The legacy of 4,500 years of polyculture agroforestry in the eastern Amazon

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Abstract:

The legacy of pre-Columbian land use on modern Amazonian forests has stimulated considerable debate which, until now, has not been satisfactorily resolved due to the absence of integrated studies between pre-Columbian and modern land use. Here we show an abrupt enrichment of edible forest species combined with the cultivation of multiple annual crops in lake and terrestrial fossil records associated with pre-Columbian occupation in the eastern Amazon. Our results suggest that ~4,500 years ago, pre-Columbians adopted a polyculture agroforestry subsistence strategy that intensified with the development of Amazon Dark Earth soils after ~2,000 cal yr B.P. These millennial-scale polyculture agroforestry systems have left an enduring legacy on the modern enrichment of edible plants, demonstrating the important role of past indigenous land management in shaping modern forest ecosystems in the eastern Amazon.

Summary Paragraph

The legacy of pre-Columbian land use in the Amazonian rainforest is one of the most controversial topics in the social[1–10] and natural sciences[11,12]. Until now, the debate has been limited to discipline-specific studies, based purely on archaeological data[8], modern vegetation[13], modern ethnographic data[3], or a limited integration of archaeological and palaeoecological data[12]. The lack of integrated studies to connect past land use with modern vegetation has left questions about the legacy of pre-Columbian land use on the modern vegetation composition in the Amazon unanswered[11]. Here we show persistent anthropogenic landscapes for the past 4,500 years have had an enduring legacy on hyperdominance of edible plants in modern forests in the eastern Amazon. We found an abrupt enrichment of edible plant species in fossil lake and terrestrial records associated with pre-Columbian occupation. Our results demonstrate that through closed-canopy forest enrichment, limited clearing for crop cultivation, and low-severity fire management, long-term food security was attained despite climate and social changes. Our results suggest that in the eastern Amazon the subsistence basis for the development of complex societies began ~4,500 years ago with the adoption of polyculture agroforestry, combining the cultivation of multiple annual crops with the progressive enrichment of edible forest species, and exploitation of aquatic resources. This subsistence strategy intensified with the later development of ADEs, enabling the expansion of maize cultivation to the Belterra Plateau providing a food production system that sustained growing human populations in the eastern Amazon. Furthermore, these millennial-scale polyculture agroforestry systems have an enduring legacy on the hyperdominance of edible plants in modern forests in the eastern Amazon. Together, our data provide a long-term example of past anthropogenic land use that can inform management and conservation efforts in modern Amazonian ecosystems.

Introduction

The extent to which pre-Columbian societies altered Amazonian landscapes is one of the most debated topics in botany[3,11,13–15], archaeology[1,2,5–7], palaeoecology[7,12,16–19], and conservation[4,20,21]. New findings show a disproportionate number of plants, accounting for half of all trees in the Amazon, are hyperdominant[22], and domesticated species are five times more likely to be hyperdominant than non-domesticated species[13]. This is particularly prevalent in archaeological sites, suggesting the effect of pre-Columbian people on modern flora is more pronounced than previously thought[13]. The pre-Columbian anthropogenic soils known as Amazonian Dark Earths (ADEs) (traditionally called *Terras Pretas de Índio*), are one of the most distinct lines of evidence of human transformation of Amazonia because these modified soils are indicators of pre-Columbian sedentary occupation[23,24]. ADEs have been associated with sustained and intensive agriculture in the past, and have been re-utilised by modern farmers because of their extremely high fertility[4]. Several studies have shown that (i) forests on ADEs have a distinct species composition, exhibiting greater richness and higher abundance of domesticated and edible plants (used as food resources)[25], (ii) the more complex the ADE archaeological context (e.g., multi-component sites), the greater the floristic composition of cultivated useful plants in modern home gardens[26], and (iii) increased fertility associated with ADEs improves conditions for the establishment and growth of exotic species that are generally more nutrient-demanding than native Amazonian species[27]. However, the lack of detailed integrated archaeological/palaeoecological studies to connect past land use with modern vegetation have left fundamental questions about land use practices and the impact of ADEs on modern Amazonian ecosystems unresolved. To address these issues we integrate archaeology and archaeobotany records which reflect local-scale vegetation histories with lake and terrestrial palaeoecology which reflect broader regional-scale vegetation histories, combined with palaeoclimate and modern botanical surveys to investigate the impact of the past 4,500 years of human land use in the eastern Amazon (Fig. 1).
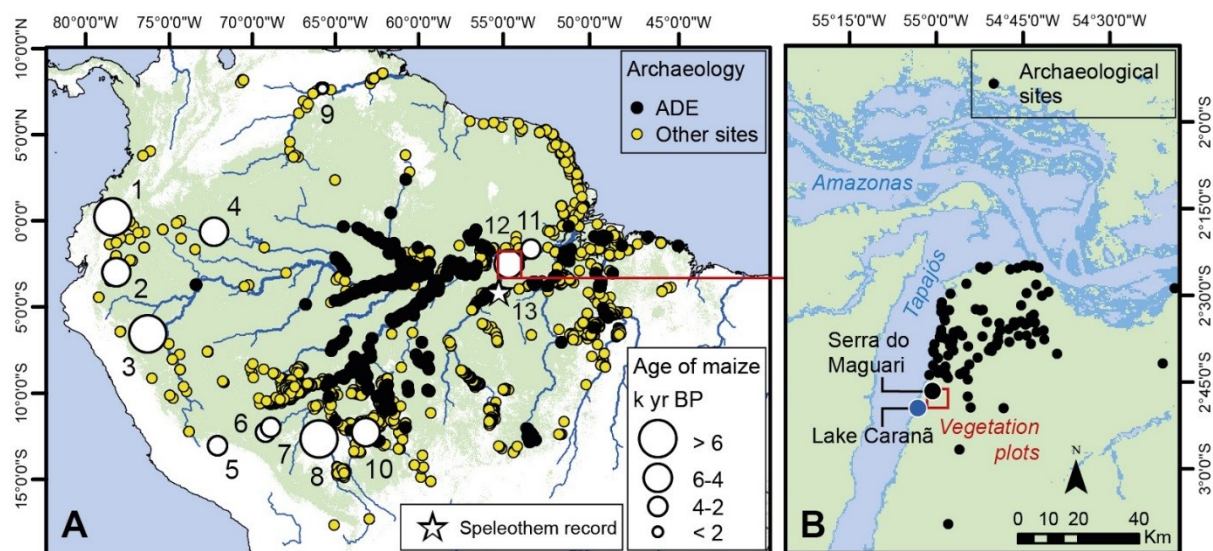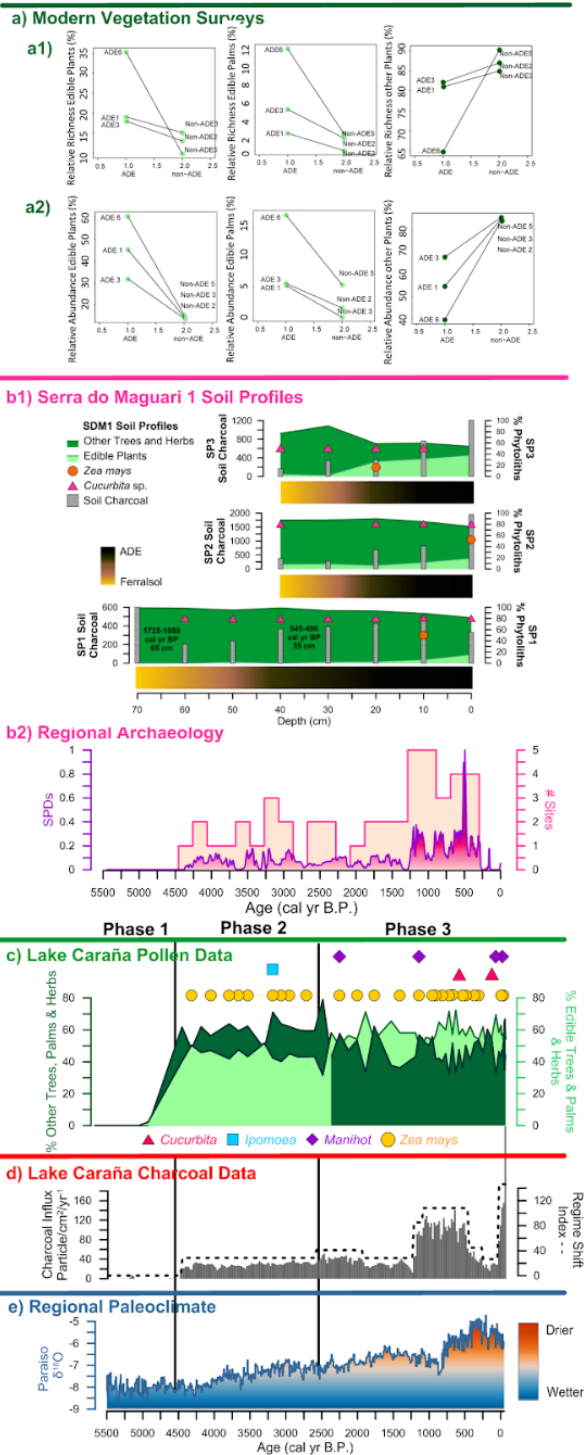

Figure 1. Regional Study Area a. Map showing Amazonian pollen, archaeological site [93,94] and records documenting early presence of maize: 1. Lake San Pablo, 2. Lake Ayauch, 3. Lake Sauce, 4. Abeja, 5. Huaypo, 6. Puerto Maldonado, 7. Lake Gentry, 8. Lake Rogaguado, 9. Parmana, 10. Monte Castelo, 11. Geral, 12. Lake Caranã (Supplementary Table S1). 13. Location of Paraíso Cave speleothem record (indicated by star). **b.** Santarém region showing location of Lake Caranã and the Serra do Maguari archaeological site [50].

Results

The study area located within the protected rainforest of the FLONA Tapajós Reserve, which provides an ideal setting because of the presence of extensive archaeological sites, high concentrations of ADE soils, a nearby lake with limited riverine influence, and the existence of a nearby high-resolution palaeoclimate record[28]. We (i) collected a 210 cm sediment core dating to ~8,500 cal B.P. from Lake Caranã (LC, ~0.7 km in diameter, ~3 m depth; 02.500 S, 55.020 W; 5 m.a.s.l.) for palaeoecological analysis (Methods M1-8); (ii) carried out excavations and sampled three ADE soil profiles at the nearby Serra do Maguari-1 (SDM1) archaeological site (Methods M 9-10), ~5 km NE of LC on the crest of the upper slope of Belterra Plateau (BTP) (02.480 S, 55.040 W; 126 m.a.s.l.) (Fig. S4), compiled existing regional archaeological data (Methods M11), and (iii) set up survey plots (three in ADE and three in non-ADE sites) to perform modern vegetation inventories (Supplementary Fig. S6; Methods M12). Due to the extensive landscape level modification of soils in this region, we define non-ADEs plots as less modified soils without ceramics, located at least 150 m from dark ADE soils. As the formation and utilisation of ADEs is closely associated with food production, we focus our analysis on edible plant taxa in the pollen, phytolith and botanical assemblage. We classify edible plants as taxa that are ethnographically used as food resources in the Americas following Clement[29], Levis et al[13], and Hanelt[30]. These proxies are compared to the nearby

Figure 2. Interdisciplinary data summary: Comparison of a, Comparison of modern vegetation surveys from the three ADE and the three non-ADE sites. b, The phytolith percentage summary diagram of soil profiles, including edible, other trees and herbs, soil charcoal records, and the ADE soil lithology from SDM1 (top). The SPDs from complied archaeological sites of the Santarém region are also shown (bottom)(Supplementary Table 3). c–e, A summary of the Lake Caranã pollen data (c), the charcoal influx (grey bars) and regime shift index (dashed line) from Lake Caranã (d) and the Paraíso cave speleothem record (e). The age-depth model for Lake Caranã is based on calibrated C and Pb dates (Supplementary Table 2). Data in e from ref. [28].

speleothem record of Paraíso Cave (Fig. 2E), which provides a high-resolution record of natural climate variability for the past ~45,000 years[28].

We used a combination of ^{210}Pb and AMS-radiocarbon dating techniques to develop a robust chronology for the age-depth model for LC. [210]Pb dating was used to constrain the most recent palaeoenvironmental changes (<250 years), while AMS-radiocarbon dating was used to date sediments >200 years (Methods M3). Based on the compiled charcoal, pollen and geochemical data, three main phases are identified at LC representing the past ~8,500 years (Fig. 2 and 3, Supplementary Figs. S1-3, Methods M2-8, and Supplementary Table S2):

Phase 1 (210-128 cm; Before ~4,500 cal B.P.). Geochemical data (Supplementary Fig. S2 and Methods M3-M5) characterise Phase 1 as a high-energy environment with increased allochthonous inputs, likely associated with increased riverine influence (Supplementary Discussion D1). Pollen concentration is very low during this period (i.e., <100 grains cm^{-3}) and is attributed to poor preservation associated with sandy soils and low organic material (Supplementary Fig. S1-3). Fire activity is low (Fig. 2D) and there is no palaeoecological evidence of human occupation in the near vicinity during this phase despite documented human activity in the region[9] (Supplementary Discussion D2). Phase 1 is associated with the wettest period in the past ~45,000 years[28].

Phase 2 (128-79 cm; ~4,500-2,500 cal B.P.). Phase 2 begins with the formation of LC following decreased riverine inputs, as indicated by the shift in geochemistry and increase in sediment organics (Supplementary Fig. S2). Pollen is dominated by >50% rainforest taxa (Fig. 2C). ~30% of the total pollen taxa, and the frequency of herbs and grasses remains low throughout the length of the record (<10%). Our record documents the earliest arrival of maize (*Zea mays*) to the eastern Amazon, which is then present consistently after ~4,300 cal B.P.; combined with sweet potato (*Ipomoea batatas*) recorded at ~3,200 cal B.P., the assemblage indicates the lake inhabitants practiced polyculture (mixed cropping) including cereal and tubers crops (Fig. 2C and Supplementary Fig. S3). The occurrence of maize pollen is consistent with a temporal gradient of maize dispersal that begins outside Amazonia and reaches the eastern Amazon ~4,300 cal B.P. (Fig. 1A and Supplementary Table S1), ~3,800 years prior to the development of ADE soils at SDM1. The formation of LC is followed by increased charcoal accumulation, indicating low severity fire activity around the lake (Fig. 2D). Although regional climate data document a gradual shift towards drier conditions from ~4,500 cal B.P., which continues into Phase 3 (Fig. 2E), the synchronous onset of fire activity combined with the presence of maize pollen suggests intentional human-caused ignitions associated with local forest clearance for crop cultivation around the lake. The Sum of the calibrated Probability Distributions (SPDs) from dated archaeological contexts in the lower Tapajós indicate an increase in regional scale pre-Columbian activity after ~4,300 cal B.P. (Fig. 2B2, Methods M11, and Supplementary Table S3). During Phase 2, the residents of Lake Caranã were likely hunting and fishing and utilising the seasonally flooded, nutrient-rich soils surrounding the lake shore, practicing agroforestry and exploiting wild plants, combined with low-level fire activity to clear land for polyculture.

Phase 3 (79-0 cm; 2,500 cal yr BP to modern). Phase 3 is characterised by an increase in edible plants (from ~45 to >70% of terrestrial pollen taxa), a decrease in non-edible plants (from ~50 to 30%), followed by the arrival of manioc (*Manihot esculenta*) ~2,250 cal B.P. (Fig. 2C). The increase in edible plants is not associated with significant change in the regional climate data, suggesting pre-Columbian forest enrichment is the driver of this abrupt change in forest composition. LC exhibits an increase in fire activity ~1,250 to 500 cal B.P., associated with the increase in pre-Columbian activity (Fig. 2B2), coupled with the arrival of squash (*Cucurbita* sp.) ~600 cal B.P. in the lake pollen.

