human activities in the forest will be found in other parts of Amazonia given results in other areas of the world. Around ancient Roman ruins in France, the composition and diversity of plants reflects the impacts of agriculture 1500 years after abandonment (38). In the Maya forests in Central America, past human management of useful species was identified 1000 years after this civilization's decline (39, 40). In Central Africa, current tree species composition and diversity still reflects human disturbances after nearly four centuries (41). Our results showing a gradient of pre-Columbian human manipulation in the forest from the major rivers into the interfluve agree with these other studies. Using only simple regressions with distance to major and minor rivers, which reflect the distance from possible pre-Columbian settlements we explained 50-80% of the variation in the useful tree community. Therefore, our results suggest that past human impacts in the forest extend over large areas considered primary forest today.

Ecological factors and past human management influence useful tree and palms abundance and distribution. Ecological conditions can explain arboreal monodominance without invoking the need for human dispersal, especially of some palm species, e.g., *Mauritia flexuosa* in swamp forests (42). A gradient of hydrological conditions runs from the floodplain to the interfluve, and in wetlands the flood-level is a determinant of plant distribution along this gradient (43). Also in upland forests, some palm species respond to the hydrological condition of the soils (44). As we expected, we found in our multiple regression model a significant effect of the hydrologic gradient on the abundance of useful palms. However, the effect of the distance to rivers, even after partitioning out the effect of the hydrologic gradient, was stronger, probably due to past human management.

If ecological conditions were the sole determinants of plant distributions in the interfluve, we should find roughly the same useful communities on *paleo-várzeas*, which are pre-Holocene floodplains with similar geomorphological and hydrological conditions. Instead, we found different dominant useful species on these *paleo-várzeas*, which are known to be naturally associated with very different ecological conditions (*Euterpe precatoria, Hevea brasiliense* in M1, are naturally associated with riparian forests, and *Bertholletia excelsa, Attalea speciosa* in M6, are naturally associated with upland forests; see also Table S2).

Phillips *et al*. (45) quantified the importance of different forest types for traditional populations in Peru and showed that the *várzea* and *paleo-várzea* forests are the most used, mainly because they provide numerous foods and construction materials. We also found higher concentrations of useful plants on paleo-várzeas. We observed forests dominated by a number of useful species with different environmental preferences, including species that are commonly not found in poorly drained soils, hence occurring outside of their natural environments. Thus, ecological conditions alone can't explain useful tree dominance and distribution in the interfluve. Pre-conquest and historical management is the most probable cause of the current useful tree community distribution in the Purus-Madeira interfluve.

Palm adults are the most abundant useful arboreal species. The family Arecaceae had the largest number of individuals per site (Table S2), especially due to the high density of *Euterpe precatoria, Oenocarpus bataua* and *Attalea speciosa* in the sites closest to the rivers. These species have wide geographical distributions in Amazonia and form oligarchic forests (11, 20, 42). In general, the high dominance of palm trees can be explained by their incredible tolerance to extreme environmental conditions, such as severe flooding (11).

In Central Amazonia *Euterpe precatoria* and *Oenocarpus bataua* occur in higher densities mainly in low areas with poorly drained soils (27). However, we found these two species in the same plots with *Attalea maripa* and *Theobroma* spp. (Table S2), which are disturbance indicators and associated with archaeological sites (16, 46, 47) normally found in non-flooded areas (48). The co-occurrence of these species, therefore, is unlikely to be due to environmental characteristics, but is likely to be due to their usefulness to humans. Considering that *Oenocarpus bataua* and *Attalea maripa* are usually more abundant in forests with more open canopies (49, 50), the high density of these species at M2 is likely associated with the historical presence of humans and fire in the region, which may have increased light penetration in the forest.

Other studies also found a relationship between the abundance of palms and past human intervention (20). Native Amazonians encouraged many species of palms in places where they lived (20, 22) and palm remains are commonly found in archaeological sites (45). Even today, palms are the most useful botanical family for Amazonian indigenous groups (51) and for Amazonian peoples in general. Our results strongly suggest that the ancient human populations of the interfluve affected the distribution and abundance of palms, even in places that were not ideal for their establishment.

Charcoal and landscape modification. The occurrence of charcoal particles in soils is an evidence of fire. The record of such events in different soil depths indicates repeated fires in the past (26). We found charcoal in all areas and almost all depths, indicating that interfluvial forests were burnt at different moments in the past. If charcoal particles in the top 20 cm soil depth are quite likely to be modern (52), most of the charcoal at depths greater than 20 cm can be considered pre-Columbian. The large scale occurrence of charcoal in Amazonia has already been reported, and was shown to be associated with increased frequency and intensity of natural and anthropogenic fires during extremely dry years (53).

Despite the widespread occurrence of charcoal in the landscape, its abundance was high in only two sites (M1 and M2). The mean charcoal mass in these soils, especially in M2, was greater than the median charcoal mass found in an upland site in northern Central Amazonia (29). M1 is located 10 km from the Solimões River and was the site with the highest number and diversity of archaeological evidence and with the largest density of useful species in the two sampled plots (Table S1). The forests in M1 were re-occupied by rubber tappers (*SI Text*), so the charcoal in the top 20 cm soil depth may be related to their activities. At M2 we observed even larger amounts of charcoal in all soil layers. This site is located 36 km from the Solimões River and 5 km from the Janauacá River, a wide river stretching into the center of this portion of the interfluve (Fig. 1). We also found high densities of useful species in these plots (Table S1). Paleoecological studies in Amazonia found charcoal associated with pollen of cultivated plants indicating that fire was associated with agricultural practices (54). All this evidence of landscape domestication is a strong indication of intensive agricultural activities in these areas, even though we did not study pollen or phytoliths. The charcoal we found shows that the forest was transformed, at least locally, probably through agricultural activities. Still, this association of greater abundance of charcoal and past agricultural activities needs more detailed investigation through the studies of phytoliths and pollen in interfluvial soils.

