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Slash-burn-and-churn: Landscape history and crop cultivation in pre-Columbian Amazonia

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ABSTRACT

Palaeoecologists argue that the vegetation of Amazonia has changed markedly since the late Pleistocene and show that forest fires have been increasingly more common since the beginning of the Holocene. Because these occurrences coincide with the onset of human colonisation of the region, students of Amazonia discuss the extent to which it's Holocene fire record reflects climatically-related and/or anthropogenic causes. One factor that complicates inferences is the overall heterogeneity of the basin's vegetation: during drier moments of the Holocene and/or within less humid sub-regions of the basin, it is difficult to conclude whether fire signals reflect more frequent natural fires or more intense burning by human communities. Another factor is that pre-Columbian livelihoods were not homogenously distributed throughout the region and changed over the course of the Holocene. This paper seeks to help establish an 'anthropogenic baseline' against which Holocene evidence for burning can be assessed. To this end, it reviews the role that slash-and-burn cultivation has had in discussions about pre-Columbian Amazonia, discusses how this account has been modified by recent research on pre-Columbian anthropogenic soils, and queries the extent to which the regionally-heterogeneous timing of crop domestication and cultivation may have influenced the fire history of pre-Columbian Amazonia.

1. Introduction

Stephen Pyne (1998) illustrates fire regimes as two-cycle engines that oscillate between wet and dry conditions: in order for fires to start, the spark of lightning must take place and conditions must be dry. In the Amazon basin, home to the planet's largest rainforest, lightning is by no means a rare occurrence. The combustibility of plant biomass, however, depends on the prevailing type of vegetation, which in turn is conditioned by year-round precipitation, the actual length of the dry season, and soil fertility: dense aseasonal rainforests are associated with high precipitation and well-drained clayey soils; open rainforests grow on soils with low water tables, poor drainage and/or drier conditions; semi-deciduous or seasonally dry rainforests grow in drier regimes with fertile soils or in areas of transition to savannah vegetation; and savannahs, which vary from sedge- and/or grass-dominated treeless landscapes to open parkland with patches of woodland, prevail in regions with poor soils and low overall precipitation (Piperno and Pearsall, 1998; Walsh, 1998; Daly and Mitchell, 2000; Mayle and Power, 2008). While all such formations may have above-threshold 'spark' potential, the duration of their wet and dry is different (Fig. 1): regions with thick rainforest, high rainfall, and unmarked seasonality should theoretically experience infrequent burning; regions with semi-deciduous or seasonally dry forest, as well as areas dominated by savannah vegetation, should experience more frequent natural fires.

Theoretical expectations aside, research dating soil charcoal near San Carlos de Rio Negro, one of the most humid regions of the Amazon basin (Fig. 1.v), documents the occurrence of forest fires in pre-Columbian times (Sanford et al., 1985; Saldarriaga and West, 1986; Saldarriaga, 1994). Ethnographic research from neighbouring areas show that vegetation clearance through burning – typically as part of slash-and-burn cultivation – is possible during the driest months of the year (Hugh-Jones, 1979; Hill and Moran, 1983; Saldarriaga et al., 1988; Moran, 1991; van der Hammen, 1992). Considering the fact that archaeological evidence for the human occupation of Amazonia appears to span the entire Holocene (Miller, 1992a, 1999; Kipnis et al., 2005; Neves, 2008; Arroyo-Kalin, 2010), and that evidence for plant cultivation in northern South America is ancient (Piperno and Pearsall, 1998; Piperno, 2009a,b; see also; Clement et al., 2010), it is difficult to dismiss the possibility that humans may have set off forest fires even in these very humid

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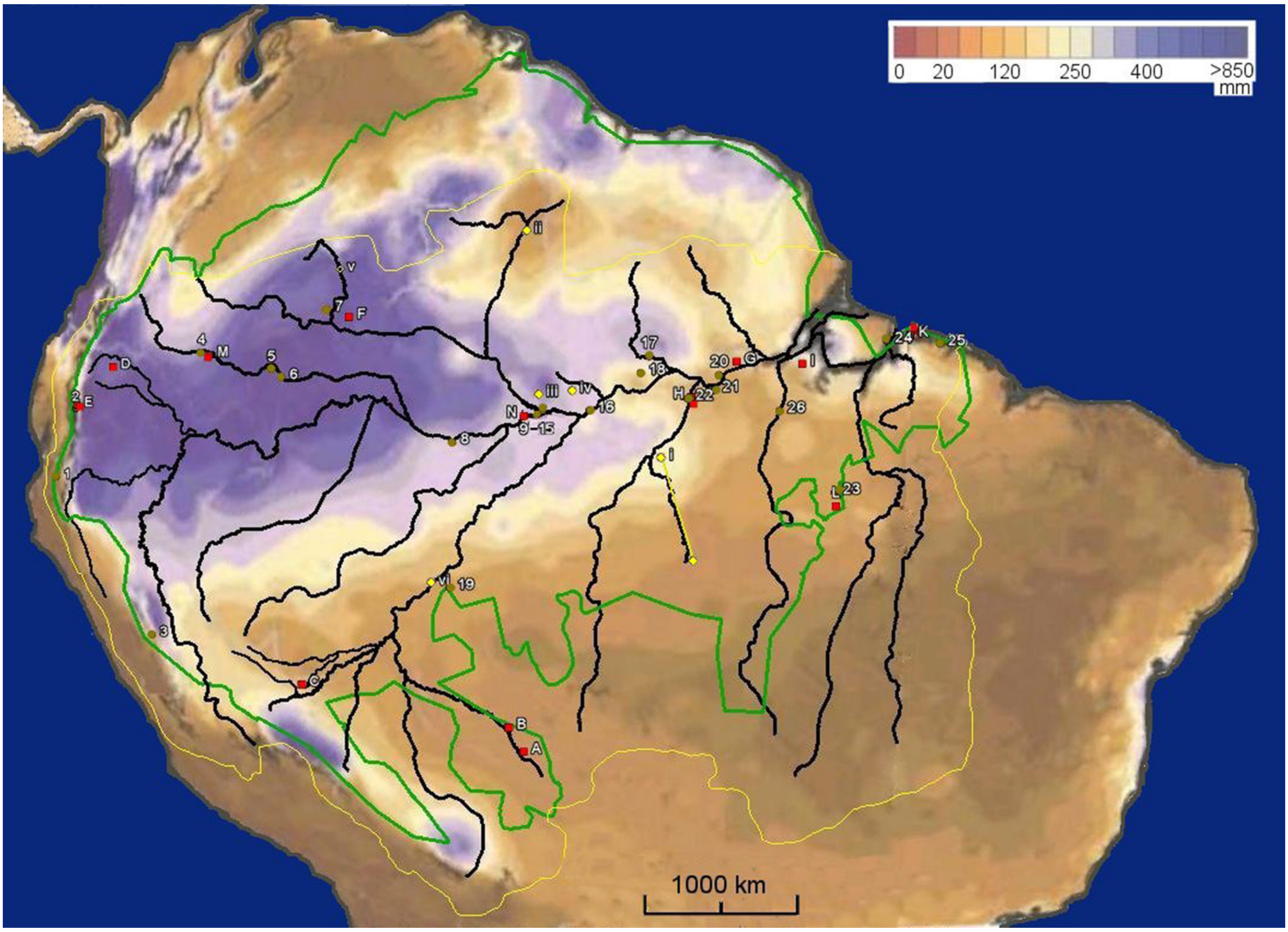

Fig. 1. Map of the Amazon basin. Red squares, yellow diamonds and brown circles mark the location of, respectively, pollen records, soil charcoal studies, and archaeological sites referenced in the paper (see Table 1). Green line shows the overall extent of forest vegetation today (source: Google Earth). Yellow line shows the overall extent of the Amazon basin, including here the Tocantins River. Colours of terrain (adapted from Mayle and Power, 2008) show total precipitation during the driest three months.

regions. It is thus unsurprising that students of Amazonia are increasingly paying more attention to possible evidence of pre-Columbian anthropogenic burning (e.g. Piperno, 1990; Herrera et al., 1992; Piperno and Becker, 1996; Athens and Ward, 1999; Behling et al., 1999; Bush et al., 2000, 2007a, 2008; Mora, 2003a; Heckenberger et al., 2007; Dull et al., 2010).

Assessing the empirical evidence for past forest fires demands some sense of how the vegetation of the Amazon basin has changed over time. Palaeoecologists argue that the extent and composition of Amazonia's forests have undergone significant changes since at least the late Pleistocene (Mayle et al., 2000; Mayle, 2004; Mayle et al., 2004): between the end of the Last Glacial Maximum (c. 19 cal ka BP) and the onset of the Holocene (ca. 11 cal ka BP) a non-analogous forest in which cloud forest-adapted *Podocarpus* sp. trees persisted until c. 9–8 cal ka BP (Absy et al., 1991; Sifeddine et al., 1994; Behling et al., 1999; Haberle and Maslin, 1999; Behling, 2001; Burbridge et al., 2004; Bush et al., 2004; De Oliveira, 2005) is thought to have expanded from the more humid sub-regions of the basin (van der Hammen and Hooghiemstra, 2000; Anhuf et al., 2006). This formation appears to have overtaken more open vegetation of drier sub-regions (Mayle and Beerling, 2004) and, already by the early Holocene, shaped much of the extent of rain-forest vegetation that is observed today (Irion et al., 2006; Bush et al., 2007a). However, spells of drier conditions, which may have reached their maximum intensity during the mid Holocene (Soubies, 1979–80; Absy et al., 1991; Sifeddine et al., 2001; Bush et al., 2007b; Mayle and Power, 2008), also appear to have driven vegetation in peripheral areas of the basin – especially the ecotones of its southern rim – to become more dominated by dry-adapted forest and/or savannah. By the late Holocene, as increased austral summer insolation accentuated the strength of summer precipitation in South America, more humid conditions prevailed, in turn leading forests to expand once again (Mayle et al., 2000; Freitas et al., 2001; Pessenda et al., 2001; Mayle et al., 2007).

Palaeoecological evidence for burning in Amazonia consists of microscopic charcoal recorded in pollen cores and/or charcoal fragments collected from exposed soil profiles. Burning begins to be recorded in the terminal Pleistocene although signals are scant and infrequent (Burbridge et al., 2004; Bush et al., 2004). Fire signals become more common in the early Holocene (Behling, 1996, 2001), i.e. in the same time range as the earliest evidence of human occupation of the basin (Roosevelt et al., 2002; Mora, 2003b). After the early Holocene the overall trend is an increased frequency of fires (Power et al., 2008), albeit with some interesting regional variation (Fig. 2): many of the palaeoecological records from regions with longer dry seasons show high fire frequencies during the mid Holocene (Mayle and Power, 2008); some pollen records from more humid regions (e.g. Pantano de Monica, Behling et al.,

Table 1
Data sources for Figs. 1 and 2.