Phase 3 is contemporaneous with the archaeobotanical data from SDM1, a ~15 ha mounded village with a central plaza surrounded by a mosaic of ADE sites (Supplementary

Fig. S4). Mound construction and ADE formation at SDM1 occurred between ~530 and 450 cal B.P. (Supplementary Table S3), and ceramic material at the site is characteristic of the late pre-Columbian Tapajós Period (Supplementary Discussion D2). Herb phytoliths from the three profiles account for ~4 to 18% (Fig. 2B1 and Supplementary Fig. S5). Phytolith data indicate a gradual increase in edible plants (Methods 10, Supplementary Tables 9-10) following the formation of ADE soils that reach the highest levels (>66%) in modern surface soils. Squash is present in the phytolith assemblage at SDM1 from before the formation of the ADE, consistent with the presence of squash in the lake; however, maize does not appear at SDM1 until the ADE has formed. Soil charcoal is present in all three profiles at SDM1 and increases with the formation of ADE soils ~530 cal B.P (Fig. 2B1). The increase in soil charcoal in the ADE layers suggests in-field burning was likely implemented to ameliorate nutrient poor ferralsols on BTP to cultivate nutrient demanding crops, such as maize. Similar practices have been recorded in indigenous Amazonian groups[31]. Sediment charcoal from the lake however, indicates an overall decrease in fire activity in the watershed at this time, synchronous with the driest regional climate conditions in the past 5,500 years (Fig. 2). Modern fire activity in the eastern Amazon is associated with increased droughts[32], thus this decrease in fire suggests pre-Columbian fire management likely suppressed large wildfires during the apex of pre-Columbian activity in the region. This interpretation is further supported by the continued presence of rainforest vegetation at LC (~30 to 45%) and closed canopy forest at SDM1 (~56 to 82%), indicating that large-scale, labour-intensive deforestation did not occur around the lake nor on the plateau over the past 4,500 years. High percentage of trees, increased abundance of palms, low and continuous percentages of herbs, presence of cultigens, and low levels of fire, suggests that the residents of SDM1 were practicing polyculture agroforestry and fire management from ~4,500 cal B.P. The increase of edible plants in the pollen record suggests that the land cleared for cultivation was not abandoned, but instead was managed during early succession to promote edible plant species. Similar cultivation practices are reported in the early accounts of the sixteenth and seventeenth centuries[33], as well as in palaeoecological and archaeobotanical studies in other regions of Amazonia[34,35].

The persistent enrichment of edible plants and palms in the watershed, which began ~2,500 cal B.P. and progressively increased with the formation of ADE soils at SDM1, demonstrates that millennial-scale polyculture agroforestry systems have an enduring legacy on modern forest composition. Modern botanical inventories indicate a heightened enrichment in relative frequency, relative richness, and relative abundance of edible plants (trees and palms) on vegetation plots on the nutrient rich ADE soils in comparison with non-ADE soils (Fig. 2A, Methods M11, Supplementary Fig. S7, and Supplementary Table S4). These data demonstrate the formative conditions that likely account for the disproportionate hyperdominance of edible species in modern Amazonian forests[13,22].

Discussion

Collectively, our study evidences persistent anthropogenic landscapes for the past 4,500 years in the eastern Amazon with a long-lasting effect on the modern hyperdominance of edible species. The low percentage of herbs, permanence of forest cover and increasing charcoal levels at SDM1 are consistent with shaded agroforestry systems that suppress weeds and practice controlled in-field burning as recorded among several indigenous groups today[36,37]. Our record is consistent with a practice of short cropping/long fallow polyculture agroforestry practiced with inefficient stone axes characterised by a mosaic of patches in different stages of succession, forming a complex landscape that transitions from forest to field and back to forest again[3,31,38,39]. Maize was initially cultivated along the LC shore and only with the development of human-enriched soils could it be cultivated in the *terra firme*

upland plateau areas. The development of ADEs may have allowed for the expansion of the cultivation of this productive crop beyond lake margins, which likely increased carrying capacity to sustain the large populations recorded in the region during the historic period[2].

In the periodisation traditionally adopted for South American archaeology, the emergence of sedentary village life coupled with an increased reliance on staple crops has been associated with the onset of the Formative[23,40–42]. The validity of the Formative as a cultural horizon in Amazonia is somewhat questionable due to its temporal heterogeneity across the basin as well as the persistence of Formative lifestyles after the arrival of Europeans to the region[43]. Our data indicates that a diverse polyculture agroforestry system had a more important role in the subsistence base for sedentism and population growth seen during the late Holocene. Additionally, the procurement of aquatic resources (fish, turtles), hunting, and the collection of wild plants likely significantly contributed to the subsistence strategy of eastern Amazonia populations[44,45]. Through the maintenance of closed canopy forest enrichment of edible plants, with limited clearing for crop cultivation and low-severity fire management, long-term food security was attained despite climate and socio-economic changes. The patterns observed in the LC record are concomitant with key periods of cultural transformation in the lower Tapajós. The abrupt increase in fire activity after ~1,250 cal B.P. followed
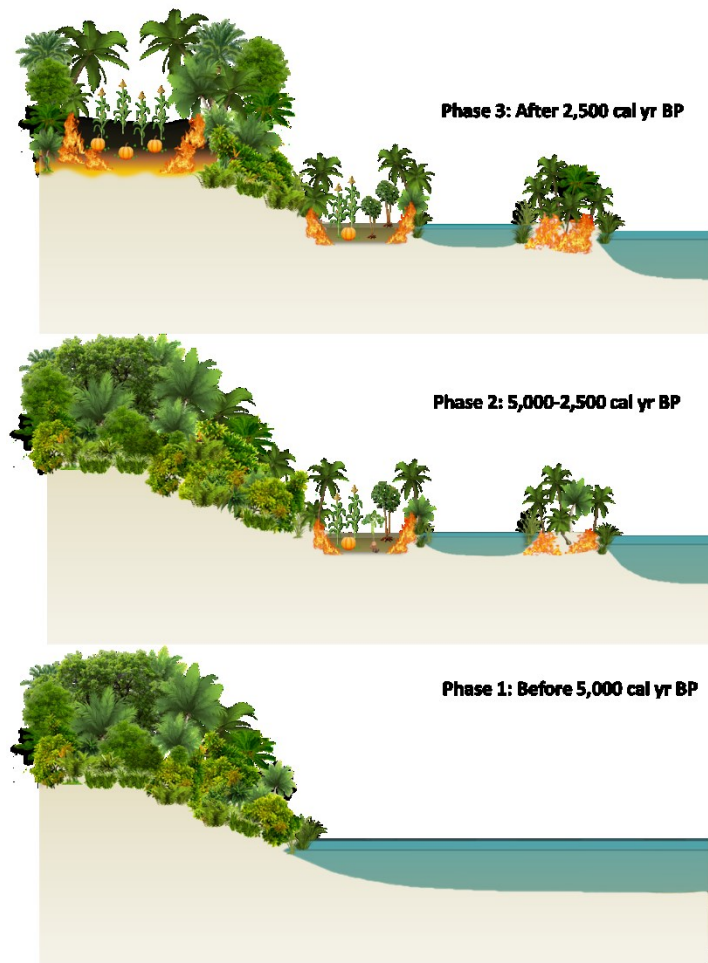

Figure 3. Conceptual landscape drawing of changing vegetation and disturbance regimes as inferred from analysis of pollen, phytoliths, and charcoal from the Lake Caranã core and the SMD1 archaeological site associated with the three phases discussed in results and discussion.

by the arrival of new cultigens (*Cucurbita* sp.) ~600 cal B.P. coincide with the development of the Santarém culture, centered at the modern city of Santarém ,where the largest site comprised of ~16 ha of ADE is located[2]. The Santarém polity purportedly comprised an area of 23,000 km^2 with sites extending for hundreds of miles along river bluffs and interior plateaus[46]. During this period, the lower Tapajós concentrated one of the highest population densities in Amazonia[47–49]. Initially interpreted as a warlike, tribute-based chiefdom that persisted until colonial times[47], the degree of centralisation of the Santarém polity has been recently questioned given the absence of differential access to prestige goods or other clear evidences of hierarchy[50]. Moreover, peripheral sites were shown to be independent of Santarém influence during the early stages of that cultural expansion, although they were ultimately abandoned after ~1,000 cal B.P.[50]. Irrespective of the social organisation implied,

the changes observed in the LC record after ~1,250 cal B.P could reflect changing land management practices aimed to increase subsistence demands associated with the Santarém culture expansion.

As modern deforestation and agricultural plantations expand across the Amazon Basin, coupled with the intensification of drought severity driven by warming global temperatures, these data provide a detailed history of over four millennia of anthropogenic land use that progressively intensified, in the absence of large-scale deforestation, that has a lasting legacy on composition of modern rainforests in the eastern Amazon. These data provide valuable new insights into the vital role indigenous land management practices played in shaping modern ecosystems that can inform ecological benchmarks and future management efforts in the eastern Amazon.

Methods
Palaeoecology Methods
M1. Regional study area. To investigate coupled human-environment systems we designed a multi-proxy approach integrating local (archaeological site/terrestrial palaeoecology) and regional (lake palaeoecology) spatial scales. We selected the Tapajós National Forest (FLONA), located on the eastern side of the white water Tapajós River, ~50 km south of Santarem (Pará state, Brazil), which forms part of the Cretaceous Alter do Chão Formation[51]. Climate is seasonally dry, inter-tropical humid with a distinct wet-season between January to June. Mean annual rainfall ranges between 1900 to 2200 mm year^{-1} and average annual temperatures are between 21 and 31 °C[52]. The vegetation is composed of dense *terra firme* humid evergreen rainforest[53]. An understanding of the spatio-temporal nature of the pre-Amazonian Dark Earths (ADE) subsistence strategies was gained by comparing radiocarbon dated lake sediment core data from Lago Caranã (pollen, charcoal, geochemistry, and magnetic susceptibility) with AMS dated archaeobotanical soil profile data (phytoliths) from *Serra do Maguari-1* (SDM1), which allowed the reconstruction of pre-Columbian land-use and subsistence strategies for the past 5,000 years. These records provided two distinct spatial scales: pollen and charcoal from the lake sediment core provided watershed scale ($<10^6 \, m^2$) vegetation composition(Sugita, 1994) whereas phytoliths, which are deposited *in situ*[55], represent local-scale (~1 m^2) vegetation structure. These data were compared with modern botanical inventory data to evaluate the legacy of pre-Columbian land-use on modern vegetation in the eastern Amazon.

M2. Palaeoecology site selection and core collection. Lago Caranã (LC) (S 02, 50', 08", W55, 02', 33", 5 m a.s.l.) is ~0.7 km in diameter, ~3 m deep, flat bottom lake located on the fluvial terrace on the eastern bank of the Rio Tapajós. LC is located within a small closed basin and is separated from the main river channel (except during extreme flood events) by a depositional sand berm (200 m long, ~3 m tall) located on the NE edge of the lake. A 210 cm sediment core was collected using overlapping drives from a Livingston drive rod piston corer[56] with a modified Bolivia surface corer to collect the sediment-water interface. Cores were transported back to the University of Exeter for cold storage. LC was selected because it is located at the base of the Belterra Plateau, which is rich in archaeological sites and ADE soils and today, receives limited sediment inputs from the Tapajós River. LC is thus ideally located to reconstruct changes in human land use around the Belterra Plateau.

M3. Palaeoecological age-depth model. The chronology for the LC sediment core relies on six radiocarbon (^{14}C) dates, ^{210}Pb radionuclide analysis of recent sedimentation and an age-depth model constructed in Bacon v2.2[57] within R[58]. Ages for the upper sediments of core LC were modelled using ^{210}Pb radionuclide analyses following standard procedures[59].

Atmospheric fallout of ^{210}Pb can be used to estimate the age of sedimentary sequences by measuring the rate of its decay across approximately six to nine half-lives, or 130 to 200 years. The addition of ^{210}Pb dating was used in this study to develop a robust chronology for the most recent palaeoenvironmental changes, which also to provides an important validation tool for the youngest part of the age-depth model that otherwise relies on radiocarbon analyses. Radiocarbon ages that are younger than ~250 cal yrs B.P. contain large calibration uncertainties due to a ~200 year plateau in the calibration curve and are of limited use for tightly constraining recent centuries when developing an age-depth model . Activity of ^{210}Pb was determined by measuring alpha decay of its daughter product ^{210}Po as a proxy [60]. Sediment subsample was spiked with a ^{209}Po chemical yield tracer, acid digested using sequential HNO_3:H_2O_2:HCl (1:2:1) chemical washes at 90°C, and then extracted from the solution, electroplated onto a silver disc, and measured using an Ortec Octête Plus Integrated Alpha-Spectrometry System at the University of Exeter. The age-depth profile was calculated from the total ^{210}Pb inventory, the ^{210}Pb decay constant (0.03114 yr^{-1}), sample-specific activity and cumulative mass using the constant rate of supply model [59], which provided ten ages for the top 0.17 m of the core with modelled root-mean-square-error 2σ uncertainties (Supplementary Table S2). Bulk sediment organic material was collected from the sediment core for conventional AMS radiocarbon dating[61] and sent to Beta Analytic for standard pretreatments and radiocarbon analysis. Radiocarbon ages were calibrated (Supplementary Table S1) within Bacon using IntCal13[62] and modelled using Student-t test distributions with wide tails to negate the need of identifying and removing potential outliers in the age-depth model[63,64]. The use of Bacon and Bayesian statistics to reconstruct the accumulation history at LC allowed us to include every radiocarbon date that was taken throughout the LC core and develop robust estimations of age-depth uncertainty. Age-depth model mean accumulation rate priors in Bacon were calculated using the ^{14}C chronology (*acc.mean=42*) and memory priors were set slightly below default so that the model would capture accumulation rate changes driven by variable sediment delivery from the catchment (*mem.strength=2; mem.mean=0.4*). Model means and 2 σ age distributions were calculated from millions of Markov chain Monte Carlo age-depth iterations through the core (Supplementary Fig. S1). The distribution of profile iterations identified radiocarbon ages Beta-469035 and Beta-469038 as potential outliers. Rather than omit these data points, they were retained and contributed to the uncertainty distribution of the model. For example, at depths 1.00 ±0.005 m and 1.15 ±0.005 m where a possible reversal occurs, the outliers allow for a greater range of age-depth iterations, which provide age estimations (3562 ±423 and 4555 ±514 cal yr B.P. respectively) with larger uncertainties in comparison to the younger part of the model where the age profile distributions were narrower and showed more certainty.

M4. X-ray fluorescence. X-ray fluorescence (XRF) analysis was conducted using a portable XRF Thermo Scientific Niton 3L3t GOLDD at the University of Reading at a step size of 2000 or 5000 μm. A micro-X-ray beam focused through a flat capillary waveguide was used to irradiate samples to enable both X-radiography and XRF analysis. Data were acquired incrementally at 0.25 cm contiguous intervals by advancing the split core through the X-ray beam[65] and results were normalized using z-scores.