Since not all charcoal particles found in Amazonian forests can be attributed to past human intervention (29), the charcoal particles we found in other sites of the interfluve may be from natural fires or low impact human activities. Low intensity fires without another indication of intensive clearing are probably not a signal of extensive forest disturbance. In two of 13 sites studied on the Purus-Madeira interfluve, charcoal was found associated with phytoliths, confirming human agricultural activities at these sites, but little clearing of the interfluve forest in general (52).

In addition, charcoal analysis is not useful to detect the existence of human activities not related to fire, such as planting useful species on trails inside the forest (32) and discarding seeds while walking to extract fruit or while hunting (22, 31, 55). Even though we did not find a considerable mass of charcoal in M6, useful species composition suggests a history of intense human intervention at this site. *Attalea speciosa*, *Astrocaryum aculeatum* and *Bertholletia excelsa*, indicators of anthropogenic forests (20, 23, 33, 46), were found in the same plots as *Astrocaryum murumuru* and *Elaeis oleifera*, both related to ADE (56).

Understanding the past to conserve and manage for the future. Our study provides a new and realistic view of the extension of the impacts caused by ancient Native Amazonians in a forested landscape. We found a gradient of human manipulation in the forest from the rivers into the Purus-Madeira interfluve. Since this interfluve is full of secondary and smaller rivers crossing its interior, the effect of human manipulation should also be directly related to the distance from these minor rivers. ADE in the vicinity of a secondary river, even more than 5 km away from the Madeira River, contains a unique species composition related to past human activity when compared with non-anthropogenic soils (56). As most ecological studies focus on the vicinity of navigable rivers (36), these studies need to incorporate the effect of human history to better understand the patterns and mechanisms that explain biodiversity. This issue has been raised previously (57, 58), but is still remarkably ignored by many biologists and ecologists (59). Future research must associate floristic inventories with paleoecological and archaeological data to build a more reliable view of the impact of pre-Colombian populations in Amazonia, especially in other interfluvial areas.

Our results have important implications for the conservation and sustainable use of forest resources today, contrary to the claims of Barlow *et al*. (8). Although Amazonia is mostly sparsely populated and filled with apparently empty areas today, such as the interfluves, people live in these forests in remote locations. These people, both indigenous and peasant, depend on the forest’s resources for their well-being. We argue that the modifications left by ancient Native Amazonians in the landscape and in the useful trees and palms community are extremely important to plan sustainable practices for the use of these forests today (60).

The strategies for Amazonian conservation, suggested by the National System of Conservation Units (61), recognize the existence of people living within the forest and extracting non-timber forest products (NTFP). Accordingly, forests that were managed and enriched in the past have an important role for biodiversity conservation, as they concentrate NTFPs that need to be sustainably managed by human populations today (62). Conservation policy makers must also consider that Amazonian forests were domesticated in different degrees. From this point of view, the role of traditional populations, with their management practices, becomes crucial to ensure the conservation of the forest and the culture of the people who live there.

Material and Methods

Study Area. The study was conducted in the interfluve between the Purus and Madeira rivers, in the state of Amazonas, Brazil (Fig. 1), covering an area of approximately 90,000 km². The study was carried out in mature lowland forests along the BR-319 Highway in six previously installed sites of the Research Program in Biodiversity (PPBio) (63, for more details about the sites see: http://ppbio.inpa.gov.br/Eng/inventarios/br319/). The sites are located at different distances from the major rivers and in different environments. M1, M2 and M6 are on *paleo-várzeas*, old floodplains formed during previous glacial periods (27, 30). The other sites are on low plateaus (27).

Botanical Data. First, 10 plots were installed in each site by PPBio, one km from each other. In five of them, all trees were marked and measured. We choose two of these five plots to sample tree composition, considering the high topographic variation between plots, using SRTM (Shuttle Radar Topography Mission) images. All trees and palms with diameter at breast height (DBH) ≥ 10 cm were sampled in plots of 0.5 ha (250 x 20 m). Trees with DBH ≥ 30 cm were sampled in 1 ha plots (250 x 40 m). We inventoried trees with DBH ≥ 10 cm because they may be descendants of pre-conquest management, since old trees that may have been planted or promoted by ancient people will reproduce and their recruits will persist in old anthropogenic forests. Ross (41) found small individuals of useful tree species (> 2.5 cm DBH) in ancient Maya forest gardens after a millennium of abandonment, confirming this expectation. The botanical material was pre-identified in the field by parataxonomists and also collected for comparison with herbarium collections (INPA).

Charcoal Data. We surveyed soil characteristics, including charcoal, in 4-5 plots in each site, for a total of 29 plots surveyed. Two of them are the same plots used for botanical analysis. At the beginning, middle and end of each of the five plots, a small pit were excavated to 50 cm in depth. Using a Kopecky cylinder (100 cm^3), a horizontal collection of undisturbed soil was made at 10 cm intervals. The soil was dried and then visible charcoal was removed for weighing.