Charcoal from pollen records (all data from Power et al., 2008 except Ayauchi):
A. Chaplin (Mayle et al., 2000; Burbridge et al., 2004; Mayle and Power, 2008); **B**. Bella Vista (Mayle et al., 2000; Burbridge et al., 2004; Mayle and Power, 2008); **C**. Gentry, Vargas, Parker, Werth-2 (Bush et al., 2007a; Bush et al., 2007b); **D**. Maxus Core (Athens and Ward, 1999); **E**. Ayauchi (Piperno, 1990); **F**. Pata (Bush et al., 2004); **G**. Geral, Comprida, Saracuri, Santa Maria (Bush et al., 2000; Bush et al., 2007a); **H**. Tap 02 and TAP 99 (Irion et al., 2006); **I**. Curia (Behling and da Costa, 2000); **J**. Crispim (Behling and da Costa, 2001); **K**. Curuça (Behling, 1996; 2001). Additional pollen records discussed in text: **L**. Carajas (Sifeddine et al., 2001), **M.** Pantano de Mónica Pantano de Mónica (Behling et al., 1999; van der Hammen and Hooghiemstra, 2000), **N**. Calado (Behling et al., 2001).
Soil charcoal:
i. BR-163 (Soubies, 1979–80); ii. FSB_R (Desjardins et al., 1996); **iii**. Km 41 (Santos et al., 2000); **iv**. Reserve 501 (Piperno and Becker, 1996); v. San Carlos de Rio Negro (Sanford et al., 1985; Saldarriaga, 1994).
Dated archaeological remains:
Region 1: 1. Santa Ana-La Florida (Valdez et al., 2005), 2. Huapula, (Porras, 1987; Rostain, 1999), 3. PAC-14 (Allen, 1968); region 2: 4. Araracuara, Abeja, Peña Roja (Herrera et al., 1980-1; Eden et al., 1984; Andrade, 1986; Mora et al., 1988; Mora, 1991; 2003b), 5. La Pedrera (Myers, 2004), 6. Mangueiras (Hilbert, 1968), 7. Fortaleza (Neves, 1998); **region 3**: 8. Coarí, 9. Manacapurú, (Hilbert, 1968), 10. Açutuba (Heckenberger et al., 1999), 11. Lago do Limão, Oswaldo, 12. Lago Grande, 13. Dona Stella, 14. Hatahara, (Costa, 2002; Donatti, 2003; Neves, 2003; Neves et al., 2003; Neves et al., 2004; Machado, 2005; Moraes, 2006; Neves and Petersen, 2006; Costa, 2009), 15. Paredão, 16. Itacoatiara (Hilbert, 1968), 17. Boa Vista, 18. Pocó (Hilbert and Hilbert, 1980); region 4: 19. RO-PV-27, RO-PV-48 and other sites of the Jamari river (Miller, 1992a; 1992b; Miller, 1999); region 5: 20. Caverna da Pedra Pintada, 21. Taperinha (Roosevelt et al., 1991; Roosevelt, 1995; Roosevelt et al., 1996; Roosevelt, 2000), 22. *Terra preta*, Lago do Jacaré, Zenóbio, (Gomes, 2008); region 6: 23. Gruta do Gavião (Magalhães, 1993), Gruta do Rato, Gruta do Pequiá, and other reported by Kipnis et al. (2005); **region 7**: 24. Castanheira (Simões, 1969), PA-JO-21, PA-JO-26, PA-JO-36 (Meggers and Danon, 1988), 25. Ponta de Pedras, Porto de Mina, (Simões, 1981; Roosevelt, 1995), 26. PA-AL44, PA-AL-45, PA-AL-18 (Perota, 1992; Perota and Botelho, 1992).

1999; see also Guyanese soil charcoal, Charles-Dominique et al., 1998; Francis and Knowles, 2001; Hammond et al., 2007) lack clear evidence of mid Holocene burning while yet others from humid regions show interesting fire histories (e.g. Ayauchi, Piperno, 1990; Maxus core, Athens and Ward, 1999; Power et al., 2008). Overall, the frequency of fires suggested by burning evidence increases throughout the basin towards the late Holocene, reaching an apparent peak from approximately the 5th to the 16th century AD (Bush et al., 2007a; Power et al., 2008; Dull et al., 2010). This peak is consistent with the presence of archaeological remains of large sedentary, and intensive human settlement in rainforest-clad regions of the basin, mostly dated to the last millennium before European colonisation (Hilbert, 1968; Lathrap, 1970; Eden et al., 1984; Heckenberger et al., 1999, 2007; Roosevelt, 1999a, 2002; Bush and Silman, 2007; Neves, 2007; Arroyo-Kalin, 2008a).

Human fires are easier to set off – and therefore more likely to be recorded in palaeoecological records – in dry conditions. However, under dry conditions natural fires are also more prone to occur, such that burning evidence is difficult to discriminate as anthropogenic (Bush et al., 2008; Mayle and Power, 2008). In humid regions, on the other hand, evidence for burning at first glance appears easier to link to anthropogenic causes. Notwithstanding, it is possible that the Holocene was characterised by short, ENSO-related periods of drier conditions – effectively acting as windows of opportunity for burning – and this complicates interpretations. (Sandweiss et al., 2001; Moy et al., 2002; Marengo et al., 2008). Cleary, in short, it is inherently difficult to conclusively associate palaeoecological burning evidence from the Holocene to anthropogenic causes.

Some may feel that drawing a distinction between anthropogenic and natural fires is a red herring. However, understanding better the anthropogenic dimension of past fires is a goal worthy of pursuing: reconstructing the basin's human fire history is evidently crucial to assess the extent and time-depth of human manipulation of the region's biodiversity (Balée, 2006, 2010; Bush and Silman, 2007). One approach to the matter is to strive for tighter integration between palaeoecological and archaeological evidence (e.g. Bush et al., 1989, 2007a; Piperno, 1990). Another, one which this paper adopts, is to examine in sharper detail the 'fire potential' of different past livelihoods. This is equivalent to establishing an 'anthropogenic baseline' against which Holocene evidence for burning can be assessed. With this aim in mind, therefore, this paper seeks to reviews the role of slash-and-burn cultivation in discussions about pre-Columbian Amazonia, discuss how recent research on pre-Columbian anthropogenic soils invites modification of this account, and examine how the regionally-heterogeneous timing of crop domestication (and hence the inception of specific cultivation practices) may have influenced the fire history of pre-Columbian Amazonia.

2. Pre-Columbian slash-and-burn cultivation

Burning of forest vegetation to create and maintain gardens, the latter generally between 0.5 and 2 ha in size, is widely reported in the ethnographic record of Amazonia. Once derided as a primitive form of agriculture, many specialists regard this practice as part of a sophisticated technique to manipulate the nutrient cycle of rainforest vegetation: cutting and burning – slash-and-burn – mineralises the nutrients of the standing plant biomass and amends the generally thin and nutrient-poor topsoil on which much forest vegetation grows. The soil thus amended, with a temporarily higher pH and added plant-available nutrients, allows for year-long cropping over periods of 1–3 years before fertility begins to once again decrease. After this, land can be left to fallow for short periods and secondary re-growth can subsequently be burned to re-mineralise nutrients once or twice. However, an ever-decreasing pool of nutrients eventually permits pioneer species to out-compete crops and, at this point, cultivation is abandoned in favour of longer – often decadal – periods of fallow. These fallow periods allow re-growth of thick 'primary' vegetation (which, at some point, can again be felled and torched) and, over the mid- to long-term, produce a spatially-extensive rather than spatially-intensive farming pattern. Landscapes modified by slash-and-burn, however, are not automatically abandoned: in many instances tree crops (which continue to yield beyond the cycle of fast maturing crops and, in point of fact, beyond the decline in garden productivity due to nutrient loss) continue to be managed in 'fallow' land. This leads to the formation of mosaics of vegetation at different stages of sucession. Studies show that some such landscapes can record histories of anthropogenic disturbance of bicentennial time-depth (Meggers and Evans, 1957; Harris, 1971; Carneiro, 1983; Hill and Moran, 1983; Beckerman, 1987; Denevan and Paddoch, 1987; Saldarriaga et al., 1988; Balée, 1989; Moran, 1991; van der Hammen, 1992; Saldarriaga, 1994; Piperno and Pearsall, 1998; Balée, 2006).

Slash-and-burn cultivation has occupied an important position in archaeological discussions about pre-Columbian Amazonia. In a debate spanning over fifty years of scholarship, Betty Meggers (Meggers and Evans, 1957; Meggers, 1971, 1995, 1997) followed Julian Steward (1948a) in suggesting that slash-and-burn was an adaptation of late Holocene immigrating agriculturalists who encountered adverse conditions as they moved into Amazonia. She emphasised that high labour demands associated with felling trees to make gardens, coupled with the low nutrient status of

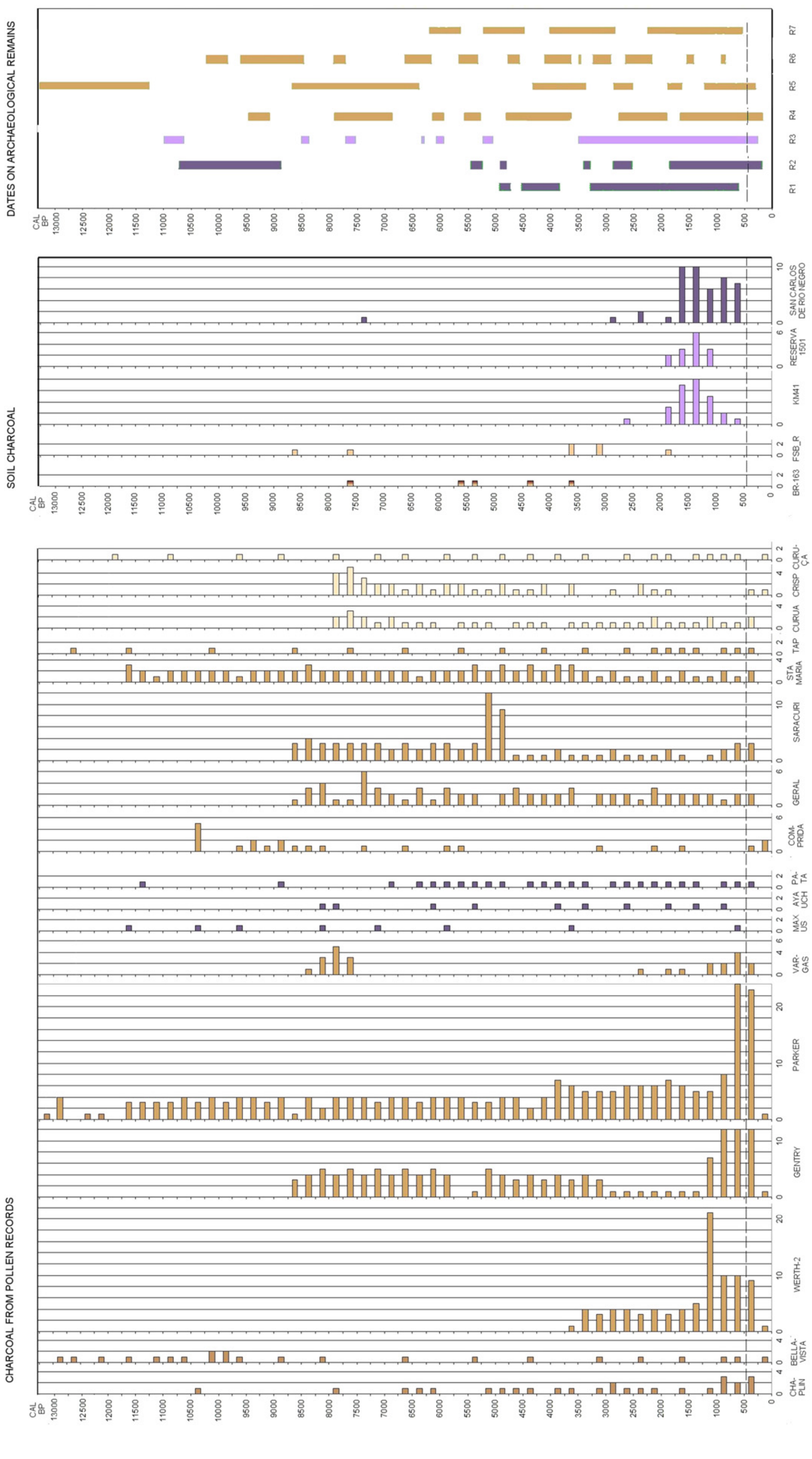

Fig. 2. Terminal Pleistocene and Holocene burning in the Amazon basin. The colour of bars reflects the length of the dry season in sampling region (after terrain colours in Fig. 1). Left, Middle: frequency of fires every 250 years (see Table 1 for data sources). Right: Vertical bars show overlapping calibrated age ranges (at 1 sd) from dated archaeological remains in different regions of the Amazon basin (see Table 1 for archaeological regions).