M5. Magnetic susceptibility. Magnetic susceptibility (MS) was measured to identify mineralogical variation in the sediments[66]. The MS of sediments is reflective of the relative concentration of ferromagnetic (high positive MS), paramagnetic (low positive MS), and diamagnetic (weak negative MS) minerals or materials. Typically, sediment derived from freshly eroded rock has a relatively high MS, whereas sediments that are dominated by

organic debris, evaporites, or sediments that have undergone significant diagenetic alteration have a low or even negative MS[67]. Sediment cores were scanned horizontally, end to end through the ring sensor. MS was conducted at 1 cm intervals using a Bartington ring sensor equipped with a 75 mm aperture.

M6. Loss-on-ignition. Organic and carbonate sediment composition was determined by loss-on-ignition (LOI) conducted at 4 cm intervals throughout the core. For each sample, 1 cm^3 of sediment was dried in an oven at 100˚C for 24 hours. The samples underwent a series of 2 hour burns in a muffle furnace at 550˚C and 1000˚C to determine the relative percentage of the sample composed of organics and carbonates. Organic composition was determined by weight following standard methodologies[68].

M7. Macrocharcoal. The LC sediment core was subsampled for macroscopic charcoal analysis at 0.5 cm intervals from 0 to 210 cm depth. Samples were analyzed for charcoal pieces greater than 125 μm using a modified macroscopic sieving method[69]. Subsampled material (1 cm^3) was treated with 5% potassium hydroxide in a hot water bath for 15 minutes. The residue was sieved through a 125 μm sieve. Macroscopic charcoal (particles >125 μm in minimum diameter) was counted in a gridded petri dish at 40× magnification on a dissecting microscope. Charcoal counts were converted to charcoal influx (number of charcoal particles cm^{-2} yr^{-1}) and charcoal accumulation rates by dividing by the deposition time (yr cm^{-1}). Charcoal influx data (particles cm^{-2} yr^{-1}) were used as an indicator of *fire severity* (the amount of biomass consumed during a fire episode or period of increased burning). A regime shift detection algorithm (RSI) based on sequential t-tests was applied to determine the occurrence of statistically significant shifts in the charcoal influx data[70]. Shifts were detected in both the mean fluctuations and the variance of raw charcoal counts. The algorithm for the variance is similar to that for the mean, but based on a sequential F-test[71]. RSI values were plotted against charcoal influx data to identify statistically significant changes in past fire regimes, which were interpreted as indicators of fire intensity changes.

M8. Pollen. The LC sediment core was subsampled for pollen analysis at 2 cm intervals between 0 and 128 cm depth (0 to ca. 5,000 cal B.P.) and at 16 cm intervals between 128 and 205 cm depth (5,000 to 8,500 cal B.P.), due to low pollen preservation (<100 terrestrial pollen grains cm^{-3}) below 128 cm. Subsampled material (1 cm^{-3}) was prepared using standard digestion protocol[72], including an additional sieving stage to concentrate large cultigen pollen types such as *Z. mays*[73]. Following this sieving stage, equal numbers of exotic *Lycopodium clavatum* L. tablets[74] were added to both the filtrate and residue of the sieved samples allow for direct comparison of cultigen pollen abundance with the standard terrestrial pollen counts[73]. Large pollen grains (>53 μm) concentrated through the fine-sieving methodology were scanned for *Z. mays* and other crop taxa producing large pollen such as *Manihot esculenta* and *Ipomoea batatas*[73]. The coarse fractions were counted to a standardized equivalent count of 2,000 *Lycopodium* grains (~3 to 4 slides). The pollen in the fine fractions was counted to the standard 300 terrestrial grains. *Mauritia/Mauritiella* were counted and totaled separately due to high concentrations. Larger non-crop pollen that was sieved into the coarse fraction (e.g. *Mauritia/Mauritiella*), was factored back into the total terrestrial pollen sums using abundance calculations from *Lycopodium* counts from the fine and coarse fractions using standard methods[73]. Fossil pollen was identified with reference to the collection of tropical pollen specimens housed at the University of Exeter. Maize pollen grains were distinguished from those of other wild grasses according to defined morphological and size criteria (e.g., grain size: > 80 μm)[75]. Pollen of *Ipomoea batatas* type, *Manihot* and *Cucurbita* are indistinguishable between that of cultigens (sweet potato, manioc,

and squash respectively) and wild relatives, but we are confident that the grains we report come from cultigens since a) wild species of these crops were absent in the botanical survey carried around the lake that represent the catchment area for these large heavy pollen grains, b) the co-occurrence of *Ipomoea*, *Manihot*, and *Cucurbita* pollen, c) their absence at the site before the first signs of human land use, and d) the presence of *Cucurbita* phytoliths in the soil depth profiles. Therefore we interpret it as evidence for sweet potato, manioc, and squash cultivation. Where possible, members of the Moraceae family were identified to genus level using published pollen reference material and morphological descriptions[76]. Pollen taxa were grouped into edible trees, palms, and herbs, crops, other trees and herbs in the pollen diagram based on modern botanical classifications[13,29,30] (Tables S5-S8). In addition to edible palms (e.g. *Mauritia/Mauritiella*), we have included in the 'edible' category of all the plant taxa identified to the genus level in the pollen record that are ethnographically used as food resources in the Americas[30]. Over seventy percent of these pollen taxa are present in the modern botanical inventories, thus these pollen genera likely represent edible species in past anthropogenic forests around Lake Caranã (Table S8). This edible plant classification is a conservative estimate since a large proportion of the families in the 'Other Trees and Herbs' category contain species that are edible, however, these taxa were excluded if they could not be taxonomically identified higher than family level. Pollen percentage data is available in SI. Raw pollen data will be uploaded to Neotoma following publication.

Archaeology Methods

M9. Archaeological site selection. The Serra do Maguari-1 (SDM1) archaeological site (ca. 15 ha) is located on the crest and upper slope of Belterra Plateau (S 02, 47', 87", W55, 03', 53", 126 m a.s.l.). This site was selected due to its proximity ca. 5 km from LC and the presence of mounded architecture and a mosaic of ADE soils which is representative of the regional archaeology. Additionally, SDM1 is within the watershed of LC and provides a comparison of the local, in-situ vegetation reconstruction from the phytoliths soil profiles with the regional vegetation reconstruction from the pollen data. Together, this paired methodology enables the examination of past human disturbance on multidimensional spatial scales.

M10. Soil phytoliths. The three ADE soil profiles from SDM1 were analyzed at 10 cm intervals. Phytolith extraction followed standard protocols[55]. Subsampled material (200 g) was deflocculated by shaking for 24 hours in 900 ml warm water with sodium hexametaphosphate ($NaPO_36$). Clays were removed by gravity sedimentation and separated into silt (<50 µm) and sand (>50µm) fractions by wet sieving. Carbonates were removed with 10% HCl and organic matter with nitric acid (HNO_3). Phytoliths were floated in a heavy metal solution ($ZnBr^2$) and drawn off by pipette. Slides were mounted using Entellan. Identification was carried out using an Axiovision 40 microscope at 200x (>50 µm) and 500x (<50 µm) magnification, respectively. The identification was based on comparison with the reference collection of the Archaeobotany Laboratory at the University of Exeter and by consulting an extensive comparative literature[55,77–83]. In addition to the edible palms (Arecaceae), we included in the edible plants category all the phytolith taxa identified to genus level that are ethnographically used as food resources in the Americas[13,29,30] (Tables S9-10). Test pit samples were analyzed in 10 cm homogenized sample intervals from 0 to 70 cm at Profile 1, and 0 to 40 cm at profiles 2 and 3. Phytolith percentage data is available in SI. Raw phytolith data will be available at: Travassos, D. 2018. 'Dark Earth Plant Management in the Lower Tapajós. Unpublished PhD Dissertation. Department of Archaeology, University of Exeter.

M11. SPDs and site frequencies: The Sum of the calibrated Probability Distributions (SPDs) is a standard method for representing chronological trends in radiocarbon datasets. SPDs are produced by calibrating each independent date in the sample and adding the results to produce a single density distribution. This has the advantage of including the full range of probabilities associated with calibrated dates, instead of using single point estimates[84–88]. SPDs were built in OxCal using the Sum function and the IntCal13 calibration curve[62,89] with an original dataset of 85 radiocarbon dates from the Lower Tapajós. In order to account for oversampling of some sites and phases within those sites, we applied a binning procedure[85,87]. Dates within sites were ordered and those occurring within 100 years of each other were grouped into bins and merged with the R_combine function. Timpson et al.[87] found that different values for the bin-width did not affect the final shape of the SPD. This procedure is necessary because a sum of the calibrated dates assumes that observations are independent, whereas this is not the case when multiple dates were obtained for single sites or phases within them, as was the case with many sites of the Tapajós. The final filtered dataset contained 52 dates. Despite the decrease in sample size, the filtered SPD is highly correlated with an SPD built with all radiocarbon dates ($r^2 = 0.991$, $p < 0.001$). In addition to the SPD, a histogram of the number of occupied sites is used as another proxy of human activity, based on the medians of the calibrated dates per 200 year intervals. Although the radiocarbon record is inherently biased by research (privileged dating of certain sites or periods) and taphonomic factors (greater preservation of charcoal towards more recent periods), SPDs have been shown to be a reliable method to assess past population dynamics in relative terms, provided an adequate sample size and measures of chronometric hygiene[86,87], which were employed here. The trends in the SPD for the Santarém region are confirmed by cultural changes that provide independent evidence of population dynamics: the initial increase after ~4500 cal BP coincides with the appearance of ADE in the Tapajós[90], and the peak after ~1250 cal BP corresponds to the development of the Santarém culture and proliferation of ADE sites in the Belterra plateau[48,91,92].

Modern Vegetation Methods
M12. Modern botanical survey. Three pairs of 0.25 ha plots (50 x 50 m) were sampled in ADE and non-ADE sites on the Belterra Plateau (Supplementary Figure S6). The vegetation is classified as modern *terra firme* forests[53]. All live trees, palms, and lianas with diameter at breast height (~1.30 m above the ground) larger or equal to 10 cm were measured. Species were identified in the field by taxonomic specialists. Vouchers specimens were collected and transferred to the collections Nova Xavantina Herbarium, Nova Xavantina, Mato Grosso following identification. Botanical inventory data was grouped into cultivated edible plants (trees and palms) based on a revised list of domesticated plants from Clement (1999)[29], Levis et al. (2017) [13], and cultivated plants within the Americas - North, Central and South America from Mansfeld's Encyclopedia of Agricultural and Horticultural Crops[30], and other uncultivated trees (Supplementary Tables S5-S7). Relative richness and relative abundance of edible plants, palms and other trees plants were calculated and presented in Fig.2a. The relative abundance indicates the number of individuals of edible/palms/other plants divided by the total number of individuals found in the plot and the relative richness is the number of edible/palms/other plants divided by the total number of species found in the plot. Bar charts for the frequency of edible plants, edible palms and other plants that occur in the vegetation plots and are presented in Supplementary Figs. S7. Data generated or analysed during this study are included in this published article (see supplementary information files).

Data Availability The botanical and archaeological source data used to support the findings of this study are published as supplementary items along with this paper. The pollen, charcoal, and geochemical data from LC have been made publically available through Neotoma and the Latin American Pollen Database.

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Author contributions: JI, SYM, and DPS designed the research; SYM, JI, DA, MR carried out palaeoecological and archaeological fieldwork; EAO carried out botanical inventories; SYM carried out pollen, charcoal, geochemistry and magnetic susceptibility analyses; DA carried out the analysis of archaeological data; RLB built the age-model chronology; JGS compilation and analysis of archaeological radiocarbon dates; CL carried out analysis of modern vegetation and compiled the list of edible plants; SYM and JI led the writing of the paper with inputs from all other authors.

Supplementary Information

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Site name	Latitude	Longitude	presence (cal B.P.)	
Lake San Pablo	0.22	-78.22	~4900	Athens et al. 2016[1]
Lake Ayauch	-3.04	-78.03	~6000	Bush et al. 1989[2]
Lake Sauce	-6.7	-76.21	~ 6320	Bush et al. 2016[3]
Abeja	-0.57	-72.4	~ 5500	Mora et al. 1991[4]
Huaypo	-13.4	-72.13	~ 2800	Mosblech et al. 2012[5]
Lake Gentry	-12.33	-68.87	~ 3630	Bush et al. 2007[6]
Lake Rogaguado	-13	-65.93	~ 6500	Brugger et al. 2016[7]
Parmana	7.86	-65.77	~1600	Roosevelt 1980[8]
Monte Castelo	-12.55	-63.09	~4310	Hilbert et al. 2017[9]
Geral	-1.64	-53.59	~4030	Bush et al. 2000[10]

Table S1. Site *metadata for Figure 1 documenting the early presence of maize in the Amazon.*

Method	Depth	^{210}Pb (Bq kg^{-1})	^{210}Pb (Bq kg^{-1})	Cal. Age (2σ)
	(m)	(supported)	(excess)	(yrs BP)
^{210}Pb	0.005 ±0.005	509.09 ±11.05	421.93 ±11.61	-62.9 ±
^{210}Pb	0.015 ±0.005	552.61 ±20.50	465.45 ±20.81	-60.4 ±
^{210}Pb	0.025 ±0.005	657.43 ±23.43	570.27 ±23.70	-57.3 ±
^{210}Pb	0.045 ±0.005	610.75 ±21.61	523.59 ±21.90	-48.2 ±2.7
^{210}Pb	0.065 ±0.005	709.05 ±26.33	621.88 ±26.57	-36.5 ±4.8
^{210}Pb	0.085 ±0.005	384.40 ±14.81	297.24 ±15.23	-21.5 ±7.2
^{210}Pb	0.105 ±0.005	295.22 ±12.41	208.06 ±12.91	-13.1 ±8.9
^{210}Pb	0.125 ±0.005	163.75 ±7.11	76.59 ±7.95	-6.0 ±10.9
^{210}Pb	0.145 ±0.005	394.06 ±16.48	306.90 ±16.86	5.6 ±15.4
^{210}Pb	0.165 ±0.005	196.66 ±7.83	109.50 ±8.60	42.2 ±45.2
		Lab Code	**^{14}C yrs BP**	
^{14}C	0.30 ±0.005	Beta-469035	1030 ±30	941 ±107
^{14}C	0.60 ±0.005	Beta-469036	1130 ±30	1067 ±105
^{14}C	0.80 ±0.005	Beta-469037	2350 ±30	2394 ±68
^{14}C	0.100 ±0.005	Beta-469038	1830 ±30	1752 ±113
^{14}C	0.115 ±0.005	Beta-427240	4340 ±30	4936 ±91
^{14}C	0.205 ±0.005	Beta-424296	7700 ±40	8492 ±83

Table S2. *Lago Caranã Dates used in age-depth model.*

Site name	14C yr BP	Laboratory number	Reference
Porto	3830 ± 30	Beta-388953	this study
Lago do Jacaré 1	3800 ± 70	Beta-186952	Gomes 2011[11]
Zenóbio	3680 ± 50	Beta-186960	Gomes 2011
Lago do Jacaré 1	3660 ± 70	Beta-186955	Gomes 2011
Lago do Jacaré 1	3660 ± 40	Beta-186956	Gomes 2011
Lago do Jacaré 1	3600 ± 70	Beta-186957	Gomes 2011
Porto	3530 ± 30	Beta-388955	this study
Lago do Jacaré 1	3260 ± 50	Beta-187492	Gomes 2011
Porto	3260 ± 30	Beta-322223	Alves 2014[12]
Porto	3070 ± 30	Beta-386143	this study
Porto	3060 ± 30	Beta-322221	Alves 2012
Porto	3050 ± 30	Beta-386145	this study
Porto	3030 ± 30	Beta-388950	this study
Porto	3030 ± 30	Beta-388954	this study
Aldeia	3000 ± 40	Beta-283902	Gomes 2011
Porto	2912 ± 56	WK6836	Quinn 2004[13]
Porto	2900 ± 30	Beta-322219	Alves 2012
Água azul	2880 ± 30	Beta-293284	Martins 2012[14]
Porto	2820 ± 30	Beta-386138	this study
Lago do Jacaré 1	2740 ± 60	Beta-186958	Gomes 2011
Terra Preta	2490 ± 80	Beta-180713	Gomes 2011
Aldeia	2370 ± 60	Beta-248482	Gomes 2011
Porto	2270 ± 63	WK6834	Quinn 2004
Serraria Trombetas	2200 ± 30	Beta-324198	Martins 2012
Aldeia	2040 ± 40	Beta-248485	Gomes 2011
Terra Preta	1840 ± 50	Beta-186959	Gomes 2011