Distance Measures. The distances from botanical plots to rivers were calculated using Landsat Thematic Mapper (TM) images. We considered a straight-line distance from the plot to the closest major river (Solimões, Purus or Madeira). To measure the distance to smaller rivers, a buffer zone with a 25 km radius around each plot was traced. We considered 25 km the maximum distance that could be covered on foot leaving the center of occupation for long hunting activities (64). Within each buffer, the shortest distance from the plot to perennial rivers (greater than 50 m in width) was calculated. Only 50 m wide rivers were chosen, as these represent the minimum width of navigable rivers in the region detected using TM images. An index of rivers distances was calculated by the sum of all inverse distance values from each plot to perennial rivers inside the 25 km buffer zone [index of rivers distances = 1 - (1/distance river 1 + 1/distance river 2 + 1/distance river n)].

Hydrological Measures. The gradient of hydrological conditions between plots was composed with two distinct measurements. One measured only in plots that flooded during the rainy season. In these plots, we used the height of water marks on tree trunks left by the highest water level in the previous year. In plots that did not flood we used another method to measure the hydrological condition of the soil. For these plots, we installed a piezometer from the soil surface to seven meters below the ground level. Then, the distance from the soil surface to the highest groundwater level in March in 2011 was measured, as this is the period with the highest groundwater level during the rainy season.

Data Analysis. To evaluate the relationship between useful "tree" parameters (abundance, basal area, richness) and the distance to rivers we used simple linear regressions and nonlinear regressions. For abundance and basal area parameters, the values of all trees and palms with DBH < 30 cm in 0.5 ha were extrapolated to 1 ha. The dependent variables were: 1) the relative abundance of useful trees – number of individual useful trees as a percentage of the total number of individual trees per plot; 2) the relative richness of useful species – number of useful species as a percentage of the total number of species per plot; and 3) relative basal area occupied by useful species – basal area of useful species as a percentage of the total basal area per plot. We used relative values of abundance, richness and basal area due to the high variation in total numbers from one plot to another (Table S1). The shortest distance from major rivers and the index of rivers distances, which reflect the ability of human movement within the interfluve, were the independent variables used in the regressions.

Palm Analysis. In our study area, hydrological conditions seem to be an important factor influencing the distribution and abundance of trees and palms. To determine if the patterns of useful palm abundance observed are associated with environmental parameters, rather than the distance from possible occupation sites, we used multiple regression models. These models included the hydrological gradient as environmental predictor and the distance to rivers as a predictor of human activity, and relative abundance of palms as response variable. These two variables had a low Pearson correlation ($r = 0.25$, $p = 0.46$).

See *SI Text* for more details of study area, useful species, botanical identification and data analysis.

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Supporting Information

Material and Methods

Study Area. Rainfall is high, ranging from 2300 mm in the southern portion of the interfluve to 2750 mm in the north (1). There is an increase in seasonality from one to three months with less than 100 mm of rain towards the south (2). The region is characterized by very flat topography (1). The soils are mostly Plinthosols (FAO soil taxonomy), with hydromorphic soils on the terraces and alluvial plains (3). Most soils are poorly drained during the rainy season, causing flooding. The vegetation is defined as Dense Lowland Rainforest in the north and Open Lowland Rainforest in the south (4). The BR 319 Highway, which connects the cities of Manaus and Porto Velho, is the only access to the interfluve, allowing the placement of sites in areas far from the major rivers.

History of human presence in the region. During the pre-colonial period, the main indigenous ethnic group mentioned as inhabitants of the northern part of the region was the Mura (5). With the arrival of Europeans, disputes over the territory and diseases resulted in the deaths of most indigenous people (6). In the late nineteenth century, the Madeira River was reoccupied for the production of latex extracted from the rubber tree (*Hevea brasiliensis*), which collapsed in 1920. Fifty years later, the region experienced a new process of population expansion with the construction of the BR-319 Highway, allowing a movement of migrants into the interfluve. Currently, the road is almost impassable in most parts (only the northern and southern sections are used regularly), and most people live in cities and small towns near rivers. However, the BR-319 road is being repaved. Consequently, the region will experience another expansion process.

Kern *et al*. (7) report some patches of Amazonian Dark Earth (ADE) along the Purus River. Most of them are present in the southern portion of this river's basin. However, the lower Purus, where it empties into the Solimões River, is part of the largest known center of past human occupation in Central Amazonia (8). On the banks of the Madeira River and its tributaries, a large number of archaeological sites with ADE were also found (9). Furthermore, the lower Madeira River also has high crop genetic diversity (10). Despite the lack of information about the extent of anthropogenic forests in the interfluve, there is abundant evidence of domesticated landscapes (André B. Junqueira, unpublished data). Most of this evidence is present in areas closest to the main rivers.

Mapping Archaeological Evidence. Archaeological evidence and anthropogenic forests were identified and mapped around each research site. The main evidence of pre-modern human activities documented were Amazonian Dark Earths (ADE) and two types of anthropogenic forests, the *castanhais* and *caiauezais*. The identification of ADE and anthropogenic forests was obtained by interviews with local residents and, when possible, GPS coordinates were recorded on site. Characteristics of the evidence, such as the presence of archaeological artifacts (ceramics and lithics), were documented.

Useful Species. To create the list of useful species considered in this study, we used the most important papers in ethnobotany and previous inventories in anthropogenic forests (10-18) in Amazonian forests and archeological sites. The useful species mentioned in at least two studies were included in the list. We also considered their degree of domestication (10), their use as food resources in the daily diet of human populations during long periods in the forest for game hunting or other activities, and also their capacity to attract game. Species with commercial value in the post-colonial period, such as *Hevea brasiliensis* and *Carapa guianensis*, were also included in the list.