Amazonian soils, had imposed stringent limitations to population growth and livelihoods demanding the frequent relocation of communities. In contrast, Lathrap and his colleagues (Lathrap, 1970, 1977; Myers, 1974; Brochado, 1980; Oliver, 2001) argued that practices of slash-and-burn had originated in the extension of Amazonian house gardens. They were more enthusiastic about the productive potential of slash-and-burn cultivation yet ultimately envisioned an era of agricultural intensification based on cultivation of nutrient-rich floodplain soils. Projecting back from ethnographic observations in the upper Xingu River, Carneiro (1961, 1983) pointed out that pre-Columbian slash-and-burn cultivation would not have been limited by soil fertility but, instead, by the increasingly more labour-intensive need to handle weed growth (see also Oliver, 2001, 2008). Denevan (1992b; 2001), in turn, offered another intriguing projection: that the extensive and long-fallow pattern characteristic of ethnographic slash-and-burn ought to be regarded as an artefact of the European introduction of metal tools. In his account, pre-Columbian cultivation would have been more intensive, more based on short fallow periods, more fire-reliant, and more labour-demanding.

Some of these perspectives have been incorporated into more recent archaeological accounts of the Amazon rainforest. Roosevelt (1989, 1993; 1999a; 1999b) and Oliver, (2001) have followed the overall gist of Lathrap's suggestion – that tropical forest cultures (slash-and-burn cultivators) would have been the norm in Amazonia before agricultural intensification in the late Holocene. Researchers in some regions of the Brazilian Amazon have been hesitant about the actual potential, let alone spatial extent of pre-Columbian agriculture (Miller, 1992a, 1999). In contrast, researchers in Colombia (Andrade, 1986, 1988; Mora, 1991; Herrera et al., 1992) and Ecuador (e.g. Bush and Colinvaux, 1988; Piperno, 1990; Athens and Ward, 1999) have discussed clearance and cultivation on the basis of anthropogenic soils, plant microfossils and charcoal evidence. More recently, Neves and Petersen (2006) have marshalled Denevan's suggestion that pre-metal gardening would have demanded high labour to interpret long-term disturbance of

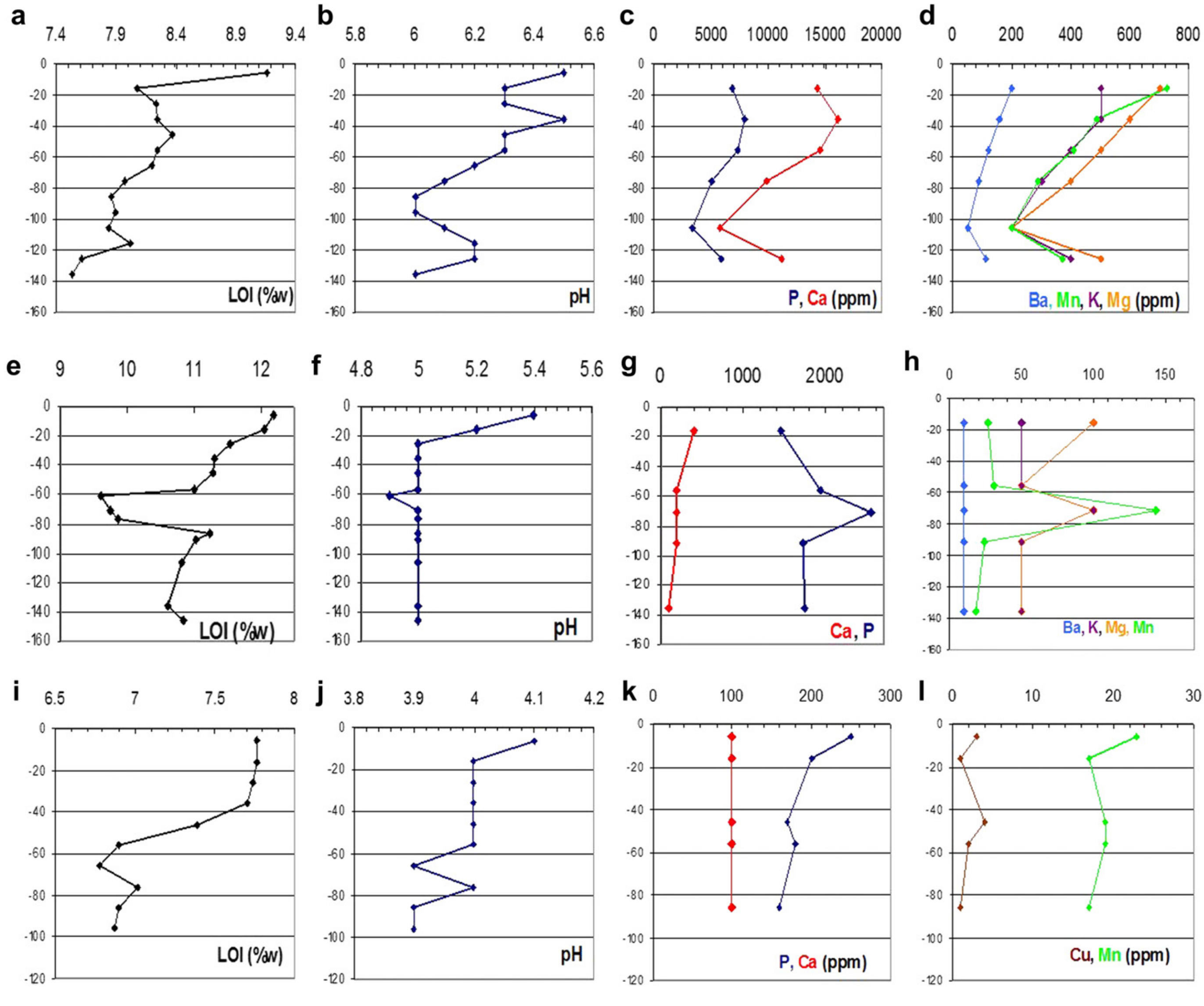

Fig. 3. Carbon estimates (LOI, 550C), pH (1:2 solution), and total elemental concentrations (measured by ICP-AES) in soil profiles (*y* axis is depth in cm) of (a–d) exposed *terras pretas* at the Hatahara site, (e–h) buried *terra mulata* horizon at Lago Grande site, and (i–l) control off-site exposed Yellow Latosol (≈Oxisol or Ferralsol) on Hatahara landform. Graphs a–d: note curve inflecting below 100 cm, pointing to early first millennium AD occupation. Graph e,f: note *lower* pH and LOI of *terra mulata* horizon, suggesting possible different parent material with lower mineral carbon contents. Graph i: note that thick, carbon-rich, A horizon of control profile records presence of soil charcoal from sub-recent burning; graphs j, k, l record thin A horizon more accurately. All soil profiles are texturally clayey.

vegetation as a result of former settlements (rather than outfields), while Heckenberger and colleagues (Heckenberger et al., 2003b, 2007) have interpreted scarring of forest vegetation in satellite imagery as evidence of long-term disturbance of forest due to 1–2nd millennium AD clearance. All along, Lathrap's (1970) model of intensive floodplain cultivation remains archaeologically untested: even if it can be invoked on the basis of ethnographic observations (e.g. Hiraoka, 1989; Fraser, 2010), the presence of archaeological evidence of large settlements that are not associated with large floodplains (e.g. Heckenberger et al., 1999) clearly undermines its overall significance.

3. Anthrosols, soil churning, and fire

Crucial evidence to discuss the overall importance of slash-and-burn cultivation during pre-Columbian times comes from studies of Amazonian Dark Earths (Sombroek, 1966; Smith, 1980; Lehmann et al., 2003; Glaser and Woods, 2004; Woods et al., 2008). These are soils also known as ADEs or as *terras pretas de índio*. ADEs are anthropogenic soils of pre-Columbian origin that have been known to Amazonian scholars since the very onset of modern naturalist investigations (Smith, 1879; Hartt, 1885; Katzer, 1944; Gourou, 1949; Nimuendajú, 1949; Neves, 2004). Their neglect in traditional archaeological accounts of the Amazon basin has strongly distorted understandings of the region's pre-Columbian history (Arroyo-Kalin, 2008a).

ADEs are generally associated with late Holocene archaeological evidence, generally dating to the first or second millennium AD (Eden et al., 1984; Arroyo-Kalin, 2008a). Reported expanses extend over areas ranging between <1 and 80 ha and generally show a much higher agricultural aptitude than unmodified soils. In the 1960s pedologist Wim Sombroek (1966) hypothesised that *terras pretas* were the result of soil enrichment due to the decomposition of village refuse. With some amendments (Smith, 1980; Glaser et al., 1998; Lima et al., 2002; Arroyo-Kalin et al., 2008b), this interpretation has withstood the passage of time. Sombroek also noticed that larger expanses of less-enriched anthrosols, which he labelled *terras mulatas*, surrounded or were adjacent to *terras pretas*. He hypothesised that these areas recorded the effects of burning associated with past agricultural practices. Archaeologists and geographers in the Colombian (Andrade, 1986, 1988; Mora, 1991; Herrera et al., 1992) and Brazilian Amazon (Woods, 1995, 2002; McCann et al., 2001, 2003) identified and measured the chemical properties of similar anthrosols and variously argued for wide-area clearance, intensive cultivation, and/or crop intensification in pre-Columbian times.

A study by the author of this paper (Arroyo-Kalin, 2008a,b; Arroyo-Kalin, 2010) has recently expanded existing knowledge about *terras pretas* and *terras mulatas*. Focusing on anthrosols associated with ceramists' archaeological remains studied by the Central Amazon Project (Neves, 2001, 2003, 2005, 2008), which are generally dated from the late first millennium BC to the second millennium AD (Donatti, 2003; Machado, 2005; Lima et al., 2006; Moraes, 2006), the study confirms previous observations that a gradient from higher to lower pH, organic carbon, and soil nutrients occurs along the *terra preta* > *terra mulata* > Oxisol catena (Fig. 3). In addition, it shows that in *terras pretas* these values (and very high magnetic susceptibility) are associated with high densities of sand- to silt-sized fragments of charcoal, pottery, rubified clay, and bone (Fig. 4a, b, c). These kinds of debris point to the concentration of soot in the interior of dwelling structures (Arroyo-Kalin, 2008a) as well as the contributions of debris and burning

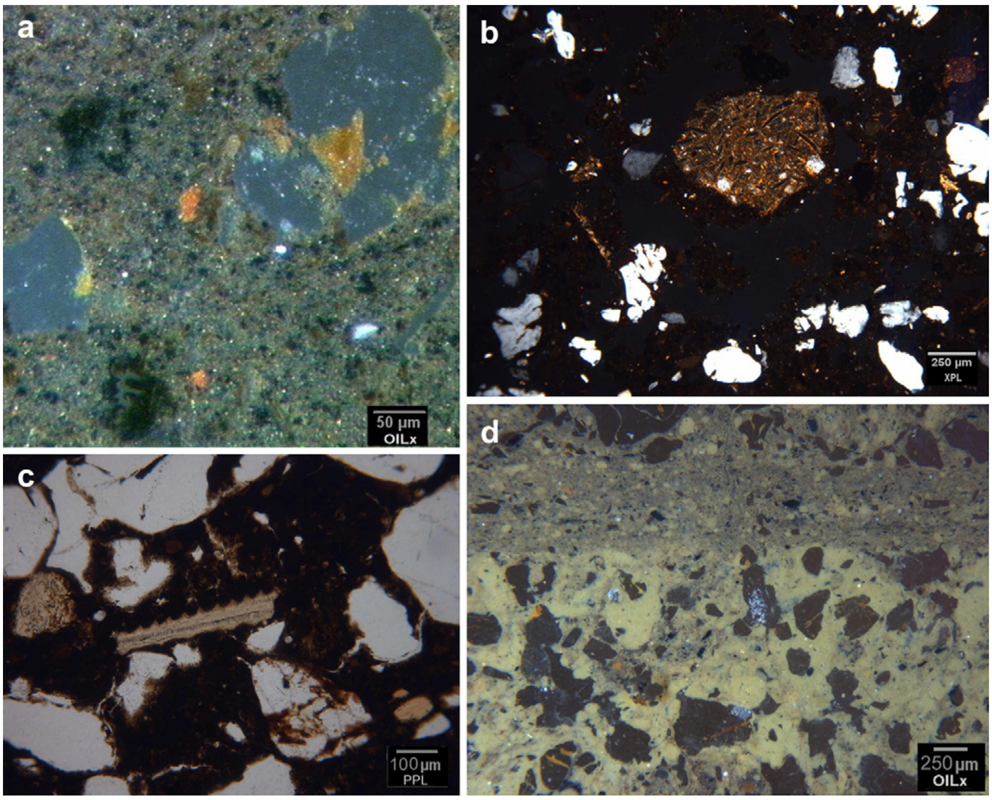

Fig. 4. Microphotographs of samples from *terras pretas*: (a) microscopic fragments of charcoal; (b) fragments of spicule-tempered pottery; (c) microscopic fragments of fish bone; (d) microscopic microstructure records build-up of anthropogenic A horizon over A/B horizon. All samples from the Hatahara site. PPL = Plain Polarised Light. XPL = Cross Polarised Light. OILx = Oblique Incident Light and Low intensity XPL.