Aldeia	1800 ± 40	Beta-283903	Gomes 2011
Maguari	1680 ± 30	Beta-433636	this study
Porto	1550 ± 30	Beta-386144	this study
Terra Preta	1320 ± 60	Beta-178443	Gomes 2011
Porto	1260 ± 30	Beta-386139	this study
Fé em Deus	1220 ± 30	Beta-324179	this study
Iruçanga	1220 ± 30	Beta-324179	Schaan 2016[15]
Terra Preta	1220 ± 60	Beta-178442	Gomes 2011
Porto	1210 ± 30	Beta-388952	this study
Maguari	1190 ± 30	Beta-433633	this study
Porto	1140 ± 30	Beta-386135	this study
Lago do Jacaré 1	1020 ± 50	Beta-186954	Gomes 2011
Porto	960 ± 30	Beta-322202	Alves 2012
Terra Preta	910 ± 60	Beta-178444	Gomes 2011
Serraria Trombetas	890 ± 30	Beta-293289	Martins 2012
Serraria Trombetas	780 ± 30	Beta-324188	Martins 2012
Alvorada	680 ± 50	Beta-293282	Martins 2012
Porto	664 ± 57	WK6844	Quinn 2004
Porto	660 ± 30	Beta-386141	this study
Porto	652 ± 56	WK6837	Quinn 2004
Porto	650 ± 59	WK6843	Quinn 2004
Porto	640 ± 30	Beta-386134	this study
Porto	590 ± 30	Beta-386136	this study
Bom Futuro	586 ± 30	Ua-46306	Stenborg 2016[16]
Porto	586 ± 56	WK6839	Quinn 2004
Porto	583 ± 57	WK6833	Quinn 2004
Serraria Trombetas	580 ± 30	Beta-324187	Martins 2012
Cedro	550 ± 30	Beta-324192	Schaan 2016

Bom Futuro	540 ± 30	Ua-46305	Stenborg 2016
Porto	537 ± 58	WK6840	Quinn 2004
Porto	512 ± 59	WK6846	Quinn 2004
Porto	500 ± 30	Beta-386140	this study
Bom Futuro	497 ± 30	Ua-46304	Stenborg 2016
Porto	490 ± 30	Beta-386148	this study
Maguari	470 ± 30	Beta-433637	this study
Fazenda Cacau	460 ± 30	Beta-293286	Martins 2012
Porto	460 ± 30	Beta-386142	this study
Porto	455 ± 63	WK6845	Quinn 2004
Porto	452 ± 57	Wk6837	Quinn 2004
Maguari	430 ± 30	Beta-433632	this study
Porto	425 ± 56	WK6841	Quinn 2004
Porto	418 ± 59	WK6842	Quinn 2004
Porto	413 ± 56	WK6838	Quinn 2004
Porto	410 ± 30	Beta-386146	this study
Porto	400 ± 30	Beta-386147	this study
Porto	400 ± 30	Beta-388951	this study
Maguari	390 ± 30	Beta-433631	this study
Maguari	390 ± 30	Beta-433630	this study
Porto	386 ± 62	WK6832	Quinn 2004
Maguari	380 ± 30	Beta-433629	this study
Porto	380 ± 64	WK6835	Quinn 2004
Bom Futuro	350 ± 30	Beta-324178	Schaan 2016
Maguari	330 ± 30	Beta-433635	this study
Amapá	300 ± 30	Beta-324176	Schaan 2016
Maguari	300 ± 30	Beta-433634	this study
Maguari	290 ± 30	Beta-433628	this study

| Cedro | 240 ± 30 | Beta-324193 | Schaan 2016 |

Table S3. *Dates for local and regional archaeology.*

Individual sum	Sites					
Species	**Non-ADE2**	**Non-ADE3**	**Non-ADE5**	**ADE 1**	**ADE 3**	**ADE 6**
Abarema auriculata Fabaceae	4	2	0	0	0	0
Abuta sp. Menispermaceae	1	0	0	0	0	0
Acrocomia aculeata Arecaceae	0	0	0	0	0	2
Agonandra silvatica Opiliaceae	0	0	0	0	0	0
Amphiodon effusus Fabaceae	2	1	2	0	1	0
Anacardiaceae Anacardiaceae	1	0	0	0	0	2
Aniba panurensis Lauraceae	0	0	1	0	0	0
Aniba rosaeodora Lauraceae	1	0	0	1	0	0
Anthodon sp. Celastraceae	0	0	0	0	0	0
Aparisthmium cordatum Euphorbiaceae	0	0	0	0	0	0
Apuleia leiocarpa Fabaceae	1	0	0	3	0	1
Aspidosperma discolor Apocynaceae	0	0	0	0	0	0
Aspidosperma spruceanum Apocynaceae	0	1	0	0	0	0
Astrocaryum aculeatum Arecaceae	0	0	0	0	0	1
Astrocaryum vulgare Arecaceae	0	0	0	0	0	6
Astronium graveolens Anacardiaceae	0	0	0	0	0	0
Astronium lecointei Anacardiaceae	0	0	0	0	1	0
Attalea microcarpa Arecaceae	0	0	0	0	5	0
Attalea speciose Arecaceae	0	0	0	2	0	4
Bagassa guianensis Moraceae	0	0	0	0	0	0
Bauhinia sp. Fabaceae	0	0	0	1	0	0
Bauhinia ungulate Fabaceae	0	0	0	0	0	0
Bellucia dichotoma Melastomataceae	0	0	0	0	0	0
Bellucia grossularioides Melastomataceae	0	1	0	0	0	0
Bertholletia excelsia Lecythidaceae	1	1	0	3	2	4

Bignoniaceae Bignoniaceae	0	0	0	0	1	0
Bowdichia nitida Fabaceae	0	1	0	0	0	0
Bowdichia sp1 Fabaceae	0	0	0	1	0	0
Bowdichia sp2 Fabaceae	0	0	0	0	0	0
Brosimum acutifolium Moraceae	0	0	0	0	0	0
Brosimum lactescens Moraceae	2	1	0	0	0	0
Buchenavia tetraphylla Combretaceae	1	0	0	0	0	0
Buchenavia viridiflora Combretaceae	0	0	0	0	1	0
Byrsonima crispa Malpighiaceae	0	1	0	0	0	0
Cardiopetalum calophyllum Annonaceae	0	0	0	0	0	1
Cariniana rubra Lecythidaceae	0	0	0	1	0	0
Caryocar villosum Caryocaraceae	0	0	0	0	0	0
Casearia commersoniana Salicaceae	0	0	0	1	0	0
Casearia gossypiosperma Salicaceae	0	0	0	1	0	1
Casearia sp1 Salicaceae	1	0	0	0	0	0
Casearia sp2 Salicaceae	0	0	0	2	0	0
Cathedra acuminate Olacaceae	0	1	2	0	0	0
Cecropia ficifolia Urticaceae	0	0	0	4	5	0
Cecropia sciadophylla Urticaceae	0	1	0	0	0	0
Cedrela odorata Meliaceae	0	0	0	0	0	2
Ceiba pentandra Malvaceae	0	0	0	0	0	0
Celtis iguanaea Cannabaceae	0	0	0	0	1	0
Clarisia racemosa Moraceae	0	0	0	0	0	0
Coccoloba sp. Polygonaceae	0	0	0	1	2	0
Cochlospermum orinocense Bixaceae	0	0	0	0	0	0
Connarus perrottetii Connaraceae	0	0	0	0	0	0
Copaifera sp. Fabaceae	0	0	2	0	0	0
Cordia sp. Boraginaceae	0	1	1	2	4	0

Couepia sp. Chrysobalanaceae	0	0	0	0	0	0
Couratari stellate Lecythidaceae	1	0	2	0	0	0
Coussarea duckei Rubiaceae	1	0	0	0	0	0
Coussarea paniculata Rubiaceae	8	16	0	0	0	0
Crepidospermum goudotianum Burseraceae	0	0	0	0	0	0
Croton sp. Euphorbiaceae	0	0	0	3	0	0
Cupania scrobiculata Sapindaceae	0	0	0	0	0	0
Dialium guianense Fabaceae	1	2	1	1	7	1
Dimorphandra parviflora Fabaceae	1	0	0	0	0	0
Dinizia excelsa Fabaceae	0	0	1	0	0	0
Diospyros cavalcantei Ebenaceae	0	0	0	0	0	0
Diospyros guianensis Ebenaceae	0	1	0	0	0	0
Diplotropis sp1 Fabaceae	0	0	1	0	0	0
Diplotropis sp2 Fabaceae	0	0	0	0	1	0
Dipteryx odorata Fabaceae	0	1	0	0	0	0
Duguetia echinophora Annonaceae	2	4	0	0	0	0
Duguetia Annonaceae	0	0	0	1	0	0
Duroia genipoides Rubiaceae	1	0	0	0	0	0
Duroia macrophylla Rubiaceae	0	1	0	0	0	0
Enterolobium schomburgkii Fabaceae	0	1	0	0	0	0
Ephedranthus parviflorus Annonaceae	0	0	0	0	0	0
Eriotheca globosa Malvaceae	0	0	0	0	2	1
Erisma calcaratum Vochysiaceae	1	0	0	0	0	0
Erisma uncinatum Vochysiaceae	2	10	2	0	0	0
Eschweilera coriacea Lecythidaceae	8	5	7	3	0	1
Eschweilera grandiflora Lecythidaceae	1	4	2	1	0	0
Eschweilera obversa Lecythidaceae	0	0	0	0	0	0

Eugenia cupulata Myrtaceae	0	1	0	0	0	0
Eugenia patens Myrtaceae	0	0	0	0	1	0
Eugenia sp1 Myrtaceae	0	0	0	0	1	0
Eugenia sp2 Myrtaceae	0	0	1	0	0	0
Euphorbiaceae-1 Euphorbiaceae	0	0	0	0	0	0
Euphorbiaceae-2 Euphorbiaceae	0	0	0	0	0	0
Exostyles amazonica Fabaceae	0	0	0	1	0	0
Fabaceae-1 Fabaceae	0	0	1	1	0	0
Fabaceae-2 Fabaceae	0	0	0	1	0	0
Fabaceae-3 Fabaceae	1	0	0	0	0	0
Fabaceae-4 Fabaceae	0	0	0	0	1	0
Ficus sp1 Moraceae	0	0	0	0	0	1
Geissospermum urceolatum Apocynaceae	2	1	1	0	0	0
Glycydendron amazonicum Euphorbiaceae	1	2	0	0	0	0
Guatteria poeppigiana Annonaceae	1	0	1	1	0	0
Guatteria sp1 Annonaceae	0	0	0	0	0	0
Guatteria sp2 Annonaceae	0	0	0	0	0	0
Guazuma ulmifolia Malvaceae	0	0	0	0	0	0
Gustavia augusta Lecythidaceae	0	0	0	0	2	0
Gustavia longepetiolata Lecythidaceae	0	0	0	0	1	0
Handroanthus capitatus Bignoniaceae	0	0	0	0	0	0
Handroanthus incanus Bignoniaceae	0	0	0	0	0	0
Heisteria sp. Olacaceae	0	1	0	0	0	0
Helicostylis elegans Moraceae	0	0	0	0	1	0
Helicostylis tomentosa Moraceae	0	1	0	1	1	0
Hevea brasiliensis Euphorbiaceae	0	0	0	0	0	12
Homalium racemosum Salicaceae	2	0	1	0	0	0

Hymenaea courbaril Fabaceae	0	0	0	0	1	0
Inga alba Fabaceae	2	0	0	1	0	2
Inga edulis Fabaceae	0	0	0	0	3	0
Inga laurina Fabaceae	0	0	1	0	0	0
Inga marginata Fabaceae	0	0	0	0	1	0
Inga nobilis Fabaceae	0	0	0	0	1	1
Inga sp1 Fabaceae	0	1	0	0	0	0
Inga sp2 Fabaceae	0	0	1	0	0	0
Iryanthera juruensis Myristicaceae	0	0	0	0	0	0
Jacaranda copaia Bignoniaceae	1	0	0	0	0	0
Jacaratia spinosa Caricaceae	0	0	0	0	2	0
Lacmellea arborescens Apocynaceae	0	1	0	2	0	0
Lauraceae-1 Lauraceae	2	0	0	0	0	0
Lauraceae-2 Lauraceae	0	0	1	0	0	0
Lauraceae-3 Lauraceae	0	0	1	0	0	0
Lecythis lurida Lecythidaceae	1	0	1	0	0	0
Lecythis Pisonis Lecythidaceae	0	0	0	0	0	0
Leonia sp. Violaceae	0	1	0	0	0	0
Licania kunthiana Chrysobalanaceae	0	0	0	0	0	0
Licania polita Chrysobalanaceae	1	0	1	3	1	0
Licaria guianensis Lauraceae	0	0	0	0	0	0
Lonchocarpus sp. Fabaceae	0	0	0	0	1	0
Luehea cymulosa Malvaceae	1	0	0	2	0	1
Machaerium amplum Fabaceae	1	0	0	0	0	0
Machaerium isadelphum Fabaceae	0	0	0	0	1	1
Machaerium sp1 Fabaceae	0	0	0	0	0	0
Machaerium sp2 Fabaceae	0	0	0	0	0	0
Machaerium sp3 Fabaceae	0	0	0	0	0	0

Machaerium sp4 Fabaceae	1	0	0	0	0	0
Maclura tinctoria Moraceae	0	0	0	0	0	0
Malpighiaceae Malpighiaceae	0	0	0	0	0	1
Malvaceae 1 Malvaceae	0	0	0	0	0	0
Matayba guianensis Sapindaceae	0	0	0	0	0	0
Matayba sp. Sapindaceae	1	0	0	0	0	0
Matayba spruceana Sapindaceae	2	1	0	0	0	0
Mezilaurus itauba Lauraceae	1	0	1	0	1	0
Miconia affinis Melastomataceae	0	0	0	0	1	0
Miconia egensis Melastomataceae	1	0	0	0	0	0
Miconia regelii Melastomataceae	1	0	0	0	0	0
Miconia tomentosa Melastomataceae	1	0	0	0	0	0
Minquartia guianensis Olacaceae	1	0	1	0	0	0
Mouriri grandiflora Melastomataceae	0	0	0	0	0	0
Mouriri sp. Melastomataceae	0	0	0	0	0	0
Moutabea sp. Polygalaceae	0	0	0	0	0	0
Myrcia sp1 Myrtaceae	1	0	0	1	0	0
Myrcia sp2 Myrtaceae	0	0	0	0	0	0
Myrciaria floribunda Myrtaceae	1	0	0	0	0	0
Neea oppositifolia Nyctaginaceae	1	1	1	2	5	0
NI-1 NI-1	0	0	0	0	0	1
NI-2 NI-2	0	0	0	0	0	0
NI-3 NI-3	0	0	0	0	0	0
NI-4 NI-4	0	0	0	0	1	0
NI-5 NI-5	0	0	0	0	1	0
NI-6 NI-6	0	0	1	0	0	0
Ocotea camphoromoea Lauraceae	1	1	0	0	0	0
Ocotea cujumary Lauraceae	0	0	3	0	0	0