Collection of botanical data. At M4, only two plots had been installed at collection time, and one of them is located less than 500 meters from the highway and on the edge of a shifting cultivation plot. We intended to work only in mature forest, so we excluded this plot from analysis.

After a preliminary identification in the field with the aid of parataxonomists, the botanical identification was confirmed by Priscila Souza, graduate student in Botany at INPA, specialists, identification guides and by comparing the vouchers collected to specimens at the INPA Herbarium (Manaus, Brazil) and virtual herbariums (http://fm1.fieldmuseum.org/vrrc/index.php, http://sciweb.nybg.org/science2/vii2.asp). Fertile specimens will be deposited at INPA and sterile material will be deposited at EAFM. Floristic and charcoal data will be available on the PPBio web site (http://ppbio.inpa.gov.br/Eng/inventarios/br319/) and may be requested from the first author.

Results

Archaeological and anthropogenic forest evidence. The M1 site had the highest number and diversity of evidence (Fig. 1). *Castanhais* and *caiauezais* were close to the studied plots (Table S1). ADE was only 4 km from the plots and was located in a soil susceptible to flooding in years with very intense floods. M2 was close to one *castanhal* and the Janauacá River. Local residents affirm that there are many ADE sites around Janauacá Lake, but they have not yet been mapped. At M3 and M4, ADE was only mapped more than 10 km from the sites at the Igapó Açu River, which is the longest river in the interfluve. No ADE was mapped near M6, but this was the only site with Brazil nut trees, *caiaué* and other domesticated plants within the sampled plots (Table S2). At M5, *castanhais* were mapped close to the plot at the edge of a watercourse connected with the Acará River. According to local residents, this river was occupied by Mura Indians in the past and numerous Brazil nut trees occur on its banks.

Useful species. We found 34 useful species from 14 different botanical families. The highest abundance of useful species was found in one plot of M1, the closest to a major river, the Solimões, and the lowest abundance was found at M4, located in an upland forest, 80 km from the Madeira River (Table S1). The five useful species with the largest number of individuals in M1 were *Euterpe precatoria, Hevea brasiliensis, Carapa guianensis, Inga* spp. and *Anacardium parvifolium*; in M6, *Attalea speciosa*, *Euterpe precatoria, Astrocaryum murumuru*, *Oenocarpus bataua* and *Pseudolmedia laevis*; and in M2, *Oenocarpus bataua, Tapirira guianensis Micropholis guyanensis*, *Helicostylis tomentosa* and *Theobroma* spp. (Table S2). These three sites have different useful dominant species.

Table S1. Means and standard deviations of all botanical data and distances measured in the six study sites along the Purus-Madeira interfluve, Amazonas, Brazil. M4 does not have a standard deviation because one plot was discarded.

	M1	**M2**	**M3**	**M4**	**M5**	**M6**
Abundance of all useful species[1]	195,5 ± 36,5	131 ± 13	75 ± 19	42	69,5 ± 10,5	132,5 ± 5,5
Total abundance	520 ± 39	614 ±39	661,5 ±1 28,5	588	551,5 ± 41,5	531,5 ± 76,5
Abundance of useful palms trees	133,5 ± 27,5	84 ±26	19 ± 3	8	28 ± 4	85,5 ± 2,5
Abundance of useful dicotyledonous	62 ± 9	47 ± 13	56 ± 22	34	41,5 ± 6,5	47 ± 3

Basal area of all useful species[2] (m²/ha)	7,47 ± 1,64	3,6 ± 0,14	2,40 ± 0,39	1,67	3,67 ± 0,27	7,16 ± 2,74
Total basal area (m²/ha) [3]	19,99 ± 2,03	22,27 ± 0,31	23,37 ±2 ,01	26,92	24,22 ± 2,67	25,35 ± 3,13
Richness of all useful species	9 ± 1	12 ± 1	14	10	11,5 ± 1,5	12 ± 1
Total richness	44,5 ± 4,5	142 ± 9	164,5 ± 4,5	164	76 ± 1	90 ± 2
Distance from main rivers (km)	11 ± 0,5	36	91,5 ± 0,5	80	39,5 ± 0,5	18,5 ± 0,5
Index of distance	(-)0,06 ± 0,04	0,58 ± 0,03	0,87 ± 0,01	0,93	0,79 ± 0,02	0,77
Distance from ADE (km)	5 ± 0,7	33,0	23	31	-	37
Distance from Anthropogenic Forest (km)	0,5	3,0	13 ± 1,4	15	3 ± 0,7	0,5 ± 0,7

[1] The values of species abundance are the number of all useful trees and palms with DBH ≥ 10 cm in 1 ha.
[2] The value of species basal area are the basal area of all useful trees and palms with DBH ≥ 10 cm in 1 ha.
[3] The values of species richness are the sum of all trees species with DBH ≥ 10 and < 30 cm in 0.5 ha and the largest in 1 ha plot.