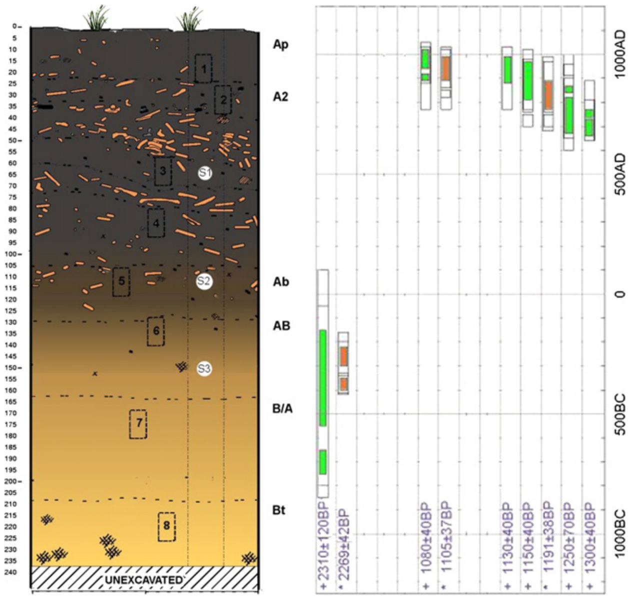

Fig. 5. Microscopic charcoal fragments from three 100 g soil samples collected by the author at Mound II of the Hatahara site (profile drawing on left: sample depths marked by S1, S2, and S3) were extracted by treating the <2 mm fraction of dry soil with hydrofluoric acid followed by repeated dilutions with hydrochloric acid. Isolated charcoal particles were radiocarbon dated using the AMS procedure at the Waikato Radiocarbon lab (chart on right: dates marked with *). Compared to radiocarbon dates on macroscopic charcoal (chart on right: samples marked with +) collected by the Central Amazon Project during excavations of the c.200 m-distant Mound I (Neves, 2003; Machado, 2005; Lima et al., 2006; Neves, 2007; Lima, 2008), samples from the anthropogenic horizons (Ab and AB) buried by mound construction (S2 and S3, WK-16223: 1105 ± 37 ^{14}C BP and WK-16224: 1191 ± 38 ^{14}C BP) cannot be distinguished statistically from numerous radiocarbon determinations from Mound I. A sample from the A2 horizon (S1, WK-16222, 2269 ± 42 ^{14}C BP), representing charcoal in soil material used to build the mound, falls within the error bars of old (pre-*terra* preta) charcoal collected under Mound I.

from both low-temperature fires (associated with waste management, cooking and fish smoking) and high-temperature fires (associated with ceramic firing). The best model for the build-up of these soils appears to be anthropogenic sedimentation (Fig. 4d) coupled with mixing by soil fauna (Woods, 1995; Vacher et al., 1998; Kern et al., 2004; Arroyo-Kalin et al., 2007; Arroyo-Kalin, 2008b).

Some controversy has existed about the extent to which *terra preta* sites reflect long-lasting, continued inhabitation as opposed to overlapping short-lived occupations (Meggers, 2001; Neves et al., 2003, 2004; Heckenberger et al., 2003a). Archaeologists directly involved in their excavation moreover, have cogently argued that 'mounds' at some archaeological sites recycle soils containing ceramic shards and charcoal from previous occupations (Neves, 2003; Machado, 2005; Moraes, 2006). Thus the possibility exists that large occupations detected on the basis of archaeological remains actually postdate the formation of anthropogenic soils themselves. To examine these questions, the study concentrated and dated the microscopic charcoal pool of samples from *terras pretas* (Fig. 5). Resulting ages on microscopic charcoal are consistent with ages from radiocarbon dates of macroscopic charcoal and pottery remains embedded in the soil, suggesting that the pyrogenic carbon pool of *terras pretas* is coeval with the most intense human occupations inferred from archaeological evidence.

The reported study also found intriguing differences between *terras pretas* and *terras mulatas*. The latter are anthropogenically-enriched soils (Fig. 3e–h) whose A horizon contain important but on the whole lower quantities of microscopic charcoal than *terras pretas* (Fig. 6a, b) as well as negligible fragments of microscopic bone, pottery, or burnt clay (Fig. 6a, b). Studied samples from the A horizon show high magnetic susceptibility compared to samples from a sub-recently fired Oxisol A horizon, suggesting that soil iron has been altered by intensive near-surface burning (Fig. 7).

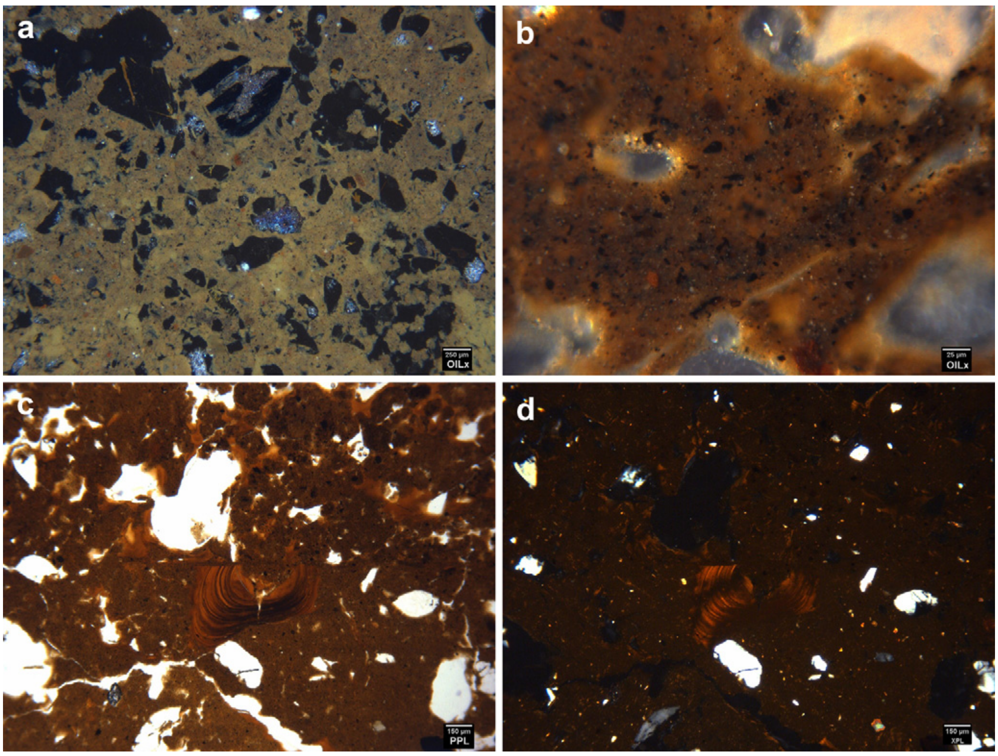

Fig. 6. Microphotographs of *terras mulatas* from the Lago Grande site. (a) and (b) A horizon of *terra mulata*, note the important quantities of microscopic charcoal but absence of bone or pottery microscopic fragments. (c, d) truncated illuvial clays highlight the lack of mixing between the *terra mulata* A horizon and limpid clays of the B horizon. Note presence of microscopic charcoal fragments in the lower part of buried A *terra mulata* horizon, and total absence of microscopic charcoal fragments in B horizon sediments.

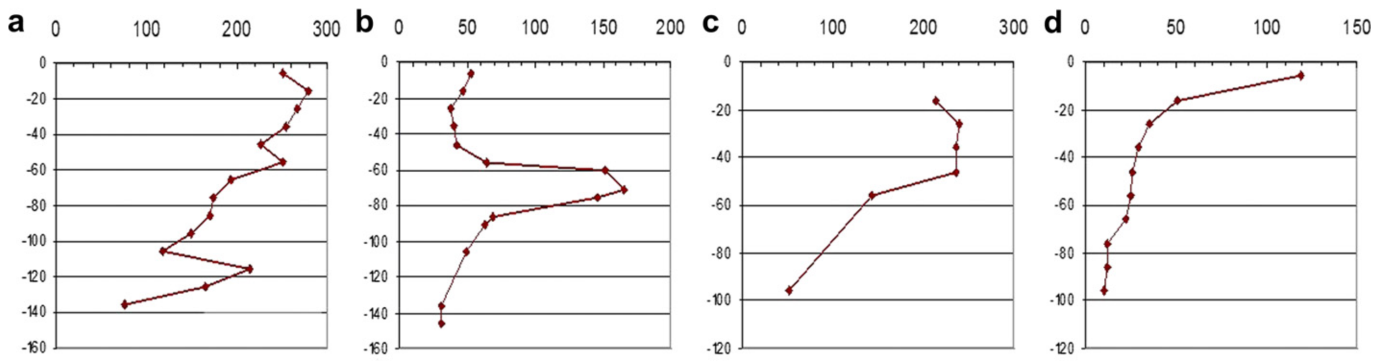

Fig. 7. Magnetic susceptibility values (Y = depth, X = Low frequency Tesla units, measured with a dual frequency Bartington MS2/MS2B sensor) from four profiles. (a) Hatahara site, *terra preta* profile; (b) Lago Grande, buried *terra mulata* profile; (c) Lago Grande, exposed *terra mulata* profile; (d) control profile on same landform as Hatahara site, with sub-recent burning. All four soil profiles are texturally clayey.

Micromorphological observations also show a clear truncation between the lower part of a well-preserved buried A horizon and its underlying B horizons (Fig. 6c, d), suggesting some form of scraping, raking, or churning of the soil.

The reported research not only questions the scenario of short, repeated occupations advanced by some scholars (Meggers, 2001) but also offers an alternative to Lathrap's model of agricultural intensification on fl floodplain soils. Its main observations suggest Sombroek's (1966) insights about *terras pretas* and *terras mulatas* are essentially correct: high concentrations of microscopic charcoal sequestered in expanses of anthropogenic soils *beyond* former settlements evidence that pre-Columbian slash-and-burn cultivation, at least in the vicinity of Manaus (a region on the whole more humid than eastern and southern Amazonia but drier that western and northwest sub-regions of the basin), was spatially-concentrated, fire-intensive, and capable of achieving a lasting enhancement of soil fertility. This inference endorses Denevan's (2004) suggestion that pre-Columbian swidden agriculture before European contact was less extensive and more reliant on permanent soil modification than observed ethnographically. It also suggests that Carneiro's defence of swidden agriculture may actually underestimate the extent of modified anthrosols in the region (Oliver, 2008; Schmidt, 2010).