Ocotea cymbarum Lauraceae	0	0	0	3	0	1
Ocotea floribunda Lauraceae	0	0	1	0	0	0
Ocotea glomerata Lauraceae	0	0	0	0	0	0
Ocotea longifolia Lauraceae	0	0	0	0	0	0
Ocotea pauciflora Lauraceae	0	1	3	0	0	0
Ocotea sp1 Lauraceae	1	0	0	0	0	0
Ocotea viburnoides Lauraceae	1	0	0	0	0	0
Oenocarpus distichus Arecaceae	2	0	6	1	0	0
Olacaceae Olacaceae	0	0	1	0	0	0
Onychopetalum amazonicum Annonaceae	0	0	0	0	0	0
Ormosia sp. Fabaceae	0	0	5	0	0	0
Ouratea sp. Ochnaceae	2	0	0	0	0	0
Platymiscium sp. Fabaceae	1	0	0	0	0	0
Poeppigia procera Fabaceae	0	0	0	0	0	2
Polygalaceae Polygalaceae	0	0	0	0	0	0
Pouteria campanulata Sapotaceae	0	0	0	1	1	0
Pouteria decorticans Sapotaceae	4	2	1	3	0	0
Pouteria glomerata Sapotaceae	0	0	0	0	0	0
Pouteria sp1 Sapotaceae	1	0	0	1	1	0
Pouteria sp2 Sapotaceae	0	6	0	0	0	0
Pouteria sp3 Sapotaceae	0	2	0	0	0	0
Pouteria speciosa Baehni Sapotaceae	2	1	0	0	1	0
Pouteria torta Sapotaceae	0	0	0	0	0	0
Pouteria venosa Sapotaceae	1	2	0	3	2	1
Protium aracouchini Burseraceae	0	0	1	0	0	0
Protium gallosum Burseraceae	1	0	0	0	0	0
Protium hebetatum Burseraceae	2	1	8	0	0	0

Protium robustum Burseraceae	0	2	0	0	1	0
Protium sp1 Burseraceae	1	0	1	0	0	0
Protium sp2 Burseraceae	0	0	1	0	0	0
Protium unifoliolatum Burseraceae	0	0	0	0	0	3
Pseudolmedia laevigata Moraceae	0	1	0	0	0	0
Pseudolmedia macrophylla Moraceae	0	0	0	0	1	0
Pseudopiptadenia suaveolens Fabaceae	0	0	0	0	0	0
Psidium sp. Myrtaceae	0	0	0	0	0	0
Pterocarpus sp. Fabaceae	0	0	0	1	0	0
Qualea sp. Vochysiaceae	0	0	0	0	0	0
Quiina amazonica Ochnaceae	0	1	0	0	0	0
Rinoreocarpus ulei Violaceae	2	0	3	4	0	0
Salicaceae Salicaceae	0	1	0	0	0	0
Sapindus saponaria Sapindaceae	0	0	0	0	0	2
Sapium glandulosum Euphorbiaceae	0	0	0	0	0	1
Sarcaulus brasiliensis Sapotaceae	1	0	1	0	1	0
Schefflera morototoni Araliaceae	0	1	1	0	0	1
Senegalia polyphylla Fabaceae	0	0	0	0	0	5
Sloanea floribunda Elaeocarpaceae	0	0	0	0	0	0
Sloanea obtusifolia Elaeocarpaceae	0	0	0	0	1	0
Solanum acanthodes Solanaceae	0	0	0	1	0	0
Sorocea sp1 Moraceae	1	0	0	2	0	0
Spondias mombin Anacardiaceae	0	0	0	0	7	9
Sterculia apetala Malvaceae	0	0	0	0	0	0
Stryphnodendron pulcherrimum Fabaceae	0	0	0	0	1	0
Stryphnodendron sp. Fabaceae	0	0	0	0	0	0
Swartzia sp. Fabaceae	0	0	0	0	0	0

Species						
Tabernaemontana sp. Apocynaceae	0	0	0	0	0	0
Tachigali chrysophylla Fabaceae	2	2	3	0	3	0
Tachigali melanocarpa Fabaceae	7	6	9	0	0	0
Tachigali paniculata Fabaceae	0	0	0	0	2	0
Tachigali paniculata Fabaceae	9	7	6	0	0	0
Talisia cerasina Sapindaceae	1	0	0	2	2	1
Talisia veraluciana Sapindaceae	0	0	0	0	0	0
Terminalia dichotoma Combretaceae	0	0	1	0	0	0
Tetragastris altissima Burseraceae	0	0	0	2	0	0
Tetragastris panamensis Kuntze Burseraceae	0	0	2	0	0	1
Tetragastris sp. Burseraceae	0	0	5	0	0	0
Theobroma obovatum Malvaceae	0	1	0	0	0	0
Theobroma speciosum Malvaceae	1	1	0	5	5	0
Trattinnickia boliviana Burseraceae	0	0	0	0	1	0
Trema micrantha Cannabaceae	0	0	0	1	0	0
Trichilia micrantha Meliaceae	0	0	0	1	0	0
Vatairea sericea Fabaceae	0	0	0	0	0	0
Vataireopsis sp. Fabaceae	0	0	0	0	0	0
Violaceae Violaceae	0	0	0	0	0	1
Virola michelii Myristicaceae	12	6	8	0	2	0
Virola sebifera Myristicaceae	1	0	1	0	0	0
Vismia japurensis Hypericaceae	0	0	0	0	0	0
Vitex orinocensis Lamiaceae	0	0	0	0	0	0
Vochysia maxima Vochysiaceae	1	0	0	0	0	0
Vochysia obidensis Vochysiaceae	0	2	0	0	0	0
Xylopia frutescens Annonaceae	0	0	0	0	0	1
Xylopia nitida Annonaceae	0	1	1	1	0	0

Xylopia polyantha Annonaceae	2	1	0	0	1	0
Zanthoxylum rhoifolium Rutaceae	0	0	0	0	0	0
Zanthoxylum sp. Rutaceae	0	0	0	0	0	0
Total	**130**	**117**	**111**	**80**	**94**	**76**

Table S4. *Complete botanical inventory data*

Genus	Species	Family	Type of food	Edible
Achyranthes	*aspera*	Amaranthaceae	vegetable	edible
Acrocomia	*aculeata*	Arecaceae	fruit	edible
Agave	spp.	Agavaceae	beverage	edible
Aiphanes	*aculeata*	Arecaceae	fruit	edible
Alibertia	*edulis*	Rubiaceae	fruit	edible
Alibertia	*myrciifolia*	Rubiaceae	food	edible
Alternanthera	*bettzickiana*	Amaranthaceae	vegetable	edible
Amaranthus	*spp.*	Amaranthaceae	grain and vegetables	edible
Ambelania	*acida*	Apocynaceae	fruit	edible
Anacardium	*giganteum*	Anacardiaceae	fruit	edible
Anacardium	*occidentale*	Anacardiaceae	fruit	edible
Ananas	*comosus*	Bromeliaceae	fruit	edible
Aniba	*rosiodora*	Lauraceae	oil of wood as food additive	edible
Annona	*montana*	Annonaceae	fruit	edible
Annona	*montana*	Annonaceae	fruit	edible
Annona	*muricata*	Annonaceae	fruit	edible
Annona	*reticulata*	Annonaceae	fruit	edible
Annona	*squamosa*	Annonaceae	fruit	edible
Aphandra	*natalia*	Arecaceae	fruit	edible
Arachis	*hypogaea*	Fabaceae	seed	edible
Astrocaryum	*aculeatum*	Arecaceae	fruit	edible
Astrocaryum	*murumuru*	Arecaceae	fruit	edible
Astrocaryum	*vulgare*	Arecaceae	fruit	edible
Attalea	*maripa*	Arecaceae	fruit	edible
Attalea	*phalerata*	Arecaceae	fruit	edible
Attalea	*speciosa*	Arecaceae	fruit	edible
Bactris	*gasipaes*	Arecaceae	fruit	edible

Bactris	*guineensis*	Arecaceae	fruit	edible
Bellucia	*grossularioides*	Melastomataceae	fruit	edible
Bertholletia	*excelsa*	Lecythidaceae	nut	edible
Bixa	*orellana*	Bixaceae	colorant	edible
Bixa	*urucurana*	Bixaceae	colorant	edible
Borojoa	*sorbilis*	Rubiaceae	fruit	edible
Brosimum	*alicastrum*	Moraceae	edible nut	edible
Bunchosia	*armeniaca*	Malpighiaceae	fruit	edible
Byrsonima	*crassifolia*	Malpighiaceae	fruit	edible
Byrsonima	*verbascifolia*	Malpighiaceae	fruit	edible
Calathea	*allouia*	Marantaceae	root	edible
Campomanesia	*aromatica*	Myrtaceae	fruit	edible
Campomanesia	*lineatifolia*	Myrtaceae	fruit	edible
Campsiandra	*comosa*	Fabaceae	fruit	edible
Canavalia	*ensiformis*	Fabaceae	seed	edible
Canavalia	*plagiosperma*	Fabaceae	seed	edible
Canna	*edulis*	Cannaceae	root	edible
Capsicum	*baccatum*	Solanaceae	condiment and spice	edible
Capsicum	*chinense*	Solanaceae	condiment and spice	edible
Carica	*papaya*	Caricaceae	fruit	edible
Caryocar	*brasiliense*	Caryocaraceae	fruit	edible
Caryocar	*glabrum*	Caryocaraceae	nut	edible
Caryocar	*microcarpum*	Caryocaraceae	kernels	edible
Caryocar	*nuciferum*	Caryocaraceae	nut	edible
Caryocar	*villosum*	Caryocaraceae	fruit	edible
Caryodendron	*orinocense*	Euphorbiaceae	nut	edible
Casearia	*decandra*	Flacourtiaceae	fruit	edible
Cassia	*leiandra*	Fabaceae	fruit	edible

Castilla	*ulei*	Moraceae	fruit	edible
Cecropia	*peltata*	Urticaceae	fruit tree	edible
Celtis	*iguanaea*	Cannabaceae	fruit	edible
Celtis	*morifolia*	Cannabaceae	fruit	edible
Celtis	*occidentalis*	Cannabaceae	fruit	edible
Celtis	*reticulata*	Cannabaceae	fruit	edible
Chrysobalanus	*icaco*	Chrysobalanaceae	fruit	edible
Chrysophyllum	*argenteum*	Sapotaceae	fruit	edible
Chrysophyllum	*oliviforme*	Sapotaceae	fruit	edible
Chrysophyllum	*venezuelanense*	Sapotaceae	fruit	edible
Cissus	*gongylodes*	Vitaceae	fruit and stems	edible
Coccoloba	*latifolia*	Polygonaceae	fruit	edible
Conceveiba	*guianensis*	Euphorbiaceae	aril	edible
Couepia	*bracteosa*	Chrysobalanaceae	fruit	edible
Couepia	*chrysocalyx*	Chrysobalanaceae	fruit	edible
Couepia	*edulis*	Chrysobalanaceae	nut	edible
Couepia	*guianensis*	Chrysobalanaceae	seeds	edible
Couepia	*longipendula*	Chrysobalanaceae	nut	edible
Couepia	*subcordata*	Chrysobalanaceae	fruit	edible
Couma	*guianensis*	Apocynaceae	fruit	edible
Couma	*macrocarpa*	Apocynaceae	fruit	edible
Couma	*utilis*	Apocynaceae	fruit, latex	edible
Cucurbita	*maxima*	Cucurbitaceae	vegetable	edible
Cucurbita	*moschata*	Cucurbitaceae	vegetable	edible
Curatella	*americana*	Dilleniaceae	fruit	edible
Cyclanthera	*pedata*	Cucurbitaceae	vegetable	edible
Cyperus	sp.	Cyperaceae	condiment	edible
Desmoncus	*polyacanthos*	Arecaceae	fruit	edible

Dialium	*guianense*	Fabaceae	fruit	edible
Dioscorea	*dodecaneura*	Ebenaceae	root	edible
Dioscorea	*trifida*	Ebenaceae	root	edible
Diospyros	*praetermissa*	Ebenaceae	food	edible
Dipteryx	*odorata*	Fabaceae	food flavouring	edible
Dipteryx	*punctata*	Fabaceae	food flavouring, spice	edible
Duroia	*eriophila*	Rubiaceae	fruit	edible
Elaeis	*oleifera*	Arecaceae	fruit	edible
Endopleura	*uchi*	Humiriaceae	fruit	edible
Erisma	*japura*	Vochysiaceae	fruit	edible
Eryngium	*aquaticum*	Apiaceae	vegetable	edible
Eryngium	*foetidum*	Apiaceae	flavouring, vegetables	edible
Erythroxylum	*coca*	Erythroxylaceae	stimulant	edible
Eschweilera	*Lecythidaceae*	Eschweilera	coriacea	seeds
Eschweilera	*Lecythidaceae*	Eschweilera	grandifolia	seeds
Eugenia	*stipitata*	Myrtaceae	fruit	edible
Eugenia	*uniflora*	Myrtaceae	fruit	edible
Eupatorium	*ayapana*	Asteraceae	condiment	edible
Euterpe	*oleracea*	Arecaceae	fruit	edible
Euterpe	*precatoria*	Arecaceae	fruit	edible
Garcinia	*brasiliensis*	Clusiaceae	fruit	edible
Garcinia	*gardneriana*	Clusiaceae	fruit	edible
Garcinia	*intermedia*	Clusiaceae	fruit	edible
Garcinia	*macrophylla*	Clusiaceae	fruit	edible
Garcinia	*madruno*	Clusiaceae	fruit	edible
Genipa	*americana*	Rubiaceae	fruit, colorant	edible
Grias	*neubertii*	Lecythidaceae	fruit	edible
Grias	*peruviana*	Lecythidaceae	fruit	edible

Hancornia	*speciosa*	Apocynaceae	fruit, latex	edible
Hedyosmum	*brasiliense*	Chloranthaceae	tea	edible
Helianthus	*annuus*	Asteraceae	seeds	edible
Heliconia	*hirsuta*	Heliconiaceae	root	edible
Hevea	*brasiliensis*	Euphorbiaceae	nut, latex	edible
Hevea	*spp.*	Euphorbiaceae	seed, latex	edible
Humiria	*balsamifera*	Humiriaceae	fruit	edible
Hymenaea	*courbaril*	Fabaceae	fruit	edible
Ilex	*guayusa*	Aquifoliaceae	stimulant	edible
Ilex	*paraguariensis*	Aquifoliaceae	stimulant tea	edible
Inga	*alba*	Fabaceae	fruit	edible
Inga	*cinnamomea*	Fabaceae	fruit	edible
Inga	*edulis*	Fabaceae	fruit	edible
Inga	*feuillei*	Fabaceae	fruit	edible
Inga	*heterophylla*	Fabaceae	seeds	edible
Inga	*ilta*	Fabaceae	fruit	edible
Inga	*ingoides*	Fabaceae	fruit	edible
Inga	*laurina*	Fabaceae	fruit	edible
Inga	*laurina*	Fabaceae	fruit	edible
Inga	*macrophylla*	Fabaceae	fruit	edible
Inga	*ornata*	Fabaceae	fruit	edible
Inga	*rubiginosa*	Fabaceae	fruit	edible
Inga	*stipularis*	Fabaceae	seeds	edible
Inga	*velutina*	Fabaceae	fruit	edible
Ipomoea	*batatas*	Convolvulaceae	root	edible
Isertia	*coccinea*	Rubiaceae	fruit	edible
Jacaratia	*spinosa*	Caricaceae	fruit	edible
Justicia	*pectoralis*	Acanthaceae	stimulant	edible