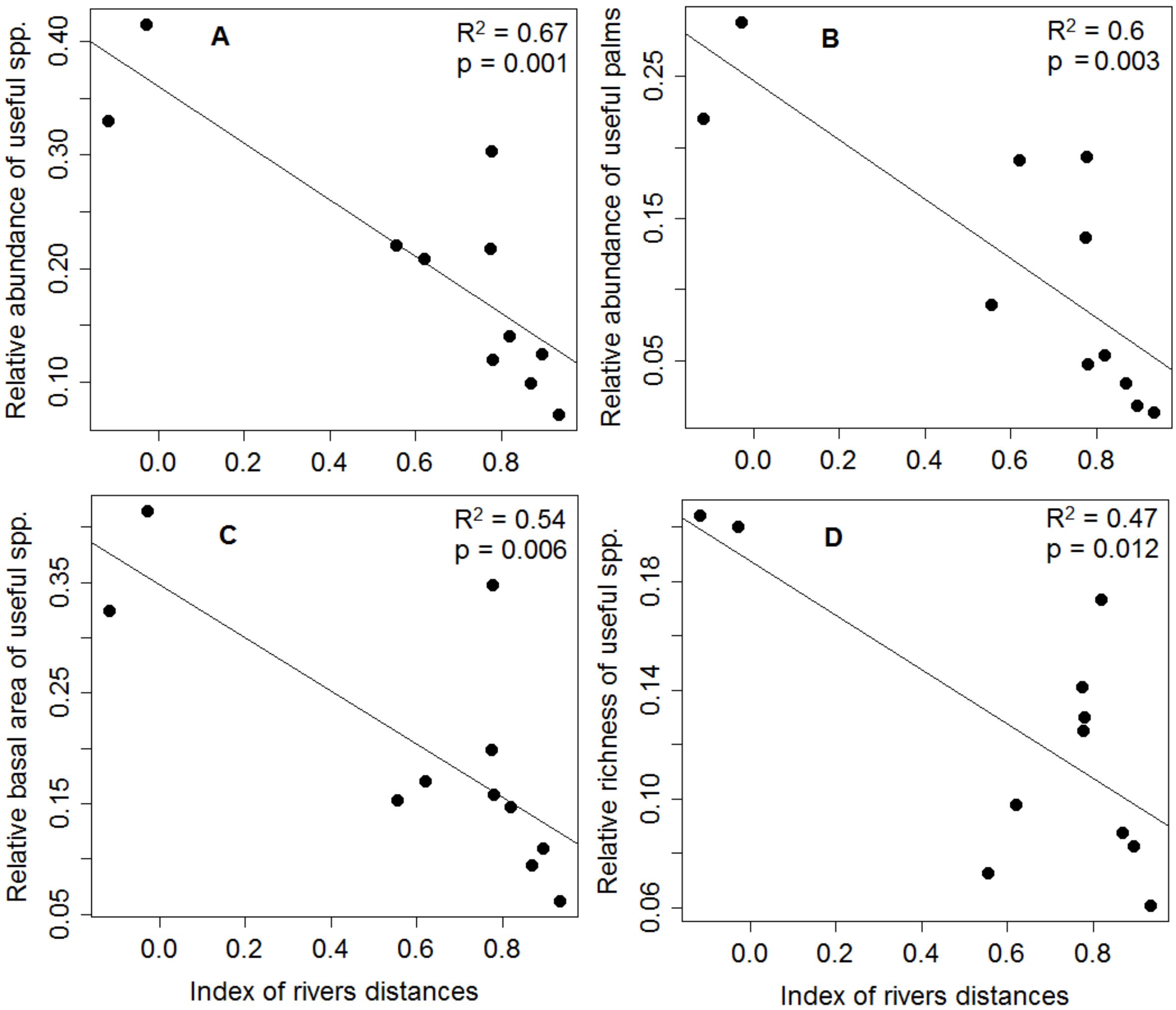

Fig. S1. Relationships between the relative abundance of useful species (A), the relative abundance of useful palms (B), the relative basal area of useful species (C) and the relative richness of useful species (D) with the distance from rivers. Points are the plots of all sites, totaling 11 plots. The index of rivers distances is the sum of the inverse distances from each plot to all perennial rivers greater than 50 m wide in a 25 km diameter zone around the sites. Since we couldn't sample sites with a high variation in distances from secondary rivers, there were two plots in site 1 (M1) with very high index values and the other plots with much lower values.

Table S2. List of useful species found in 11 plots and their respective abundances along the Purus-Madeira interfluve, Amazonas, Brazil.