In parallel, the reported research also cautions against oversimplifying data for the formation processes and presence/absence of these soils: ethnography-based studies (Zeidler, 1983; Hecht, 2003; Silva and Rebellato, 2004; WinklerPrins, 2006; Schmidt, 2010) suggest that the production and manipulation of soil inputs such as charcoal and ash are a common feature of village life in the Amazon basin, whilst archaeological studies show that charcoal-rich anthropogenic soils are not exclusive to the Amazon basin (e.g. Prous, 1991; Vacher et al., 1998; Oyuela-Caycedo and Bonzani, 2005; Castillo and Aceituno, 2006; Oliver, 2008). In other words, it is likely that the distribution of known Amazonian instances is skewed towards regions where archaeologists have paid attention to both larger archaeological sites and soil composition.

Microscopic analysis of pre-Columbian anthropogenic soils, lastly, also highlights interesting avenues for future research. On the one hand, quantification of settlement-related microscopic charcoal by unit volume of soil could be used to develop a proxy for intensity of occupation, one that would almost certainly contradict suggestions that nomadic occupations produce more charcoal than sedentary ones (cf. Mora, 2003a). Quantification of off-settlement microscopic charcoal by unit volume of soil, in turn, could eventually provide a proxy of agricultural intensification. These observations hopefully will encourage palaeoecologists to seek, quantify and calibrate coeval burning signals in nearby pollen records instead of marshalling the sum total of archaeological and soil charcoal radiocarbon dates as a proxy of intensive burning (e.g. Bush and Silman, 2007, Fig. 3).

4. When did Amazonian slash-and-burn cultivation begin?

Early Holocene human communities of the Amazon basin have generally been regarded as small, most likely nomadic populations with a forager subsistence focus. Yet, different sites along the basin (Miller, 1987; Magalhães, 1993, 1995; Roosevelt et al., 1996; Morcote-Ríos and Bernal, 2001; Costa, 2002; Mora, 2003b) highlight that these foragers relied on the harvesting of fruit trees, a practice which often led to the discard and charring of seeds and nuts at frequently-revisited locales. At least two dynamics of landscape domestication (in the sense of Clement, 1999, 2006b), both with potential for spatially-restricted impact on vegetation, can be inferred from these remains. First, practices leading to the formation of anthropogenic patches of desirable fruit-bearing trees at frequently-revisited locales, similar to those reported ethnographically (Morcote et al., 1996, 1998; Politis, 1996; Politis, 1999; Cárdenas and Politis, 2000; Clement, 2006a), most likely encouraged repeated burning at itinerantly-visited campsites. Second, considering that the oldest archaeobotanical evidence of crops in Amazonia – at Peña Roja – is associated with these finds (Fig. 1.4, Piperno and Pearsall, 1998; Mora, 2003b), and envisioning how repeated deposition of charcoal would lead to incipient enhancement of soils (Arroyo-Kalin, 2010), it is not far-fetched to argue that Amazonian gardening practices may actually date back to the early Holocene (see also Piperno, 2009b). Livelihoods so characterised, however, fall one step short of slash-and-burn cultivation: rather than being characterised by a continuous regime of felling and firing vegetation to open land for cultivation, they are likely to have resembled house gardens and forest gardens, or - in the more humid regions of the basin - perhaps approached practices of slash-and-mulch (Lathrap, 1977; Rival, 1998, 2002; Lu, 1999).

In point of fact, the antiquity of slash-and-burn cultivation in the Amazon basin continues to elude researchers: it can be expected but not established on the basis of other early northern South American evidence (Piperno, 2009b); it can be surmised but not ascertained from palaeoecological evidence for burning and disturbance (Athens and Ward, 1999; Bush et al., 2007b). One way to address the matter is to consider more specifically why people in Amazonia engage in slash-and-burn cultivation. Here it is worth pointing out a significant characteristic of Amazonian gardens managed through slash-and-burn: though often noted for their high agro-biodiversity (Harris, 1971; Beckerman, 1987; Oliver, 2001), the vast majority of Amazonian cases focus on the intercropping of maize and sweet manioc (e.g. Steward, 1948b; Descola, 1994; Salick et al., 1997), or on the cultivation of bitter manioc (Goldman, 1963; Chernela, 1987; McKey and Beckerman, 1993; Emperaire, 2002; Fraser and Clement, 2008). If cultivation of these crops constitutes the prime reason to slash-and-burn in Amazonia, attention to their specific local histories provides one way to examine the antiquity of associated cultivation practices in the region.

Maize was domesticated in Central America (Piperno and Flannery, 2001; Pope et al., 2001) and trickled into northern South America (Bray et al., 1987; Piperno and Holst, 1998; Pearsall, 2003; Piperno, 2006b) as early as the 8th millennium BP. The oldest Amazonian evidence dates to at least 5.3–5.0 cal ky BP at the Ayauchi pollen core, located in the Ecuadorian *montaña* (Fig. 1.E, Piperno, 1990), a humid region in which other fire and/or vegetation disturbance signals (Piperno, 1990; Athens and Ward, 1999; Weng et al., 2002) and occupations by ceramists dated between the 5th to 3rd millennium BP (Fig. 1.1 and 2, Valdez et al., 2005; Rostain, submitted for publication) are recorded. Maize pollen and phytoliths older than 5.5–5.3 cal ky BP are also recorded in sediments at the Abeja site, Colombian Amazon (Fig. 1.4, Mora, 1991; Herrera et al., 1992; Piperno and Holst, 1998), with an unclear association with archaeological artefacts (Mora et al., 1988:ff). Maize is also reported in segments of pollen cores dating to c. 3.6–3.7 cal ky BP in both the lower Amazon region and the Puerto Maldonado region (Fig. 1c, g,; Bush et al., 2008), findings that are broadly coeval with regional archaeological evidence for small groups of *terra firme* ceramists (lower Amazon and Marajó: Fig. 1.20,21,22,24, Simões, 1969; Roosevelt, 2000; Gomes, 2008; Peruvian Amazon: Fig. 1.3, Allen, 1968).

When evidence for maize cultivation is considered, palaeoecological and archaeological data show a suggestive temporal gradient that starts outside Amazonia and reaches both the lower Amazon region and Peruvian Amazonia by the beginning of the 4th millennium BP. It is tempting to suggest that this gradient also describes the adoption of slash-and-burn cultivation practices in the basin. However, it should be remembered that maize is readily out-competed by forest vegetation: it generally grows well intercropped with other cultivars in open plots, on floodplain soils associated with whitewater rivers, and – to judge from plant microfossil evidence (Herrera et al., 1992; Bozarth et al., 2008) – on pre-Columbian anthropogenic soils. The scant available ^{13}C isotope data on human bone for the fourth millennium BP (from the vicinity of Santarém) does not suggest a dominant intake of C4 plants in the diet (see Roosevelt, 1989; Roosevelt, 2000). This may well indicate that the cultivation of maize in places without access to rich floodplain soils or anthropogenic soils may have been difficult in the past. This point is buttressed by the fact that ^{13}C data from human bones associated with the formation of late first millennium AD (Neves, 2003) *terras pretas* do not suggest a diet dominated by C4 plants either (Arroyo-Kalin, 2010).

The other key crop of Amazonian slash-and-burn cultivation is manioc (*Manihot esculenta* ssp. *esculenta* Crantz). Many scholars underscore manioc as 'the' Amazonian staple crop because of its high starch yield, well-documented ability to grow on acid soils, and capability of keeping its tubers un-harvested for over 12 months – a trait which has been described as 'underground storage' (Carneiro, 1983; Heckenberger, 1998; Piperno and Pearsall, 1998). As hinted above, cultivated manioc in reality consists of two broad varieties – bitter and sweet manioc. The former is the main crop used in slash-and-burn cultivation in Orinoquia and the Guianas, as well as in much of the northwest, eastern and south-eastern regions of the Amazon basin: it is high starch-yielding, well-adapted to acid soils and pests, but has high concentrations of cyanogenic glucosides that require detoxification before human consumption. In contrast, sweet manioc is more common in the western and south-western regions of the Amazon basin, as well as in regions beyond the basin: it requires no prior detoxification, but is a low starch yielder that is intolerant to poor soils or pests (Fig. 8). As a result, it is generally cultivated in amended soils near dwellings and/or intercropped with maize (Denevan, 1971; Carneiro, 1983; Boster, 1984; Beckerman, 1987; Chernela, 1987; Dufour, 1989, 1995; Emperaire, 2001; Emperaire, 2002; Wilson and Dufour, 2002). The phylogenetic split between bitter and sweet manioc varieties is ancient and took place after initial domestication (Mühlen et al., 2000; Elias et al., 2004; McKey et al., 2010).

Microfossils of *M. esculenta*, *Manihot* sp. and Manihot-types are reported outside the Amazon basin as early as 10.3–9.9 and 8.5–8.3 cal ky BP (Piperno and Holst, 1998; Piperno et al., 2000; Aceituno and Castillo, 2005). However, by far the best-documented evidence are microscopic starch grains associated with lithic artefacts of preceramic occupations in Panama dating to 6th millennium BP (Piperno, 2006a). The oldest Amazonian evidence is limited to veritable amounts of pollen found in the 5.5–5.3 to 5.0–4.9 cal ky BP Tubabonipa component of the Abeja site, in northwest Amazonia (Fig. 1.4, Mora, 1991; Piperno and Pearsall, 1998). This evidence appears to mimic the north-to-south gradient of maize cultivation, which might suggest that manioc originated outside the Amazon basin. However, genetic evidence demonstrates that manioc is an Amazonian domesticate: populations of *M. esculenta* ssp. *flabellifolia* in southwest Amazonia are ancestral to all forms of cultivated manioc (Olsen and Schaal, 1999). Southwest Amazonia more than fits the part for a source region of cultivated manioc: palaeoecological data suggests an early-mid Holocene landscape characterised by more open, drier and fire-prone vegetation (Fig. 1.vi, Freitas et al., 2001) – conditions ideal for the domestication of a disturbance-adapted species with underground storage organs capable of withstanding prolonged drought and which, on the whole, is fire-friendly (McKey and Beckerman, 1993; Pujol et al., 2002). The archaeological record, in turn, shows human occupations from the Late Pleistocene onwards and, significantly, includes the oldest clearly-reported examples of anthropogenic soils in the Amazon basin, c. 5.0 cal ky BP preceramic dark earths associated with *terra firme* occupations of the Massangana phase (Fig. 1.19, Miller, 1992a; b; Miller, 1999, 2009).

Considering the fact that sweet rather than bitter manioc is cultivated in southwest Amazonia, it is not far fetched to suggest that early anthropogenic soils of southwest Amazonia played a role in the domestication of cultivated manioc. As suggested elsewhere (Arroyo-Kalin, 2010), dump heaps would have helped to cultivate away from parent populations those individuals selected for their low toxicity, such that the low starch-yielding, less pest-resistant, 'sweet' manioc varieties would have evolved. Pest-resistant but toxic bitter varieties, well-adapted to poor soils, would have evolved later, their selection driven by their high starch yields and permitted by technological innovations that allowed both sustainable outfield cultivation and crop detoxification (see also McKey and Beckerman, 1993; McKey et al., 2010).