Lacistema	*aggregatum*	Lacistemataceae	fruit	edible
Lecythis	*corrugata*	Lecythidaceae	seeds	edible
Lecythis	*pisonis*	Lecythidaceae	nut	edible
Lecythis	*zabucajo*	Lecythidaceae	seeds	edible
Leersia	*hexandra*	Poaceae	seed	edible
Licania	*incana*	Chrysobalanaceae	fruit	edible
Licaria	*puchury-major*	Lauraceae	fruit used as spice	edible
Licaria	*triandra*	Lauraceae	food flavoring	edible
Macoubea	*guianensis*	Apocynaceae	fruit	edible
Macoubea	*witotorum*	Apocynaceae	fruit	edible
Mammea	*americana*	Clusiaceae	fruit	edible
Manicaria	*saccifera*	Arecaceae	fruit	edible
Manihot	*esculenta*	Euphorbiaceae	root	edible
Manilkara	*bidentata*	Sapotaceae	fruit	edible
Manilkara	*huberi*	Sapotaceae	fruit	edible
Mansoa	*alliacea*	Bignoniaceae	condiment	edible
Maranta	*arundinacea*	Marantaceae	root	edible
Maranta	*ruiziana*	Marantaceae	root	edible
Matisia	*cordata*	Malvaceae	fruit	edible
Mauritia	*flexuosa*	Arecaceae	fruit	edible
Mauritiella	*armata*	Arecaceae	fruit	edible
Mayna	*grandifolia*	Flacourtiaceae	fruit	edible
Melicoccus	*bijugatus*	Sapindaceae	fruit	edible
Melicoccus	*pedicellaris*	Sapindaceae	fruit	edible
Miconia	*ciliata*	Melastomataceae	fruit	edible
Miconia	*longifolia*	Melastomataceae	fruit	edible
Mouriri	*acutiflora*	Melastomataceae	fruit	edible
Mouriri	*crassifolia*	Melastomataceae	fruit	edible

Myrcia	*tomentosa*	Myrtaceae	fruit	edible
Myrciaria	*cauliflora*	Myrtaceae	fruit	edible
Oenocarpus	*bacaba*	Arecaceae	fruit	edible
Oenocarpus	*bataua*	Arecaceae	fruit	edible
Oenocarpus	*distichus*	Arecaceae	fruit	edible
Oenocarpus	*mapora*	Arecaceae	fruit	edible
Omphalea	*diandra*	Euphorbiaceae	seeds	edible
Ouratea	*parviflora*	Ochnaceae	fruit, oil	edible
Pachyrhizus	*tuberosus*	Fabaceae	root	edible
Parinari	*campestris*	Chrysobalanaceae	fruit, seeds	edible
Parinari	*montana*	Chrysobalanaceae	fruit, seeds	edible
Passiflora	*edulis*	Passifloraceae	fruit	edible
Passiflora	*quadrangularis*	Passifloraceae	fruit	edible
Paullinia	*cupana*	Sapindaceae	stimulant	edible
Paullinia	*yoco*	Sapindaceae	stimulant	edible
Persea	*americana*	Lauraceae	fruit	edible
Phaseolus	*lunatus*	Fabaceae	seed	edible
Phaseolus	*vulgaris*	Fabaceae	seed	edible
Platonia	*insignis*	Clusiaceae	fruit, seed	edible
Poraqueiba	*paraensis*	Icacinaceae	fruit	edible
Poraqueiba	*sericea*	Icacinaceae	fruit	edible
Posoqueria	*longiflora*	Rubiaceae	fruit	edible
Poupartia	*amazonica*	Anacardiaceae	fruit	edible
Pourouma	*cecropiifolia*	Urticaceae	fruit	edible
Pourouma	*guianensis*	Urticaceae	fruit	edible
Pourouma	*mollis*	Urticaceae	fruit	edible
Pouteria	*caimito*	Sapotaceae	fruit	edible
Pouteria	*glomerata*	Sapotaceae	fruit	edible

Pouteria	*guianensis*	Sapotaceae	fruit	edible
Pouteria	*lucuma*	Sapotaceae	fruit	edible
Pouteria	*macrocarpa*	Sapotaceae	fruit	edible
Pouteria	*macrophylla*	Sapotaceae	fruit	edible
Pouteria	*multiflora*	Sapotaceae	fruit	edible
Pouteria	*obovata*	Sapotaceae	fruit	edible
Pouteria	*pariry*	Sapotaceae	fruit	edible
Pouteria	*procera*	Sapotaceae	fruit	edible
Pouteria	*ucuqui*	Sapotaceae	fruit	edible
Pouteria	*venosa*	Sapotaceae	fruit	edible
Protium	*heptaphyllum*	Burseraceae	fruit	edible
Protium	*unifoliolatum*	Burseraceae	fruit	edible
Psidium	*acutangulum*	Myrtaceae	fruit	edible
Psidium	*guajava*	Myrtaceae	fruit	edible
Psidium	*guineensis*	Myrtaceae	fruit	edible
Psidium	*sartorianum*	Myrtaceae	fruit	edible
Randia	*ruiziana*	Rubiaceae	fruit	edible
Rhynchoryza	*subulata*	Oryzeae	grain	edible
Rollinia	*leptopetala*	Annonaceae	fruit	edible
Sagittaria	*latifolia*	Alismataceae	food	edible
Salacia	*impressifolia*	Celastraceae	fruit	edible
Sicana	*odorifera*	Cucurbitaceae	vegetable	edible
Siparuna	*guianensis*	Monimiaceae	fruit	edible
Solanum	*sessiliflorum*	Solanaceae	fruit	edible
Solanum	*splenden*	Solanaceae	fruit	edible
Solanum	*stramonifolium*	Solanaceae	fruit	edible
Spilanthes	*acmella*	Asteraceae	condiment	edible
Spilanthes	*oleracea*	Asteraceae	condiment	edible

Spondias	*mombin*	Anacardiaceae	fruit	edible
Sterculia	*apetala*	Malvaceae	seeds	edible
Sterculia	*excelsa*	Malvaceae	seeds	edible
Sterculia	*speciosa*	Malvaceae	fruit	edible
Syagrus	*cocoides*	Arecaceae	fruit	edible
Syagrus	*inajai*	Arecaceae	kernels	edible
Talinum	*triangulare*	Portulacaceae	vegetable	edible
Talisia	*esculenta*	Sapindaceae	fruit	edible
Tapirira	*guianensis*	Anacardiaceae	fruit	edible
Tetragastris	*altissima*	Burseraceae	fruit	edible
Theobroma	*bicolor*	Malvaceae	fruit, seed	edible
Theobroma	*cacao*	Malvaceae	stimulant	edible
Theobroma	*grandiflorum*	Malvaceae	fruit	edible
Theobroma	*microcarpum*	Malvaceae	fruit	edible
Theobroma	*speciosum*	Malvaceae	fruit	edible
Theobroma	*subincanum*	Malvaceae	fruit	edible
Vitex	*cymosa*	Verbenaceae	fruit	edible
Vitex	*gigantea*	Verbenaceae	fruit	edible
Vitex	*triflora*	Verbenaceae	fruit	edible
Xanthosoma	*brasiliense*	Araceae	vegetable	edible
Xanthosoma	*sagittifolium*	Araceae	root	edible
Ximenia	*americana*	Olacaceae	fruit, seeds	edible
Zea	*mays*	Poaceae	grain	edible
Zizania	*palustris*	Oryzeae	grain	edible

Table S5. *Edible plant classifications used in this study*

Genus	Family	Edible
Aphelandra	Acanthaceae	no
Amaranthus	Amaranthaceae	no
Apiaceae	Apiaceae	no
Tabernaemontana	Apocynaceae	no
Dracontium	Araceae	no
Dendropanax	Araliaceae	no
Didymopanax	Araliaceae	no
Oreopanax	Araliaceae	no
Schefflera	Araliaceae	no
Geonoma	Arecaceae	no
Socratea	Arecaceae	no
Ambrosia	Asteraceae	no
Alnus	Betulaceae	no
Arrabidaea	Bignoniaceae	no
Jacaranda	Bignoniaceae	no
Lundia	Bignoniaceae	no
Handroanthus	Bignoniaceae	no
Cocholospermum	Bixaceae	no
Cordia	Boraginaceae	no
Symphonia	Clusiaceae	no
NA	Combretaceae	no
Doliocarpus	Dilleniaceae	no
NA	Elaeocarpaceae	no
Acalypha	Euphorbiaceae	no
Alchornea	Euphorbiaceae	no
Croton	Euphorbiaceae	no
Mabea	Euphorbiaceae	no

Phyllanthus	Euphorbiaceae	no
Sapium	Euphorbiaceae	no
Sebastiana	Euphorbiaceae	no
Acacia	Fabaceae	no
Anadenanthera	Fabaceae	no
Apuleia	Fabaceae	no
Bauhinia	Fabaceae	no
Bowdichia	Fabaceae	no
Centrolobium	Fabaceae	no
Chamaecrista	Fabaceae	no
Dalbergia	Fabaceae	no
Desmodium	Fabaceae	no
Hymenea	Fabaceae	no
Machaerium	Fabaceae	no
Macrolobium	Fabaceae	no
Mimosa	Fabaceae	no
Ormosia	Fabaceae	no
Pterogyne	Fabaceae	no
Senna	Fabaceae	no
Swartzia	Fabaceae	no
NA	Flacourtiaceae	no
Episcia	Gesneriaceae	no
Vantanea	Humiriaceae	no
*NA	Hymenophyllaceae	no
Leretia	Icacinaceae	no
NA	Lamiaceae	no
Utricularia	Lentibulariaceae	no
Heteropteris	Malpighiaceae	no

Ceiba	Malvaceae	no
*NA	Malvaceae	no
Pseudobombax	Malvaceae	no
Cedrela	Meliaceae	no
NA	Meliaceae	no
Ruagea	Meliaceae	no
NA	Moraceae	no
Pseudolmedia	Moraceae	no
Sorocea	Moraceae	no
Stylogene	Myrsinaceae	no
*NA	Myristicaceae	no
Virola	Myristicaceae	no
Myrsine	Myrsinaceae	no
Podocarpus	Podocarpaceae	no
Polygala	Polygalaceae	no
Polygalaceae	Polygalaceae	no
Polygonum	Polygalaceae	no
Gouania	Rhamnaceae	no
*NA	Rhizophoraceae	no
Borreria	Rubiaceae	no
Psychotria	Rubiaceae	no
Spermacoce	Rubiaceae	no
NA	Rutaceae	no
Simarouba	Simaroubaceae	no
Luehea	Tiliaceae	no
Typha	Typhaceae	no
Trema	Ulmaceae	No

Table S6. *Pollen taxa identified in this study with no documented edible Genus.* *Indicates pollen less than 5% and not included in pollen diagram.

Pollen Taxa	Family	Putative Edible	Type of food
Acanthaceae	Acanthaceae	*Justicia* spp.	stimulant
Agavaceae	Agavaceae	*Agave* spp.	beverage
Apiaceae	Apiaceae	*Eryngium* spp.	flavoring, vegetables
Apocynaceae	Apocynaceae	*Ambelania* sp.	fruit
Asteraceae	Asteraceae	*Eupatorium* sp.	condiment
Bignoniaceae	Bignoniaceae	*Mansoa* sp.	condiment
Cyperaceae	Cyperaceae	*Cyperus*	condiment
Lecythidaceae	Lecythidaceae	*Lecythis pisonis*	seed
Malvaceae	Malvaceae	*Sterculia apetala*	seed
Marantaceae	Marantaceae	*Maranta arundinacea, M. ruiziana*	root
Myrtaceae	Myrtaceae	*Campomanesia*	fruit
Melastomataceae	Melastomataceae	*Bellucia grossularioides*	fruit
Poaceae	Poaceae	*Leersia, Pharus, Oryzeae glumaepatula, O. alta*	grain
Sapindaceae	Sapindaceae	*Melicoccus*	fruit
Sapindaceae	Sapindaceae	*Talisia* sp.	fruit
Solanaceae	Solanaceae	*Capsicum* sp.	condiment, spice

Table S7. *Pollen taxa identified in this study identified to family level with known edible genus.*

Pollen Taxa	Family	Putative Edible	Common name	Type of food
Sagittaria	Alismataceae	*S. latifolia*	Arrowhead	food
Tapiria+	Anacardiaceae	*T. guianensis*	Wild mahogany	fruit
Spondias+*	Anacardiaceae	*S. mombin*	Hog plum, taperibá	fruit
Annona+*	Annonaceae	*A. mucosa, A. muricata*	Wild custard apple, biribá	fruit
Ilex	Aquifoliaceae	*I. guayusa*	Brazilian tea, mate	stimulant
Acrocomia +*	Arecaceae	*A. aculeata*	Mucajá, macaúba	fruit
Astrocaryum+*	Arecaceae	*A. vulgare, A. aculeatum*	Cumare palm, tucumã	fruit
Attalea+*	Arecaceae	*A. speciosa*	Babassu palm, babaçu	fruit, oil
Bactris*	Arecaceae	*B. guineensis, B. gasipaes*	Peach palm, pupunha	fruit
Mauritia+	Arecaceae	*M. flexuosa*	Buruti palm, burití	fruit
Mauritiella+	Arecaceae	*M. carana*	Caraná, caranai	fruit
Oenocarpus+	Arecaceae	*O. distichus*	Bacaba	fruit
Protium+	Burseraceae	*P. unifoliolatum, P. heptaphyllum*	Breu, ràb kudjà re	fruit
Tetragastris+*	Burseraceae	*T. altissima*	Haiawa balli, ràb ti	fruit
Celtis+	Cannabaceae	*C. iguanaea*	Garabato blanco	fruit
Jacaratia+*	Caricaceae	*J. spinosa*	Barrigudo, mamoí	fruit
Caryocar+	Caryocaraceae	*C. villosum, C.glabum, C. microcarpum*	Butternut tree, pequiá	fruit
Licania+	Chrysobalanaceae	*Licania* spp.	Gopher apple, ajaru	fruit

Garcinia	Clusiaceae	*G. brasilensis,, G. gardneriana*	Bacupari	fruit
Erythroxylum	Erythroxylaceae	*E. coca*	Coca	stimulant
Hevea+*	Euphorbiaceae	*H. brasiliensis*	Para rubber tree, seringueira	seed
Cassia	Fabaceae	*C. leiandra*	Marimari	fruit
Dialium+*	Fabaceae	*D. guianense*	Jutaí pororoca	fruit
Dipteryx+ *	Fabaceae	*D. odorata*	Tonka beans, cumarú	fruit
Inga+*	Fabaceae	*I. alba, I. edulis, I. laurina*	Icecream bean, ingá cipo	fruit
Hymenaea+	Fabaceae	*H. courbaril*	Anime resin tree, jatobá	fruit
Heliconia+*	Heliconiaceae	*H. hirsuta*	Bico de papagaio	root
Humiria	Humiriaceae	*Humiria* sp.	Blackberry, umiri	fruit
Aniba+	Lauraceae	*A. rosaeodora*	Brazilian rosewood, páo rosa	food additive
Bertholletia+*	Lecythidaceae	*B. excelsa*	Brazil nut, castanha do Pará	edible nut
Eschweilera+	Lecythidaceae	*E. coriacea, E. grandiflora*	Matamatá branco	seeds
Byrsonima+	Malpighiaceae	*B. crassifolia, B. verbascifolia*	Golden spoon, murici	fruit
Theobroma+	Malvaceae	*T. cacao, T. grandiflorum, T. speciosum*	Cacao tree, cacau, cupuaçu	fruit
Brosimum+	Moraceae	*B. lactescens, B. alicastrum*	Breadnut tree, mauratinga	edible nut
Pourouma	Urticaceae	*P. cecropiifolia P. guianensis, P. edulis*	Amazon grape fruit, mapati	fruit

Coccoloba+*	Polygonaceae	*C. latifolia*	Papalón	fruit
Paullinia	Sapindaceae	*P. cupana*	Guaraná	stimulant
Pouteria+	Sapotaceae	*P. glomerata, P. venosa, P. caimito, P. lucuma*	Egg fruit, abiu	fruit
Solanum+	Solanaceae	*S. sessiliflorum, S. splenden*	Orinoco apple, cocona	fruit
Cecropia+	Urticaceae	*C. peltata*	Trumpet tree, embaúba	fruit

Table S8. *Pollen taxa identified to family level with known edible genus in ethnographic record and present in modern botanical inventory.* + indicates genera identified in the pollen record that are present in the modern botanical inventories and the botanical reconnaissance around Lake Caranã. * indicates pollen less than 5% and not included in edible sums with the exception of crop pollen which is presented as presence data.