Species	**Family**	**Common name**	**Degree of domestication**	**M1.1**	**M1.1**	**M2.1**	**M2.2**	**M3.1**	**M3.2**	**M4**	**M5.1**	**M5.2**	**M6.1**	**M6.2**
Anacardium parvifolium Ducke	Anacardiaceae	cajuí	-	8	4	0	0	0	0	0	0	0	0	0
Astrocaryum aculeatum G.Mey.	Arecaceae	tucumã	semi-domesticated	0	0	0	0	0	0	0	0	0	8	0
Astrocaryum murumuru Mart.	Arecaceae	muru-muru	incipiently	2	4	4	0	0	0	0	0	0	0	18
Attalea speciosa Mart. ex Spreng.	Arecaceae	babaçú	-	2	0	0	0	0	0	0	8	12	70	35
Attalea maripa (Aubl.) Mart.	Arecaceae	inajá	incipiently	0	0	6	6	2	2	0	0	0	0	0
Bertholletia excelsa Bonpl.	Lecythidaceae	castanheira	incipiently	0	0	0	0	0	0	0	0	0	10	2
Carapa guianensis Aubl.	Meliaceae	andiroba	-	9	23	0	0	1	2	0	4	0	0	0
Caryocar glabrum (Aubl.) Pers.	Caryocaraceae	pequiarana	-	0	0	0	0	0	0	2	1	4	4	4
Copaifera multijuga Hayne	Fabaceae	copaiba	-	0	0	0	0	0	2	0	2	6	0	2
Couepia guianensis Aubl.	Chrysobalanaceae	pajurá	-	0	0	0	0	0	0	0	0	0	10	0
Couma macrocarpa Barb.Rod.	Apocynaceae	sorva	-	0	0	0	3	2	0	4	5	0	0	0
Dipteryx odorata (Aubl.) Willd.	Fabaceae	cumarú	-	0	0	0	0	2	3	0	0	0	0	3
Ecclinusa guianensis Eyma	Sapotaceae	guajaraí	-	0	0	0	2	0	13	2	2	7	2	7
Elaeis oleifera (Kunth) Cortés	Arecaceae	caiaué	incipiently	0	0	0	0	0	0	0	0	0	0	2
Endopleura uchi (Huber) Cuatrec.	Humiriaceae	uxí	-	0	0	0	0	4	0	2	0	1	1	0
Euterpe precatoria Mart.	Arecaceae	açaí	-	102	157	6	0	0	0	0	20	12	8	12
Garcinia sp.1 L.	Clusiaceae	bacuri	-	0	0	0	0	0	4	0	0	0	0	0
Helicostylis tomentosa (Poepp. & Endl.) Rusby	Moraceae	inharé	-	0	0	4	14	0	7	10	12	5	0	0
Hevea brasiliensis (Willd. ex A.Juss.) Müll.Arg.	Euphorbiaceae	seringueira	incipiently	7	30	0	0	6	13	0	2	3	0	0
Hymenaea parvifolia Huber	Fabaceae	jutaí	-	10	0	0	0	0	0	0	0	0	0	0
Inga gracilifolia Ducke	Fabaceae	inga	-	7	0	0	2	2	0	0	0	0	0	0
Inga alba (Sw.) Willd.	Fabaceae	inga	-	0	4	0	0	1	0	0	0	0	0	0
Manilkara bidentata (A.DC.) A.Chev.	Sapotaceae	massaranduba	-	0	0	0	0	0	3	0	6	2	0	0

Micropholis guyanensis (A.DC.) Pierre	Sapotaceae	balata	-	0	0	2	19	0	10	9	7	7	0	0
Oenocarpus bacaba Mart.	Arecaceae	bacaba	incipiently	0	0	0	6	20	4	8	4	0	0	0
Oenocarpus bataua Mart.	Arecaceae	patauá	incipiently	0	0	94	46	0	10	0	0	0	2	16
Parinari excelsa Sabine	Chrysobalanaceae	pajurá	-	0	0	3	0	0	0	1	0	0	0	10
Pseudolmedia laevis (Ruiz & Pav.) J.F.Macbr.	Moraceae	inharé	-	0	0	6	6	4	16	2	0	0	17	0
Symphonia globulifera L.f.	Clusiaceae	bacuripari	-	8	4	2	0	2	5	0	7	0	0	6
Tapirira guianensis Aubl.	Anacardiaceae	tapiriri	-	0	0	15	5	6	0	2	0	0	0	10
Theobroma obovatum Klotzsch ex Bernoulli	Malvaceae	cacaurana	-	4	6	0	0	0	0	0	0	0	6	0
Theobroma speciosum Willd. ex Spreng.	Malvaceae	cacaurana	incipiently	0	0	0	3	2	0	0	0	0	0	0
Theobroma subincanum Mart.	Malvaceae	cupuí	incipiently	0	0	0	4	2	0	0	0	0	0	0
Theobroma sylvestre Mart.	Malvaceae	cacau-do-mato	-	0	0	2	2	0	0	0	0	0	0	0

- The degree of domestication according to the classification of Clement (1999).

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Conclusão

O estudo contribuiu para produzir uma imagem mais realista da dimensão geográfica dos impactos das antigas populações da Amazônia na paisagem. Somente utilizando regressões simples com a distância dos grandes rios e dos rios menores foi possível explicar 50 a 80% da variação da proporção de espécies úteis no interflúvio Purus-Madeira. Nossos resultados indicam um gradiente de impacto humano na floresta saindo dos grandes rios e adentrando o interflúvio. Como o interflúvio está repleto de rios em seu interior, o efeito da manipulação humana também deve estar diretamente relacionado à distância desses rios. Se os estudos ecológicos concentram-se na proximidade dos rios principais (Pitman *et al*. 2011), há necessidade desses estudos incorporarem o efeito humano histórico para melhor compreensão dos padrões e mecanismos que explicam a biodiversidade atual. Este tema já foi levantado em publicações anteriores (Clark 1996, Wills *et al.* 2007), mas tem sido notavelmente ignorado pelos biólogos e ecólogos (Clement e Junqueira 2010). Pesquisas futuras precisam associar inventários florísticos com dados paleoecológicos e arqueológicos para construirmos uma imagem mais confiável do impacto das populações pré-colombianas na Amazônia, e como este passado ainda molda a biodiversidade atual.

Nossos resultados têm uma importante implicação para a conservação e uso sustentável dos recursos florestais atuais. Apesar de a Amazônia ser considerada uma região pouco populosa e cheia de vazios demográficos, principalmente nos interflúvios, existiam e ainda existem pessoas vivendo no interior da floresta em locais remotos. A vida dessas pessoas e das populações ribeirinhas e indígenas da Amazônia dependem da manutenção da floresta e de seus recursos. Acreditamos que o impacto e as marcas deixadas pelas antigas populações na paisagem e na composição florística atual são extremamente importantes para buscarmos práticas sustentáveis de utilização dessas florestas (Heckenberg *et al*. 2007, McKey *et al*. 2010).