From the point of view of the antiquity of slash-and-burn cultivation, the split between sweet and bitter manioc may epitomise two contrasting Amazonian livelihoods (Fig. 8). One is the smaller-scale maize- and sweet manioc-dependent tropical forest culture pattern characteristic of western Amazonia: slash-and-burn cultivation that accords well with ethnographic accounts and can be expected to produce little overall impact on the landscape. Another are the resilient livelihoods based on bitter manioc cultivation: these may have originated in a process of agricultural intensification that relied on the production of *terras mulatas* along the main rivers of the basin after the onset of the 1st millennium

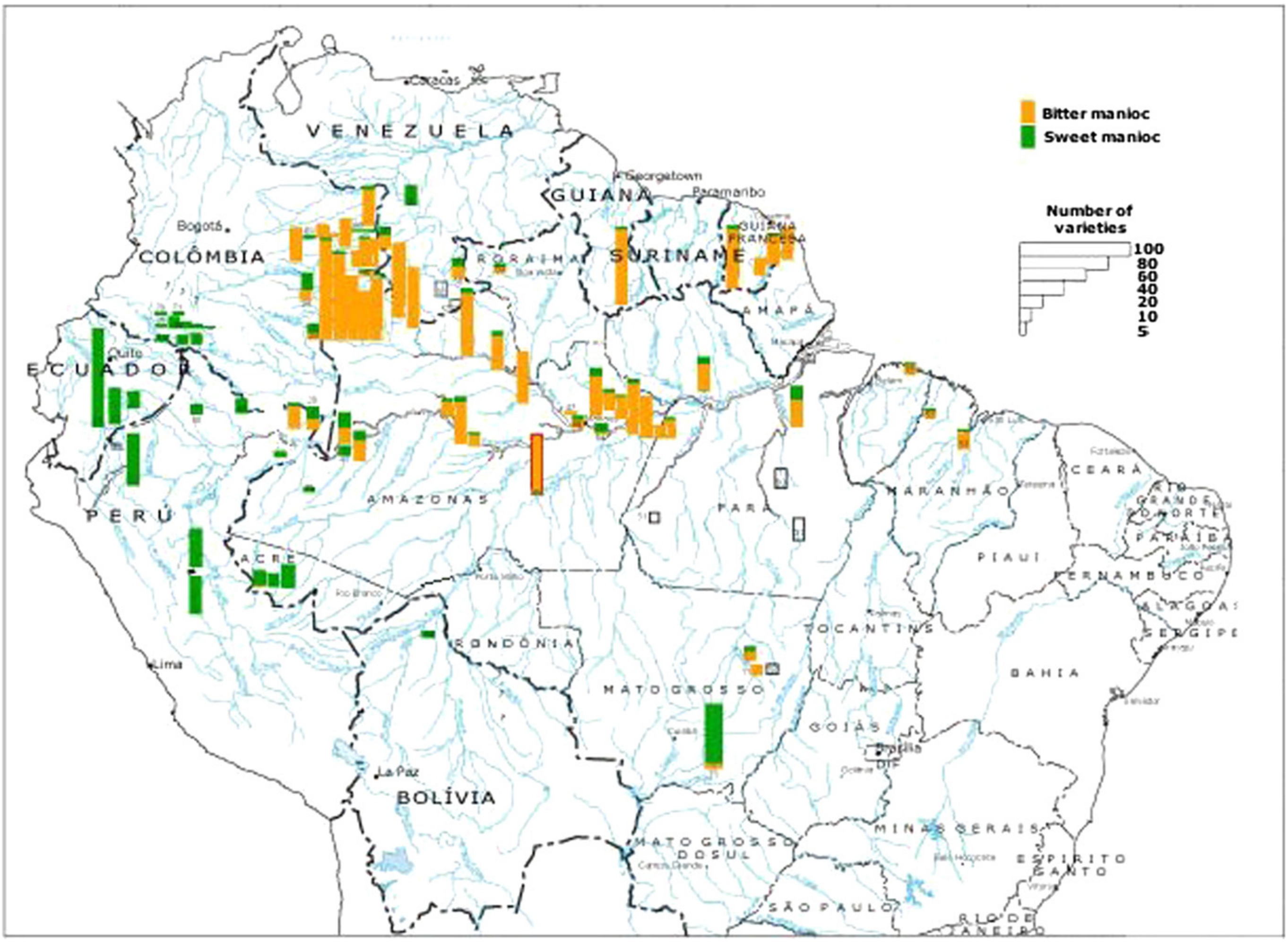

Fig. 8. Map of bitter and sweet manioc varieties compiled from ethnographic sources by Emperaire (Emperaire, 2001), modified with permission. Bar with red outline in the middle Madeira River region reflects dataset presented by Fraser et al. (2008).

AD. Burning associated with this livelihood may have had a significant but localised impact on the overall landscape. Both patterns would have relied on the burning of vegetation for clearance but only the latter would be expected to produce a consistently high frequency burning signal in some pollen records: a result of intensive cultivation and practices of charring organic matter in the large pre-Columbian settlements that today appear as expanses of *terras pretas*, and – in areas where burning vegetation extensively was more difficult – an outcome of outfield management practices that today appear as expanses of *terras mulatas*.

5. Discussion

Holocene age archaeological evidence provides important pointers to suggest that spatial heterogeneity in the adoption of specific cultivation techniques – the latter associated with specific cultivars (sweet manioc and maize vis-à-vis bitter manioc) – could account for part of the regional variability of Amazonia's fire history. For instance, the apparent paradox between the fact that some rainforest-clad, humid regions, e.g. the upper Negro and Manaus regions (Sanford et al., 1985; Saldarriaga, 1994; Piperno and Becker, 1996; Santos et al., 2000), show less evidence of fire and/or vegetation disturbance in the mid Holocene (even when evidence for human occupation is recorded, see Costa, 2002, 2009; Neves, 2008; Arroyo-Kalin, 2010), while other rainforest-clad humid regions, such as the Ecuadorian Amazon (Piperno, 1990; Athens and Ward, 1999; Weng et al., 2002) show clear fire signals could indicate that each region was characterised by different agricultural histories: maize cultivation (Bush et al., 1989; Piperno and Pearsall, 1998) appears to have expanded early but timidly into the humid reaches of western Amazonia, in parallel with early sub-Andean Formative activity (Valdez et al., 2005; Rostain, submitted for publication). It may have reached drier lowland regions, such as Puerto Maldonado (Bush et al., 2007b, 2008; McMichael et al., 2010) and the lower Amazon (Bush et al., 2008) by the fourth millennium BP, and be represented by Formative assemblages of the lowlands (Allen, 1968; Lathrap, 1970, 1971; Roosevelt, 2000). It might have gone in hand with cultivation of domesticated manioc, which had been selected in the more open or drier vegetation conditions of the early-mid Holocene in southwest Amazonia (Arroyo-Kalin, 2010). These occupations would have been characterised by the smaller-scale maize- and sweet manioc-dependent tropical forest culture pattern of western Amazonia, a pattern that would have produced tenuous, locally-discontinuous, and asynchronous fire signals. In contrast, along the main rivers of the Amazon basin, increased burning associated with intensive cultivation of bitter manioc and the formation of sedentary settlements, could be a result of population expansion along the dry-to-humid gradient of eastern, central, southwest and northwest Amazonia. This expansion, which later in time reached humid regions such as northwest Amazonia (where the highest agrodiversity of bitter manioc is recorded, see Emperaire, 2002), could explain the widespread formation of anthropogenic soils starting in the first millennium AD. Settlement and cultivation activities associated with these soils, mostly focused along the main rivers of the basin, may have driven the higher frequency of fires observed in palaeoecological records during the final millennia before European colonisation.

However broad-stroked, this contrast between cultivation regimes illlustrates how assessing Amazonian evidence of past fires requires taking into consideration not only palaeoclimatic factors and the temporal and spatial variability of Holocene vegetation change, but also the temporal and spatial variability implicit in the basin's history of food production systems. It cannot be overemphasised how Amazonian agrarian systems changed over time (Arroyo-Kalin et al., 2008a; Arroyo-Kalin, 2010): arboriculture in the early-mid Holocene involved a transition from spatially-extensive harvesting to more spatially-intensive tending and cultivation that set out the foundation of so-called fallow management. Associated burning at habitation sites and evidence for soil enrichment links the earliest indications of enduring landscape modification with the most ancient evidence for allochthonous crop cultivation. Cultivation of allochthonous maize and domestication of autochthonous sweet manioc – both of which are susceptible to pests and require nutrient-enhanced soils to grow – most likely developed in dump heaps/house gardens associated with small-scale early-mid Holocene tropical forest cultures. Selection for bitter manioc may have taken place in more open/drier regions, its subsequent use in rainforest environments coming to rely on the ability to produce micro-environmental replicas of savannah conditions with artificially-enhanced soils through intensive slash-and-burn cultivation. The end-result of this agricultural history – which might be labelled slash-burn-and-churn – strongly contrasts with post-European swidden cultivation (Denevan, 2004).

6. Conclusion

Deforestation of the world's largest and most complex rainforest biome advances at an unprecedented rate (Fearnside, 2005). Unabated, it will continue to impact negatively the array of native, peasant, and urban societies that inhabit the Amazon basin today. It will also endanger one of the world's most biologically-diverse ecosystems and – if much of the forest eventually goes – contribute significantly to global warming. Faced with the need to advocate alternative modes of rainforest use, and confronted by profit-seeking forces and energetic concerns that are at times thinly-disguised as development imperatives, it might appear tempting to fall back on tropes that portray Amazonia as a system in its 'natural' state before the recent impact of industrial society. However, the growing body of evidence about anthropogenic landscape transformations in pre-Columbian Amazonia (papers in Balée, 2010; Junqueira et al., 2010) clearly rejects this 'pristine myth' (Denevan, 1992a). In this connection, concerns have been raised about how insufficiently specific statements concerning the spatial extent of pre-Columbian landscape modifications could provide advocates of industrial farming/stock raising, forest extraction, and ore mining (and their traditional allies, power generation and infrastructure development) with a misleading yet rhetorically-powerful set of arguments: that Amazonia is some kind of overgrown woodland that has been left to fallow for five centuries (see discussion by Bush and Silman, 2007; Bush et al., 2008). Even if neither archaeological nor ethnohistorical sources suggest that pre-Columbian populations depleted local resources or irreversibly deteriorated the landscape of Amazonia, these concerns are reasonable and call for researchers to ground-truth the ubiquity of evidence for anthropogenic modification before drawing conclusions about Amazonia as a whole. In the case of Amazonian Dark Earths, it is not overdue to reiterate that all known exemplars are actually archaeological sites. Consequently, the overall density of ADEs in the landscape reflects the superimposed distribution of past human occupations. The majority of well-documented cases appear to be located in the vicinity of natural concentrations of aquatic resources, an observation that underscores the well-known complementarity between fish and cultivated plants in Amazonia (Arroyo-Kalin, 2008a). It is worthy of future attention that these modified locales most likely exerted a 'pull factor' or had an 'attractor dynamic' among Amazonian societies, heralding growing population densities in specific places of Amazonia. Rather than minimising their impact, the evidence discussed in this paper suggests these human communities were cornerstones of both environmentally-transformative dynamics and sustainable livelihoods, indeed veritable stewards of actual Holocene biodiversity (Stahl, 1996).

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References

Absy, M.L., Cleef, A., Fournier, M., Sifeddine, A., da Silva, M.F., Soubies, F., Suguio, K., Turcq, B., van der Hammen, T., 1991. Mise en evidence de quatre phases d'ouverture de la forêt dense dans le sud-est de l'Amazonie au cours des 60000 dernieres années. Premiere comparaison avec d'autres régions tropicales. Comptes Rendus de L'Académie Des Sciences 312 (Série II), 673–678.

Aceituno, F.J., Castillo, N., 2005. Mobility strategies in Colombia's middle mountain range between the early and middle Holocene. Before Farming 2 (article 2), 1–17.

Allen, W.L., 1968. A Ceramic Sequence from the Alto Pachitea, Perú: Some Implications for the Development of Tropical Forest Culture in South America Department of Anthropology. University of Illinois, Urbana, p. 386.

Andrade, Á, 1986. Investigación arqueológica de los antrosolos de Araracuara (Amazonas). Arqueología Colombiana 31, 1–101.