Phytolith Taxa	Family/Taxonomic association
Mendoncia sp.	Acanthaceae
Annonaceae	Annonaceae
Arboreal	Arboreal
Asteraceae	Asteraceae
Bamboosoideae	Bamboosoideae
Cyperaceae	Cyperaceae
Commelinaceae	Commelinaceae
Heliconiaceae	Heliconiaceae
Trichomanes sp.	Hymenophyllaceae
Marantaceae	Marantaceae
Chloridoideae	Poaceae
Poaceae	Poaceae

Table S9. *Phytolith taxa identified in this study.*

Phytolith taxa	Taxonomic association	Putatible edible	Common name	Type of food
Arecaceae+	Arecaceae	Various incl. *Astrocaryum, Attalea*, etc.	Various	fruit
Olyreae	Bamboosoideae	Various incl. *O. latifolia*	takwari (Ka'apor tribe)	grain
Celtis sp.+	Cannabaceae	*Various incl. C. iguanaea, C. morifolia*	Parinari	fruit
Chusquea sp.	Poaceae	*C. culeou*	Culeu	grain
Pharus sp.	Poaceae	*P. ciliatus*	Arroz bravo	seed

Table S10. *Edible phytolith taxa identified in this study.* + indicates genera identified in the pollen record that are present in the modern botanical inventories and the botanical reconnaissance around Lake Caranã.

Supplementary Discussion

D1. Riverine high-stand. Although the region has a long record of human occupation that starts in the Late Pleistocene, our records detect the history of coupled human and environmental systems for the past ~ 5,500 years. Relative sea-level rise was ongoing throughout the early Holocene along the east coast of South America[17], culminating in a high-stand between ~ 5,700 and 5,100 cal B.P.[18–20]. Because the base of the river channel in the eastern half of the Amazon basin is near to sea-level (<2 m), relative sea-level rise would have resulted in a deeper inland penetration of the Atlantic tidal zone, in part damming the flow of the large rivers that drain into the lower reaches of the Amazon[19]. For the tidally influenced Tapajós River, higher sea-levels results in higher river levels, which likely inundated the LC study-area (Fig. 4a). Increased water levels account for the peak Fe, Ti, MS, and bulk density values during this phase. Decreasing relative sea-level and river inundation (~ 5,000 to 4,000 cal B.P.) caused numerous lakes to form in the lower Amazon[10,20]. This process is evidenced by a mix of terrestrial and hydrarch succession and is reflected in the Tapajós TAP-02 riverine pollen core[20] and other records in the Amazon[18,21].

LC Phase 1 is characterized by the highest levels of Ti and Fe coupled with record high magnetic susceptibility (MS) and bulk density values. Ca levels were below the level of detection, thus ratios for Ti/Ca and F/Ca could not be calculated. Coupled with MS and bulk density, geochemistry from LC Phase 2 indicates decreased Fe, Ti, bulk density and MS values, coupled with an increase in bulk sediment organic content indicating a shift to lacustrine conditions signaling the formation of the lake (Supplementary Fig. S2).

D2. Archaeology. The earliest known archaeological evidence in the Lower Amazon is the Palaeoindian occupation of Pedra Pintada Cave (~ 13,000 cal B.P.)[22]. Archaic occupations in the region are represented by the Taperinha shell-midden, which contains the earliest ceramics in the Amazon (~ 7,900 cal B.P.)[23]. The Formative Period occurs between ~ 4500 and 1000 cal B.P.[24] followed by the Late pre-Columbian Tapajo Period (LPTP) from ~ 1000 to 400 cal B.P.[25]. The LPTP is a distinctive Amazonian tradition characterized by elaborate pottery vessels typically decorated with representational and geometric plastic and painted designs, anthropomorphic and zoomorphic adornos displayed in caryatid and neck vessels, as well as polished-stone figurines representing various animals and humans locally called "muiraquitas"[26,27]. Roosevelt [28] argues for a chiefdom-level society, which may have control over a territory of 23 km^2 with densely populated settlements encompassing a population of several thousand, whose capital site of the LPTP lies at the confluence of the Tapajós and the Amazon River. However, recent regional studies propose heterarchical models of political organization, either supporting the hypothesis of a centralized organization encompassing independent communities[29] or a non-centralized polity based on a collaborative network integrating the region[13,30].

The sum of probability distributions of the available radiocarbon dates from the Santarém region and its surroundings (Fig. 2D) provide a unique setting to understand the origin, development and agricultural use of ADEs. The area exhibits some of the highest densities of ADE sites[14], including Black ADEs and Brown ADEs (traditionally known as *terra preta* and *terra mulata*), located in a diversity of settings along both major waterways (Tapajós and Amazon rivers) and in *terra firme* rainforest along the Belterra Plateau (130 to 180 m.a.s.l)[26,31,32] (Fig. 1A). The word mulata has a pejorative meaning of miscegenation and impurity. *Mulata* refers to interethnic breeding that resulted