As estratégias para a conservação da Amazônia sugeridas no Sistema Nacional de Unidades de Conservação (SNUC 2001) reconhecem a existência de pessoas que vivem na floresta e dependem da extração de produtos florestais não-madeireiros (PFNM). Nesta perspectiva, as florestas que eram manejadas e enriquecidas no passado têm um importante papel na conservação da biodiversidade, já que concentram PFNM que, em certos casos, precisam continuar sendo manejados para se perpetuarem (Scoles e Gribel 2012). A partir desse ponto de vista, o papel das populações tradicionais torna-se crucial para a manutenção das práticas de manejo que, por sua vez, possam assegurar a floresta e as pessoas que nela vivem.

Apêndices

APÊNDICE A – Ata da Defesa presencial

INPA
INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA

PG-ECO-INPA
PÓS-GRADUAÇÃO EM ECOLOGIA

GOVERNO FEDERAL
BRASIL
PAÍS RICO É PAÍS SEM POBREZA

ATA DA DEFESA PÚBLICA DA DISSERTAÇÃO DE MESTRADO DO PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA DO INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA.

Aos 06 dias do mês de julho do ano de 2012, às 09:30 horas, na sala de aula do Programa de Pós Graduação em Ciências de Florestas Tropicais PPG CFT/INPA, reuniu-se a Comissão Examinadora de Defesa Pública, composta pelos seguintes membros: o(a) Prof(a). Dr(a). **Evandro José Linhares Ferreira**, do Instituto Nacional de Pesquisas da Amazônia - Acre, o(a) Prof(a). Dr(a). **Henrique dos Santos Pereira**, da Universidade Federal do Amazonas e o(a) Prof(a). Dr(a). **Valdely Ferreira Kinupp**, do Instituto Federal de Educação, Ciência e Tecnologia do Amazonas, tendo como suplentes o(a) Prof(a). Dr(a). Ana Carla Bruno, do Instituto Nacional de Pesquisas da Amazônia e o(a) Prof(a). Dr(a). José Luis Campana Camargo, do Instituto Nacional de Pesquisas da Amazônia, sob a presidência do(a) primeiro(a), a fim de proceder a argüição pública do trabalho de **DISSERTAÇÃO DE MESTRADO** de **CAROLINA LEVIS**, intitulado "A transformação humana pré-colombiana da paisagem florestal no interflúvio Purus-Madeira, Amazônia central", orientado pelo(a) Prof(a). Dr(a). Flávia Regina Capellotto Costa, do Instituto Nacional de Pesquisas da Amazônia - INPA.

Após a exposição, o(a) discente foi arguido(a) oralmente pelos membros da Comissão Examinadora, tendo recebido o conceito final:

- [x] APROVADO(A)
- [ ] REPROVADO(A)
- [x] POR UNANIMIDADE
- [ ] POR MAIORIA

Nada mais havendo, foi lavrada a presente ata, que, após lida e aprovada, foi assinada pelos membros da Comissão Examinadora.

Prof(a).Dr(a). Evandro José Linhares Ferreira ____________________

Prof(a).Dr(a). Henrique dos Santos Pereira ____________________

Prof(a).Dr(a). Valdely Ferreira Kinupp ____________________

____
Coordenação PPG-ECO/INPA

APÊNDICE B – Parecer do revisor Mark Bush

PG·ECO·INPA
PÓS-GRADUAÇÃO EM ECOLOGIA

INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA

Avaliação de dissertação de mestrado

Título: **A transformação humana pré-colombiana da paisagem florestal no interflúvio Purus-Madeira, Amazônia central**

Aluno: **CAROLINA LEVIS**

Orientador: **Flávia R. C. Costa** Co-orientador: --------

Avaliador:

Por favor, marque a alternativa que considerar mais apropriada para cada ítem abaixo, e marque seu parecer final no quadro abaixo

	Muito bom	Bom	Necessita revisão	Reprovado
Relevância do estudo	(x)	( )	( )	( )
Revisão bibliográfica	(x)	( )	( )	( )
Desenho amostral/experimental	( )	( )	(x)	( )
Metodologia	(x)	( )	( )	( )
Resultados	(x)	( )	( )	( )
Discussão e conclusões	( )	(x)	( )	( )
Formatação e estilo texto	(x)	( )	( )	( )
Potencial para publicação em periódico(s) indexado(s)	( )	(x)	( )	( )

PARECER FINAL

( ) **Aprovada** (indica que o avaliador aprova o trabalho sem correções ou com correções mínimas)

(X) **Aprovada com correções** (indica que o avaliador aprova o trabalho com correções extensas, mas que não precisa retornar ao avaliador para reavaliação)

( ) **Necessita revisão** (indica que há necessidade de reformulação do trabalho e que o avaliador quer reavaliar a nova versão antes de emitir uma decisão final)

( ) **Reprovada** (indica que o trabalho não é adequado, nem com modificações substanciais)

Florida Institute of Technology_, ____4/16/2012________, ______________________
Local Data Assinatura

Comentários e sugestões podem ser enviados como uma continuação desta ficha, como arquivo separado ou como anotações no texto impresso ou digital da tese. Por favor, envie a ficha assinada, bem como a cópia anotada da tese e/ou arquivo de comentários por e-mail para pgecologia@gmail.com e claudiakeller23@gmail.com ou por correio ao endereço abaixo. O envio por e-mail é preferível ao envio por correio. Uma cópia digital de sua assinatura será válida.