Andrade, Á, 1988. Desarrollo de los sistemas agrícolas tradicionales en la Amazonía. Boletín del Museo del Oro 21, 38–59.

Anhuf, D., Ledru, M.-P., Behling, H., Cruz Jr., F.W.d., Cordeiro, R.C., van der Hammen, T., Karmann, I., Marengo, J.A., Oliveira, P.E.d., Pessenda, L., Siffedine, A., Albuquerque, A.L., da Silva Dias, P.L., 2006. Paleo-environmental change in Amazonian and African rainforests during the LGM. Palaeogeography, Palaeoclimatology, Palaeoecology 239, 510–527.

Arroyo-Kalin, M., 2008a. Steps Towards an Ecology of Landscape: a Geoarchaeological Approach to the Study of Anthropogenic Dark Earths in the Central Amazon Region Department of Archaeology. University of Cambridge, Cambridge.

Arroyo-Kalin, M., 2008b. Steps towards an ecology of landscape: the pedostratigraphy of anthropogenic dark earths. In: Woods, W., Teixeira, W., Lehmann, J., Steiner, C., WinklerPrins, A., Rebellato, L. (Eds.), Amazonian Dark Earths: Wim Sombroek's Vision. Kluwer, Dordrecht, pp. 33–83.

Arroyo-Kalin, M., 2010. The Amazonian formative: crop domestication and anthropogenic soils. Diversity 2, 473–504.

Arroyo-Kalin, M., Clement, C.R., Fraser, J.A., 2008a. Extensive to intensive, or first fruits and then roots? Bitter/sweet thoughts on agricultural intensification in pre-Columbian Amazonia. In: Papers Presented at the Shifting Cultivation Session, 6. World Archaeological Congress.

Arroyo-Kalin, M., Neves, E.G., Woods, B., Bartone, R., Lima, E.P., Rebellato, L., Moraes, C.P., Silva, C.A.d. and Daniel, A.R.-P. (2007). Mix and grow? Assessing the geoarchaeological significance of Terras Pretas in the Central Amazon region. In, Papers presented at the Developing International Geoarchaeology 2007.

Arroyo-Kalin, M., Neves, E.G., Woods, W.I., 2008b. Anthropogenic dark earths of the Central Amazon region: remarks on their evolution and polygenetic composition. In: Woods, W., Teixeira, W., Lehmann, J., Steiner, C., WinklerPrins, A., Rebellato, L. (Eds.), Amazonian Dark Earths: Wim Sombroek's Vision. Kluwer, Dordrecht, pp. 99–125.

Athens, J.S., Ward, J.V., 1999. The late Quaternary of the western Amazon: climate, vegetation and humans. Antiquity 73, 287–302.

Balée, W., 1989. The culture of Amazonian forests. In: Posey, D., Balée, W. (Eds.), Resource Management in Amazonia: Indigenous and Folk Strategies, 7. New York Botanical Garden, Bronx, NY, pp. 1–21.

Balée, W., 2006. The research program of Historical Ecology. Annual Review of Anthropology 35, 75–98.

Balée, W., 2010. Contingent diversity on anthropic landscapes. Diversity 2 (2), 163–181.

Beckerman, S., 1987. Swidden in Amazonia and the Amazon rim. In: Turner, B.L., Brush, S.B. (Eds.), Comparative Farming Systems. Guilford Press, New York, pp. 55–94.

Behling, H., 1996. First report on new evidence for the occurrence of Podocarpus and possible human presence at the mouth of the Amazon during the Lateglacial. Vegetation History and Archaeobotany 5 (3), 241–246.

Behling, H., 2001. Late Quaternary environmental changes in the Lagoa da Curuça region (eastern Amazonia, Brazil) and evidence of Podocarpus in the Amazon lowland. Vegetation History and Archaeobotany 10 (3), 175–183.

Behling, H., Berrío, J.C., Hooghiemstra, H., 1999. Late Quaternary pollen records from the middle Caquetá river basin in central Colombian Amazon. Palaeogeography, Palaeoclimatology, Palaeoecology 145 (1-3), 193–213.

Behling, H., da Costa, M.L., 2000. Holocene environmental changes from the Rio Curuá record in the Caxiuanã region, eastern Amazon Basin. Quaternary Research 53 (3), 369–377.

Behling, H., da Costa, M.L., 2001. Holocene vegetational and coastal environmental changes from the Lago Crispim record in northeastern Para state, eastern Amazonia. Review of Palaeobotany and Palynology 114 (3-4), 145–155.

Behling, H., Keim, G., Irion, G., Junk, W., de Mello, J.N., 2001. Holocene environmental changes in the central Amazon basin inferred from Lago Calado (Brazil). Palaeogeography, Palaeoclimatology, Palaeoecology 173 (1-2), 87–101.

Boster, J.S., 1984. Classification, cultivation and selection of Aguaruna cultivars of *Manihot esculenta* (Euphorbiaceae). In: Prance, G.T., Kallunki, J.A. (Eds.), Ethnobotany in the Neotropics, 1, pp. 34–47.

Bozarth, S.R., Neves, E.G., Woods, W.I., Cascon, L., Caromano, C., 2008. Phytoliths and terra preta: the Hatahara site example. In: Woods, W.I., Teixeira, W.G., Lehmann, J., Steiner, C., WinklerPrins, A., Rebellato, L. (Eds.), Terra Preta Nova: A Tribute to Wim Sombroek. Kluwer, Dordrecht, pp. 85–99.

Bray, W., Herrera, L., Cardale de Schrimpff, M., Botero, P., Monsalve, J.G., 1987. The ancient agricultural landscape of Calima, Colombia. In: Denevan, W., Mathewson, K., Knapp, G. (Eds.), Pre-hispanic Agricultural Fields in the Andean Region, 359. British Arcaheolgoical Resports International Seireis, Oxford, pp. 443–481.

Brochado, J.P., 1980. Social Ecology of the Marajoara culture. Department of Anthropology. University of Illinois at Urbana-Champagne, Urbana.

Burbridge, R.E., Mayle, F.E., Killeen, T.J., 2004. Fifty-thousand-year vegetation and climate history of Noel Kempff Mercado National Park, Bolivian Amazon. Quaternary Research 61 (2), 215–230.

Bush, M.B., Colinvaux, P.A., 1988. A 7000-year pollen record from the Amazon lowlands, Ecuador. Vegetatio 76 (3), 141–154.

Bush, M.B., De Oliveira, P.E., Colinvaux, P.A., Miller, M.C., Moreno, J.E., 2004. Amazonian paleoecological histories: one hill, three watersheds. Palaeogeography, Palaeoclimatology, Palaeoecology 214 (4), 359–393.

Bush, M.B., Miller, M.C., De Oliveira, P.E., Colinvaux, P.A., 2000. Two histories of environmental change and human disturbance in eastern lowland Amazonia. The Holocene 10 (5), 543–553.

Bush, M.B., Piperno, D.R., Colinvaux, P.A., 1989. A 6000 year history of Amazonian maize cultivation. Nature 340 (6231), 303–305.

Bush, M.B., Silman, M.R., 2007. Amazonian exploitation revisited: ecological asymmetry and the policy pendulum. Frontiers in Ecology and the Environment 5 (9), 457–465.

Bush, M.B., Silman, M.R., de Toledo, M.B., Listopad, C., Gosling, W.D., Williams, C., de Oliveira, P.E., Krisel, C., 2007a. Holocene fire and occupation in Amazonia: records from two lake districts. Philosphical transactions of The Royal Society, Series B. Biological Sciences 362 (1478), 209–218.

Bush, M.B., Silman, M.R., Listopad, C.M.C.S., 2007b. A regional study of Holocene climate change and human occupation in Peruvian Amazonia. Journal of Biogeography 34, 1342–1356.

Bush, M.B., Silman, M.R., McMichael, C., Saatchi, S., 2008. Fire, climate change and biodiversity in Amazonia: a late-Holocene perspective. Philosphical Transactions of The Royal Society, Series B. Biological sciences 363, 1795–1802.

Cárdenas, D., Politis, G.G., 2000. Territorio, movilidad, etnobotánica y manejo del bosque de los Nukak orientales. Amazonia Colombiana. In: Estudios Antropológicos, 3. Universidad de los Andes. 105.

Carneiro, R.L., 1961. Slash-and-burn cultivation among the Kuikuru and its implications for cultural development in the Amazon basin. In: Wilbert, J. (Ed.), The Evolution of Horticultural Systems in Native South America, Causes and Consequences, 2. Editorial Sucre, Caracas, pp. 47–67.

Carneiro, R.L., 1983. The cultivation of manioc among the Kuikuru of the upper Xingú. In: Hames, R.B., Vickers, W.T. (Eds.), Adaptive Responses of Native Amazonians. Academic Press, New York, pp. 65–112.

Castillo, N., Aceituno, F., 2006. El bosque domesticado, el bosque cultivado: Un proceso milenario en el valle medio del río Porce en el noroccidente colombiano. Latin American Antiquity 17 (4), 561–578.

Charles-Dominique, P., Blanc, P., Larpin, D., Ledru, M.P., Riera, B., Sarthou, C., Servant, M., Tardy, C., 1998. Forest perturbations and biodiversity during the last ten thousand years in French Guiana. Acta Oecologica-International Journal of Ecology 19 (3), 295–302.

Chernela, J.M., 1987. Os cultivares de mandioca na área do Uaupés (Tukano). In: Ribeiro, D. (Ed.), Suma Etnológica Brasileira. Vozes, Petrópolis, pp. 151–158.

Clement, C.R., 1999. 1492 and the loss of Amazonian crop genetic resources. I The relation between domestication and human population decline. Economic Botany 53 (2), 188–202.

Clement, C.R., 2006a. Domesticação de paisagens e plantas amazônicas - a interação de etnobotânica, genética molecular e arqueologia. In: Morcote, G., Mora, S., Franky, C. (Eds.), Pueblos, Plantas y Paisajes Antiguos en la Selva Tropical Amazónica. Editorial Universidad Nacional, Bogotá, pp. 97–112.

Clement, C.R., 2006b. Fruit trees and the transition to food production in Amazonia. In: Balée, W., Erickson, C.L. (Eds.), Time and Complexity in Historical Ecology: Studies in the Neotropical Lowlands. Columbia University Press, New York, pp. 165–185.

Clement, C.R., Cristo-Araújo, M.d., d'Eeckenbrugge, G.C., Pereira, A.A., Picanço-Rodrigues, D., 2010. Origin and domestication of native Amazonian crops. Diversity 2 (1), 72–106.

Costa, F.W.d.S., 2002. Análise das Indústrias Líticas da Area de Confluência dos rios Negro e SolimõesMuseu de Arqueologia e Etnologia. Universidade de São Paulo.

Costa, F.W.d.S., 2009. Arqueologia das campinaranas do baixo rio Negro: em busca dos pré-ceramistas nos areais da amazônia centralMuseo de Arqueologia e Etnologia. Universdidade de São Paulo, São Paulo, PhD, p. 180.

Daly, D.C., Mitchell, J., 2000. Lowland vegetation of tropical South America: an overview. In: Lentz, D.L. (Ed.), Landscape Transformations in the Precolumbian Americas. Columbia University Press, New York, pp. 391–454. Imperfect Balance.

De Oliveira, P.E., 2005. Lagoa das Patas. 24-Apr-00. National Climatic Data Centre, Ashville, North Carolina. http://www.ncdc.noaa.gov/cgi-bin/paleo/poldgma.cgi?handle=DASPATAS.

Denevan, W.M., 1971. Campa Subsistence in the Gran Pajonal, Eastern Peru. The Geographical Review 61, 496–518.

Denevan, W.M., 1992a. The pristine myth: the landscape of the Americas in 1492. Annals of the Association of American Geographers 82 (3), 369–385.

Denevan, W.M., 1992b. Stone versus metal axes: the ambiguity of shifting cultivation in prehistoric Amazonia. Journal of the Steward Anthropological Society 20 (1–2), 153–165.