largely from rapes during the 354 years (1534 to 1888 A.D.) of black slavery in Brazil[33–35]. Considering the etymology of the word, the ethical choice of this work is to refuse the nomenclature *terras mulatas* as a category of classification of the lighter form of dark soils. Thus, the terminologies adopted in this study are Black ADE and Brown ADE. While Black ADEs developed as the result of village middens, the lighter Brown ADEs, devoid of artifacts are the result of cultivation practices[31,36]. The earliest ADE site is from Lago do Jacare I, located in the bluff of a *terra firme* lake dated from ~ 4405 to 3920 cal B.P.[12]. Riverine ADEs date to as early as ~ 4295 to 3990 cal B.P. and ADEs on the BTP are later dating from ~ 555 to 500 cal B.P. and represent the more recent intensification of human occupation on the plateau. The regional intensification begins ~ 1500 cal B.P. and peaks ~ 500 cal B.P. (Fig. 2D). The LPTP is also characterized by a network of ditch and causeway trails and natural ponds, which have been artificially enhanced as reservoirs. Our study site, Serra do Maguari 1 (SDM1) is a ~ 15 ha mounded village with a central plaza surrounded by a mosaic of ADE sites (Supplementary Fig. S4). Mound construction and ADE formation at SDM1 occurred between ~ 530 and 450 cal B.P. during the late phase of the LPTP. The ceramic materials and the site are characteristic of the late pre-Columbian Tapajos Period[37].
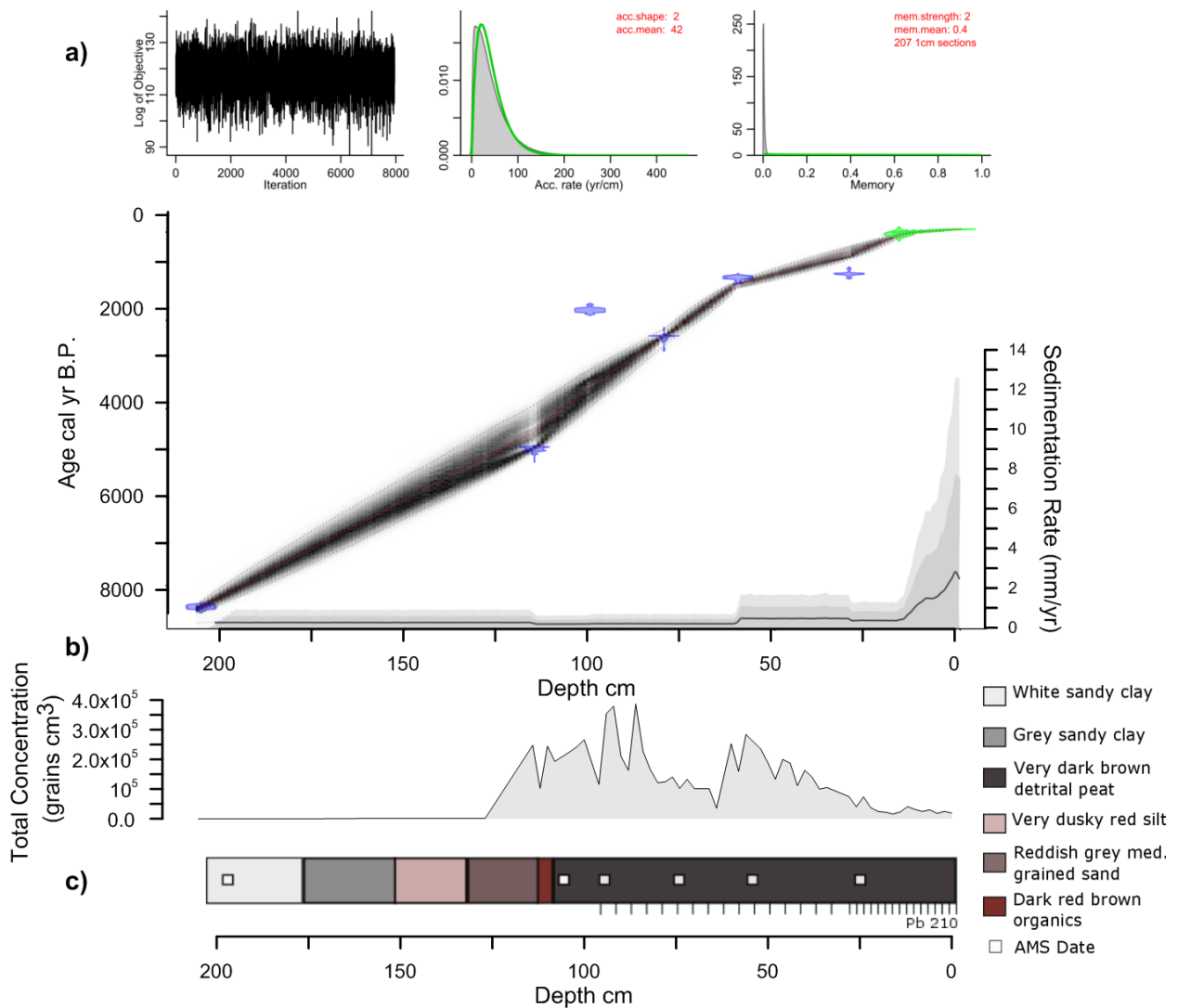
Fig. S1. Lake Caranã age-model. a) Age-depth model with MCMC iterations (top left) and priors (green curves) and posteriors (grey histograms) for accumulation rate (top middle) and memory (top right). The age model iterations (black hatching) are based on radiocarbon ages (blue pdfs) and ^{210}Pb ages (green pdfs), with model mean (red dashed) and 2σ (black dashed) distributions. b) Total pollen concentration from sediment core. c) Sediment core lithology. AMS dates indicated by the white squares, ^{210}Pb indicated by tick marks. Note: Low pollen concentration prior to ~4,700 cal yr B.P. is attributed to a combination of sandy sediments and low organics that likely reduced pollen preservation.
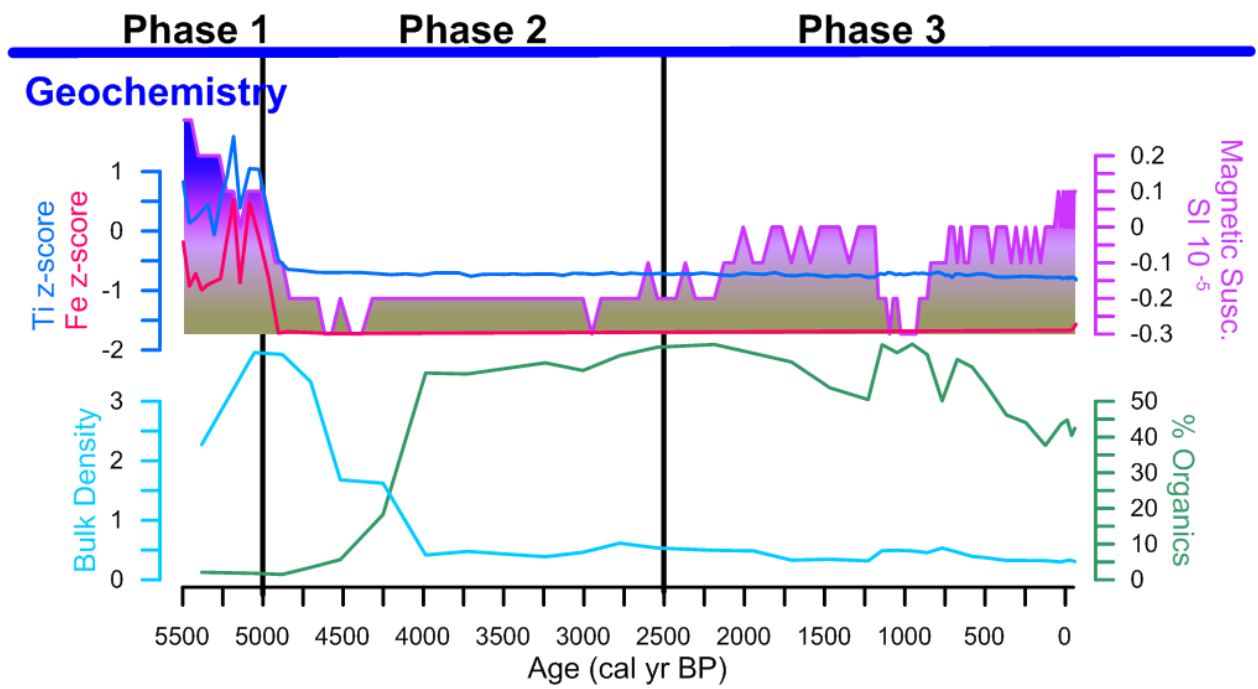
Fig. S2. Lake Caranã geochemistry. Z-score Ti (blue) and Fe (pink) XRF data. Magnetic susceptibility (purple) is represented in SI^{10-5}, bulk density (teal) and % organics from loss-on-ignition (green) indicated the transition from organic poor to organic rich lacustrine conditions between Phase 1 and Phase 2.
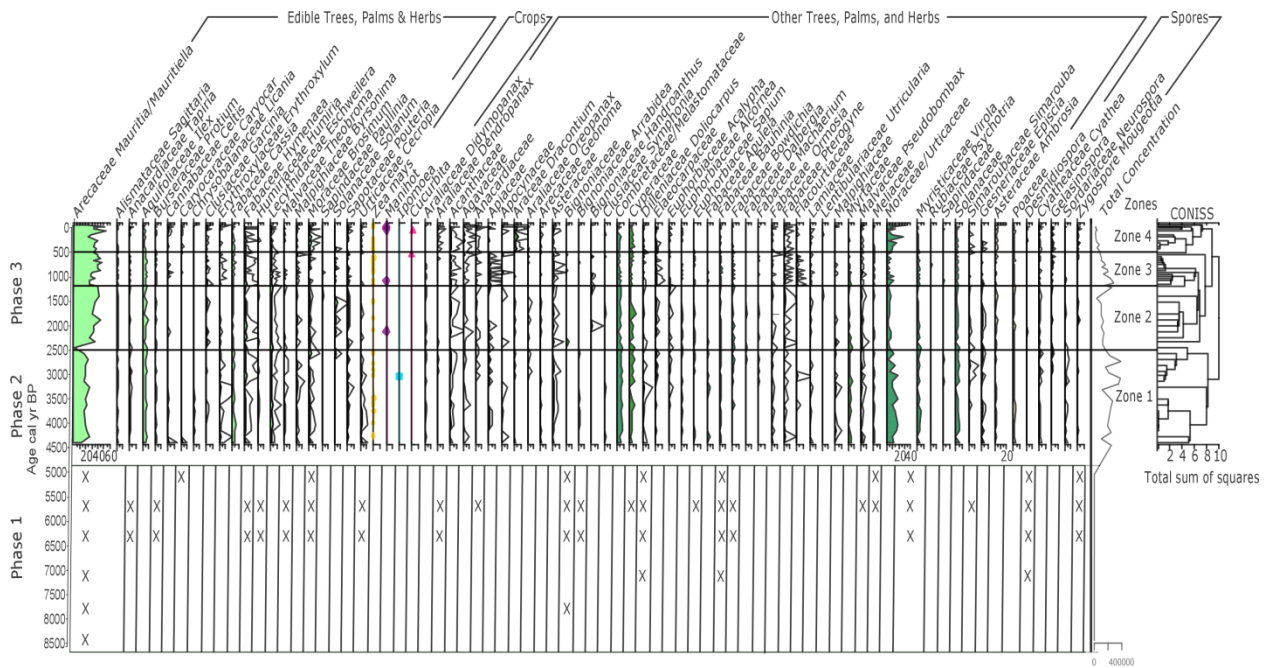
Fig. S3. Lake Caranã pollen data. Percentage pollen diagram (silhouettes show 10X exaggeration curves); Pollen Zones determined in Phase 2 and 3 from CONISS. Light green represents edible plants, dark green represents other trees, palms and herbs, symbols represent total counts of crop pollen: yellow circle *Zea mays*, purple diamond *Manihot*, blue square *Ipomoea*, pink triangle *Cucurbita*). In Phase 1 (8500 to 5000 cal yr B.P.) pollen data are shown in presence data (X) due to low concentrations indicated by total concentration data on the far right of the graph.
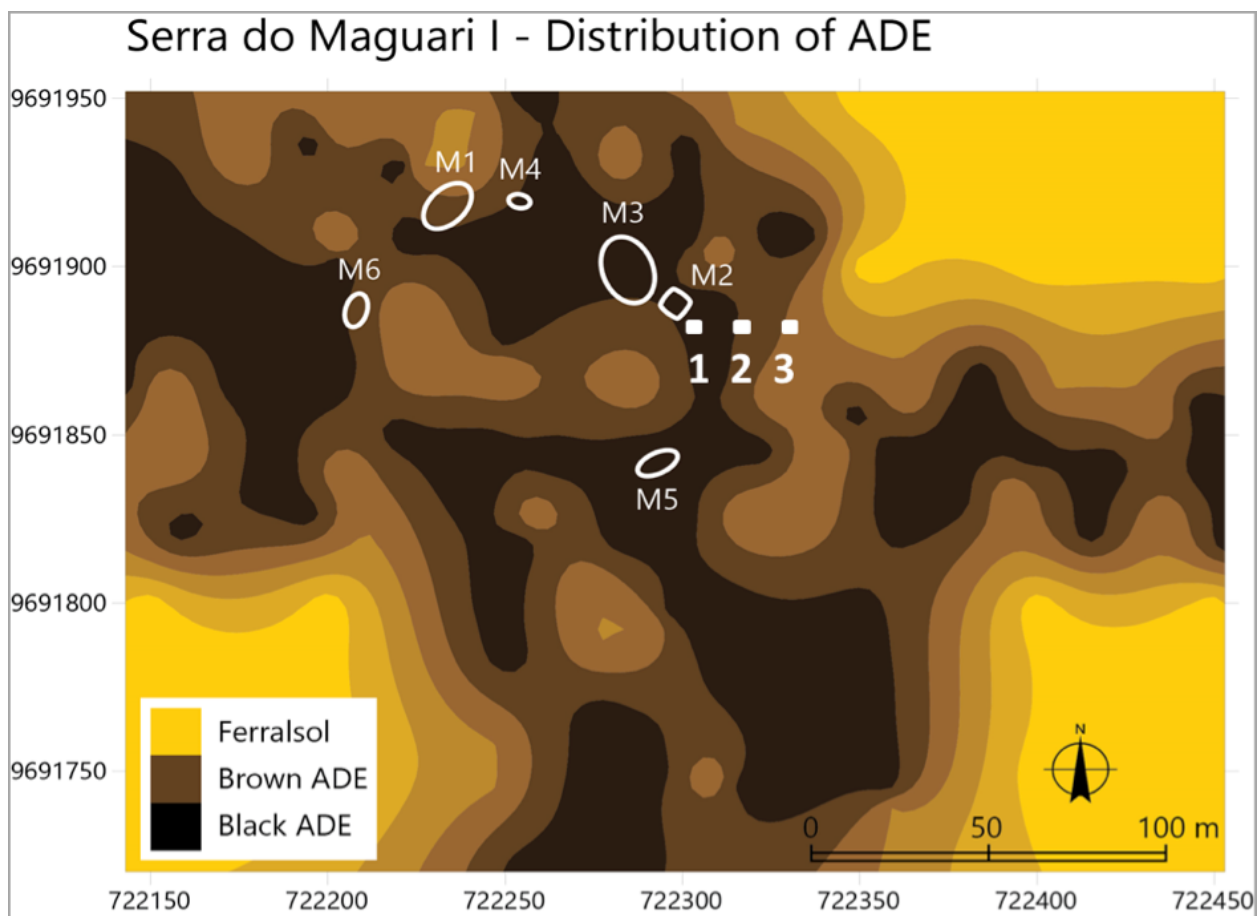
Fig. S4. Serra do Maguari-1 site map. ADE-ferralsol distribution map at Serra do Maguari-1. White circles indicate archaeological mound features (M1-6). Soil profile locations indicated by white squares (1-3).
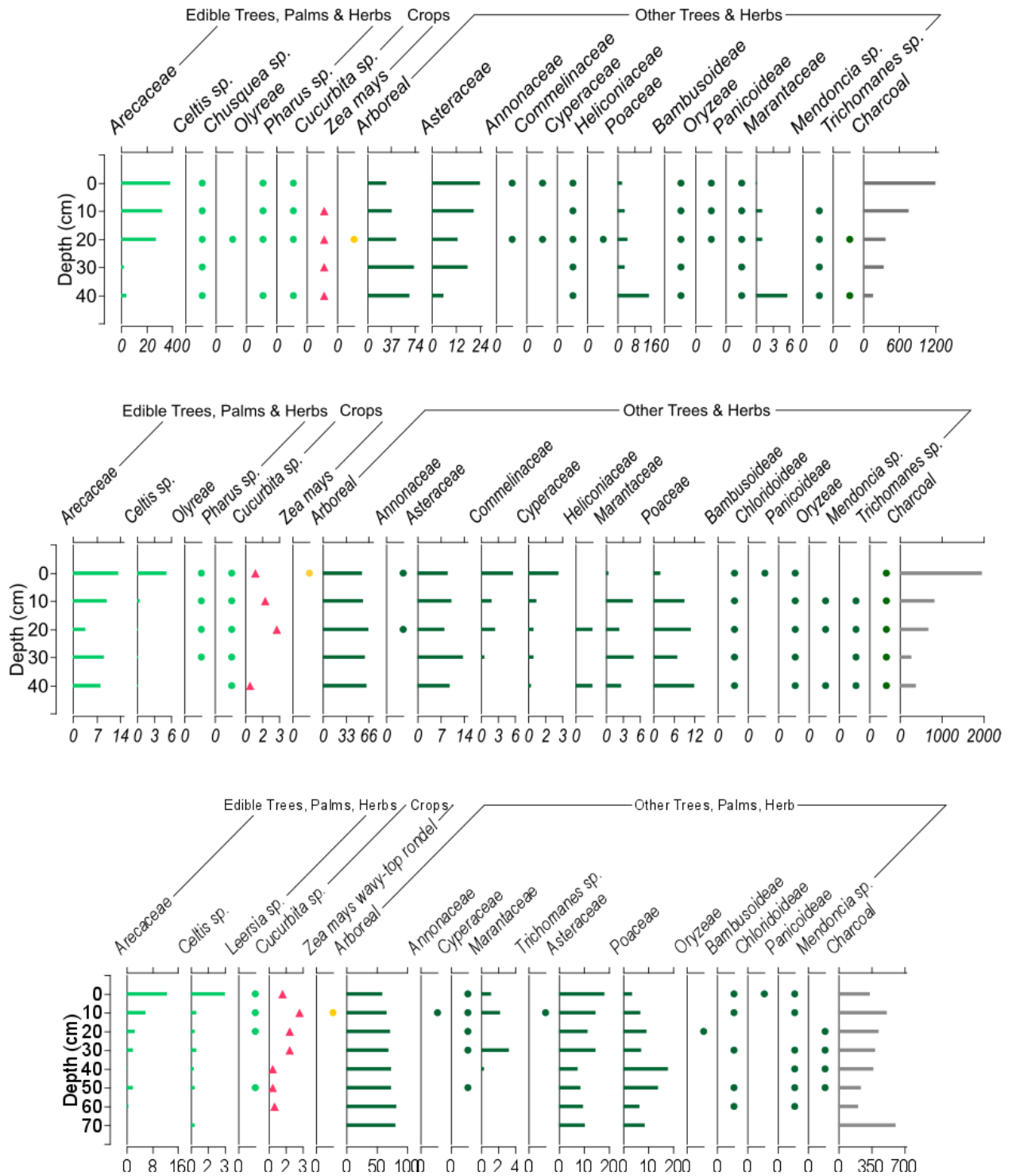
Fig. S5. Serra do Maguari phytolith soil profiles. Phytolith percentage diagrams from soils profiles (SP). Symbols represent total counts where percentage data were very low. Light green represents edible plants, dark green represents other trees and herbs. Light green circles represent counts for edible plants, dark green circles indicate total counts of other trees and herbs, pink triangles indicate *Cucurbita* and yellow circle indicate *Zea mays*. Total soil charcoal counts grey bars.
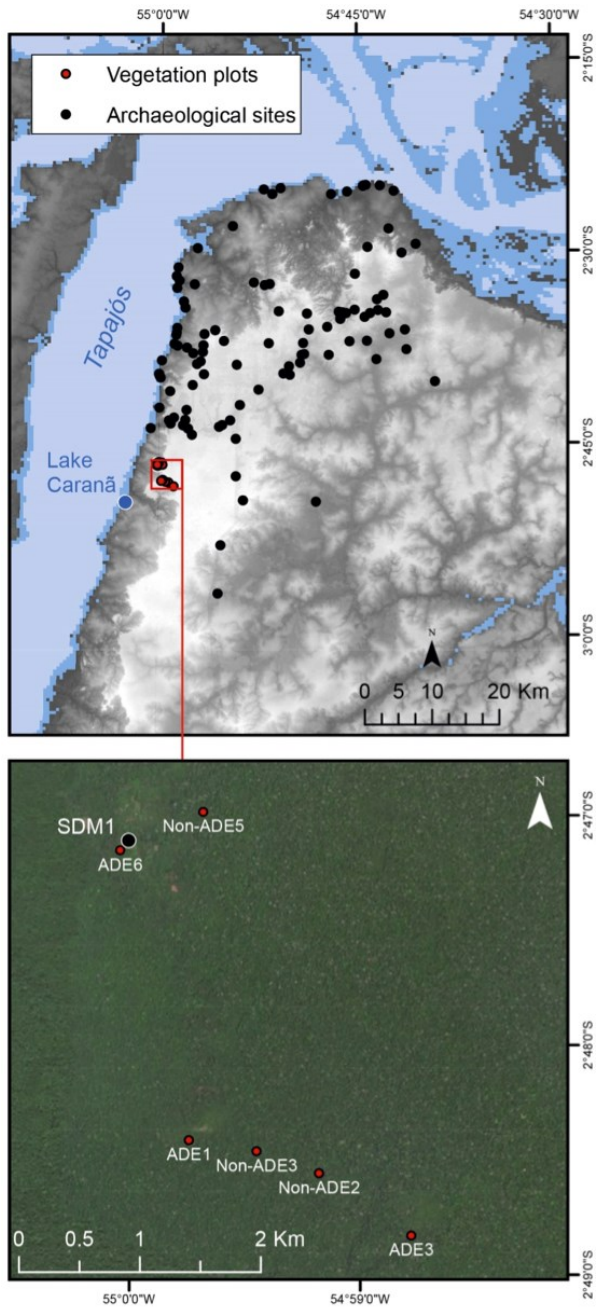
Fig. S6 Map of modern vegetation plots: Top panel indicating the location of vegetation plots in relation to Lake Caranã, Serra do Maguari, and other archaeological sites. Bottom insert indicates the location of ADE and non-ADE plots used in the modern vegetation survey in relation to Serra do Maguari.
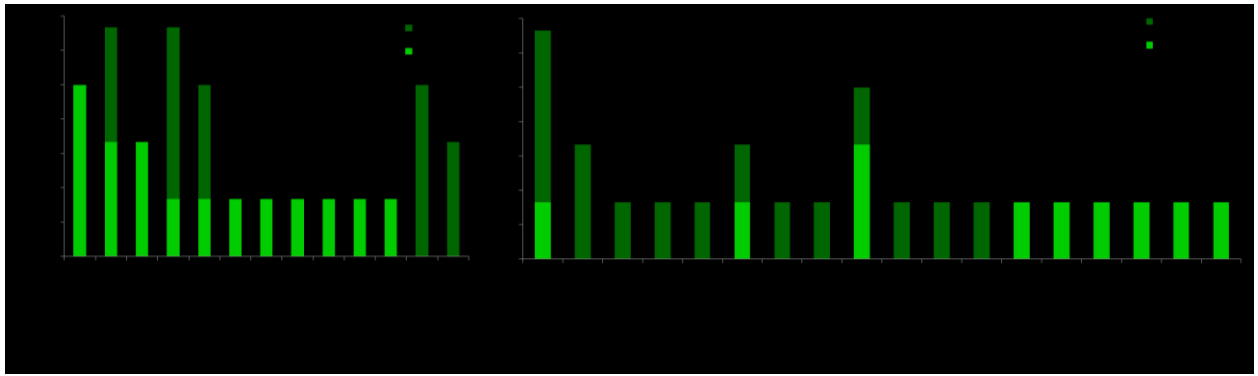
Fig. S7. Relative frequency of modern vegetation inventories: Relative frequency (%) of edible and other trees, palms, and lianas identified in ADE (light green) and non-ADE (dark green) forest plots.

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