Endereço para envio de correspondência:

Claudia Keller
DCEC/CPEC/INPA
CP 478
69011-970 Manaus AM
Brazil

APÊNDICE C – Parecer da revisora Marielos Peña Claros

PG·ECO·INPA
PÓS-GRADUAÇÃO EM ECOLOGIA

Instituto Nacional de Pesquisas da Amazônia - INPA
Graduate Program in Ecology

INPA
INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA

Referee evaluation sheet for MSc thesis

Title: **Pre-Colombian human transformation of forest landscapes of the Purus-Madeira interfluve, Central Amazonia**

Candidate: **CAROLINA LEVIS**

Supervisor: **Flávia R. C. Costa** Co-supervisor: ---------

Examiner: Marielos Peña Claros

Please check one alternative for each of the following evaluation items, and check one alternative in the box below as your final evaluation decision.

	Excellent	Good	Satisfactory	Needs improvement	Not acceptable
Relevance of the study	(X)	( )	( )	( )	( )
Literature review	( )	(X)	( )	( )	( )
Sampling design	( )	( )	(X)	( )	( )
Methods/procedures	( )	(X)	(X)	( )	( )
Results	( )	(X)	( )	( )	( )
Discussion/conclusions	(X)	(X)	( )	( )	( )
Writing style and composition	( )	(X)	( )	( )	( )
Potential for publication in peer reviewed journal(s)	( )	(X)	( )	( )	( )

FINAL EVALUATION

( ) Approved without or minimal changes

(X) Approved with changes (no need for re-evaluation by this reviewer)

( ) Potentially acceptable, conditional upon review of a corrected version (The candidate must submit a new version of the thesis, taking into account the corrections asked for by the reviewer. This new version will be sent to the reviewer for a new evaluation only as acceptable or not acceptable)

( ) Not acceptable (This product is incompatible with the minimum requirements for this academic level)

Wageningen, 9/05/2012, Marielos Peña C.
Place **Date** **Signature**

Additional comments and suggestions can be sent as an appendix to this sheet, as a separate file, and/or as comments added to the text of the thesis. Please, send the signed evaluation sheet, as well as the annotated thesis and/or separate comments by e-mail to pgecologia@gmail.com and claudiakeller23@gmail.com or by mail to the address below. E-mail is preferred. A scanned copy of your signature is acceptable.

Mailing address:

Claudia Keller
DCEC/CPEC/INPA
CP 478
69011-970 Manaus AM
Brazil

APÊNDICE D – Parecer do revisor David G. Campbell

Programa de Pós-graduação em Ecologia

PG·ECO·INPA
PÓS-GRADUAÇÃO EM ECOLOGIA

INPA
INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA

Avaliação de dissertação de mestrado

Título: **A transformação humana pré-colombiana da paisagem florestal no interflúvio Purus-Madeira, Amazônia central**

Aluno: **CAROLINA LEVIS**

Orientador: **Flávia R. C. Costa** Co-orientador: --------

Avaliador: **David G. Campbell**

Por favor, marque a alternativa que considerar mais apropriada para cada ítem abaixo, e marque seu parecer final no quadro abaixo

	Muito bom	Bom	Necessita revisão	Reprovado
Relevância do estudo	(x)	( )	( )	( )
Revisão bibliográfica	( )	(x)	( )	( )
Desenho amostral/experimental	(x)	( )	( )	( )
Metodologia	(x)	( )	( )	( )
Resultados	(x)	( )	( )	( )
Discussão e conclusões	( )	(x)	( )	( )
Formatação e estilo texto	(x)	( )	( )	( )
Potencial para publicação em periódico(s) indexado(s)	(x)	( )	( )	( )

PARECER FINAL

(X) **Aprovada** (indica que o avaliador aprova o trabalho sem correções ou com correções mínimas)

( ) **Aprovada com correções** (indica que o avaliador aprova o trabalho com correções extensas, mas que não precisa retornar ao avaliador para reavaliação)

( ) **Necessita revisão** (indica que há necessidade de reformulação do trabalho e que o avaliador quer reavaliar a nova versão antes de emitir uma decisão final)

( ) **Reprovada** (indica que o trabalho não é adequado, nem com modificações substanciais)

Grinnell, IAm EUA	**17 de Maio 2012**	David G. Campbell **David G. Campbell**
Local	**Data**	**Assinatura**

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APÊNDICE E – Ata da aula de qualificação

PG-ECO-INPA
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AULA DE QUALIFICAÇÃO

PARECER

Aluno(a): CAROLINA LEVIS
Curso: ECOLOGIA
Nível: MESTRADO
Orientador(a): FLÁVIA COSTA

Título:

"A influência humana passada sobre a comunidade arbórea em um trecho do interflúvio Purus Madeira, Amazônia".

BANCA JULGADORA:

TITULARES:
Rita C. Mesquita (INPA)
Charles Clement (INPA)
Valderly Kinup (IFAM)

SUPLENTES:
Elisa Wanderli (EMBRAPA)
Bruce Nelson (INPA)

	PARECER		ASSINATURA
Rita C. Mesquita (INPA)	(X) Aprovado	( ) Reprovado	
Charles Clement (INPA)	(X) Aprovado	( ) Reprovado	
Valderly Kinupp (INPA)	(X) Aprovado	( ) Reprovado	
Elisa Wanderli (EMBRAPA)	( ) Aprovado	( ) Reprovado	
Bruce Nelson (INPA)	( ) Aprovado	( ) Reprovado	

Manaus(AM), 04 de abril de 2011

OBS: A banca recomenda cautela redobrada quanto aos critérios de inclusão de espécies arbóreas úteis, inclusive adequando a categorização utilizada. A banca considerou que a aluna apresentou uma boa aula e respondeu satisfatoriamente os questionamentos feitos.

INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA INPA
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