Denevan, W.M., 2001. Cultivated Landscapes of Native Amazonia and the Andes. Oxford University Press, Oxford, p. 400.

Denevan, W.M., 2004. Semi-intensive pre-European cultivation and the origins of anthropogenic dark earths in Amazonia. In: Glaser, B., Woods, W.I. (Eds.), Amazonian Dark Earths: Explorations in Space and Time. Springer, Berlin; London, pp. 135–143.

Denevan, W.M., Paddoch, C., 1987. Swidden-fallow agroforestry in the Peruvian Amazon. Advances in Economic Botany 5, 1–107.

Descola, P., 1994. Homeostasis as a cultural system: the Jívaro case. In: Roosevelt, A.C. (Ed.), Amazonian Indians from Prehistory to the Present: Anthropological Perspectives. University of Arizona Press, Tucson, pp. 203–224.

Desjardins, T., Carneiro Filho, A., Mariotti, A., Chauvel, A., Girardin, C., 1996. Changes of the forest-savanna boundary in Brazilian Amazonia during the Holocene revealed by stable isotope ratios of soil organic carbon. Oecologia 108, 749–756.

Donatti, P.B., 2003. A Ocupação Pré-Colonial da Area do Lago Grande, Iranduba, AM.Museu de Arqueologia e Etnologia. Universidade de São Paulo, São Paulo.

Dufour, D.L., 1989. Effectiveness of cassava detoxification techniques used by indigenous peoples in northwestern Amazonia. Interciencia 14 (2), 88–91.

Dufour, D.L., 1995. A closer look at the nutritional implications of bitter Cassava use. In: Sponsel, L.E. (Ed.), Indigenous Peoples and the Future of Amazonia: an Ecological Anthropology of an Endangered World. The University of Arizona Press, Tucson, pp. 149–165.

Dull, R.A., Nevle, R.J., Woods, W.I., Bird, D.K., Avnery, S., Denevan, W.M., 2010. The Columbian encounter and the little ice age: abrupt land use change, fire, and greenhouse forcing. Annals of the Association of American Geographers 100 (4), 755–771.

Eden, M.J., Bray, W., Herrera, L., McEwan, C., 1984. *Terra preta* soils and their archaeological context in the Caquetá basin of southeast Colombia. American Antiquity 49 (1), 125–140.

Elias, M., Mühlen, G.S., McKey, D., Roa, A.C., Tohme, J., 2004. Genetic diversity of traditional South American landraces of Cassava (*Manihot esculenta* Crantz): an analysis using microsatellites. Economic Botany 58 (2), 242–256.

Emperaire, L., 2001. Elementos de discussão sobre a conservação da agrobiodiversidade: o exemplo da mandioca (Manihot esculenta Crantz) na Amazônia brasileira. In: Capobiando, J.-P. (Ed.), Biodiversidade da Amazônia brasileira, avaliação e ações prioritárias para a conservação, uso sustentável e repartição dos benefícios. ISA/Estação Liberdade, São Paulo, pp. 225–234.

Emperaire, L., 2002. A agrobiodiversidade em risco: o exemplo das mandiocas na Amazônia. Ciência Hoje 32 (187), 28–33.

Fearnside, P.M., 2005. Deforestation in Brazilian Amazonia: history, rates, and consequences. Conservation Biology 19 (3), 680–688.

Francis, J.K., Knowles, O.H., 2001. Age of A2 horizon charcoal and forest structure near Porto Trombetas, Pará, Brazil. Biotropica 33 (3), 385–392.

Fraser, J.A., 2010. The Diversity of Bitter Manioc (Manihot esculenta Crantz) cultivation in a Whitewater Amazonian Landscape. Diversity 2 (4), 586–609.

Fraser, J.A., Cardoso, T., Junqueira, A., Falcão, N., Clement, C.R., 2008. Historical ecology and dark earths in whitewater and blackwater landscapes: comparing the middle Madeira and lower Negro rivers. In: Woods, W.I., Lehmann, J. (Eds.), Terra Preta Nova – a Tribute to Wim Sombroek. Springer, Berlin, pp. 229–264.

Fraser, J.A., Clement, C.R., 2008. Dark earths and manioc cultivation in central Amazonia: a window on pre-Columbian agricultural systems? Boletim do Museu Paraense Emílio Goeldi 3 (2), 175–194.

Freitas, H.A.d., Pessenda, L.C.R., Aravena, R., Gouveia, S.E.M., Ribeiro, A.D., Boulet, R., 2001. Late Quaternary vegetation dynamics in the southern Amazon Basin inferred from carbon isotopes in soil organic matter. Quaternary Research 55 (1), 39–46.

Glaser, B., Guggenberger, G., Zech, W., 1998. Black Carbon in Sustainable Soils of the Brazilian Amazon Region. Ninth Conference of the International Humic Substances Society, Adelaide.

Glaser, B., Woods, W.I., 2004. Amazonian Dark Earths: Explorations in Space and Time, xiv. Springer, Berlin; London, p. 216.

Goldman, I., 1963. The Cubeo: Indians of the Northwest Amazon. University of Illinois Press, Illinois.

Gomes, D.M.C., 2008. O uso social da cerâmica de Parauá, Santarém, baixo Amazonas: uma análise funcional. Arqueología Sul-Americana 4, 4–33.

Gourou, P., 1949. Observações Geográficas na Amazônia. Revista Brasileira de Geografía 11, 355–408.

Haberle, S.G., Maslin, M.A., 1999. Late Quaternary vegetation and climate change in the Amazon basin based on a 50,000 year pollen record from the Amazon fan, ODP site 932. Quaternary Research 51 (1), 27–38.

Hammond, D.S., ter Steege, H., Van Der Borg, K., 2007. Upland soil charcoal in the wet tropical forests of central Guyana. Biotropica 39 (2), 153–160.

Harris, D.R., 1971. The ecology of swidden cultivation in the Upper Orinoco Rain Forest, Venezuela. Geographical Review 61 (4), 475–495.

Hartt, C.F., 1885. Contribuções para a ethnologia do valle do Amazonas. Arquivos do Museu Nacional do Rio de Janeiro 6, 1–94.

Hecht, S.B., 2003. Indigenous soil management and the creation of Amazonian dark earths: implications of Kayapó practices. In: Lehmann, J., Kern, D.C., Glaser, B., Woods, W. (Eds.), Amazonian Dark Earths: Origin, Properties, Management. Kluwer Academic Publishers, Dordrecht, pp. 355–372.

Heckenberger, M.J., 1998. Manioc agriculture and sedentism in Amazonia: the upper Xingu example. Antiquity 72 (277), 633–648.

Heckenberger, M.J., Fausto, C., Franchetto, B., 2003a. Revisiting Amazonia circa 1492-Response. Science 302 (5653), 2068–2070.

Heckenberger, M.J., Kuikuro, A., Kuikuro, U.T., Russell, J.C., Schmidt, M., Fausto, C., Franchetto, B., 2003b. Amazonia 1492: pristine forest or cultural parkland? Science 301 (5640), 1710–1714.

Heckenberger, M.J., Petersen, J.B., Neves, E.G., 1999. Village size and permanence in Amazonia: two archaeological examples from Brazil. Latin American Antiquity 10 (4), 353–376.

Heckenberger, M.J., Russell, J.C., Toney, J.R., Schmidt, M.J., 2007. The legacy of cultural landscapes in the Brazilian Amazon: implications for biodiversity. Philosphical transactions of The Royal Society, Series B. Biological Sciences 362 (1478), 197–208.

Herrera, L., Bray, W., McEwan, C., 1980-1. Datos sobre la arqueología de Araracuara (comisaría del Amazonas, Colombia). Revista Colombiana de Antropología 23, 183–251.

Herrera, L.F., Cavelier, I., Rodríguez, C., Mora, S., 1992. The technical transformation of an agricultural system in the Colombian Amazon. World Archaeology 24 (1), 98–113.

Hilbert, P.P., 1968. Archäologische Untersuchungen am mittleren Amazonas: Beiträge zur Vorgeschichte des südamerikanischen Tieflandes. Reimer, Berlin.

Hilbert, P.P., Hilbert, K., 1980. Resultados preliminares da pesquisa arqueológica nos rios Nhamundá e Trombetas, baixo Amazonas. Boletim do Museu Paraense Emílio Goeldi 75 (2), 1–15.

Hill, J.D., Moran, E.F., 1983. Adaptive strategies of Wakuénai people to the oligotrophic rain forest of the Rio Negro basin. In: Hames, R.B., Vickers, W.T. (Eds.), Adaptive Responses of Native Amazonian. Academic Press, New York, pp. 113–135.

Hiraoka, M., 1989. Agricultural Systems on the floodplain of the Peruvian Amazon. In: Browder, J.O. (Ed.), Fragile Lands of Latin America. Westview, Boulder.

Hugh-Jones, C., 1979. From the Milk River, Spatial and Temporal Processes in Northwest Amazonia. Cambridge University Press, Cambridge.

Irion, G., Bush, M.B., Mello, J.A.N.d., Stüben, D., Neumann, T., Müller, G., Morais, J.O., Junk, J.W., 2006. A multiproxy palaeoecological record of Holocene lake sediments from the Rio Tapajós, eastern Amazonia. Palaeogeography, Palaeoclimatology, Palaeoecology 240 (3–4), 523–535.

Junqueira, A., Shepard, G., Clement, C., 2010. Secondary forests on anthropogenic soils in Brazilian Amazonia conserve agrobiodiversity. Biodiversity and Conservation 19, 1933–1961.

Katzer, F., 1944. A terra preta. Boletim da Seção do Fomento Agrícola do Estado do Pará 3, 35–38.

Kern, D.C., Costa, M.L.d., Frazão, F.J.L., 2004. Evolution of the scientific knowledge regarding archaeological black earths of Amazonia. In: Glaser, B., Woods, W.I. (Eds.), Amazonian Dark Earths: Explorations in Space and Time. Springer, Berlin; London, pp. 19–28.

Kipnis, R., Caldarelli, S.B., de Oliveria, W.C., 2005. Contribuição para a cronologia da colonização amazônica e suas implicações teóricas. Revista de Arqueologia 18, 81–93.

Lathrap, D.W., 1970. The Upper Amazon. Thames & Hudson, Southampton.

Lathrap, D.W., 1971. The tropical forest and the cultural context of Chavín. In: Benson, E.P. (Ed.), Proceedings of the Dumbarton Oaks Conference on Chavin. Trustees for Harvard University, Washington, DC, pp. 73–100.

Lathrap, D.W., 1977. Our father the cayman, our mother the gourd: Spinden revisited or a unitary model for the emergence of agriculture in the New World. In: Reed, C.E. (Ed.), Origins of Agriculture. Mouton, The Hague, pp. 713–751.

Lehmann, J., Kern, D., Glaser, B., Woods, W., 2003. Amazonian Dark Earths. Origins, Properties and Management. Kluwer Press, Dordrecht.

Lima, H.N., Schaefer, C.E.R., Mello, J.W.V., Gilkes, R.J., Ker, J.C., 2002. Pedogenesis and pre-Colombian land use of "Terra Preta Anthrosols" ("Indian black earth") of western Amazonia. Geoderma 110 (1–2), 1–17.

Lima, H.P., 2008. História das Caretas: A Tradição Borda Incisa na Amazônia CentralMuseu de Arqueologia e Etnologia. PhD. Universidade de São Paulo, São Paulo.

Lima, H.P., Neves, E.G., Petersen, J.B., 2006. A fase Açutuba: um novo complexo cerâmico na Amazônia central. Arqueologia Sul-Americana 2 (1), 26–52.

Lu, F.E.-s., 1999. Changes in Subsistence Patterns and Resource Use of the Huorani Indians in the Ecuadorian Amazon. University of North Carolina, Chapel Hill.

Machado, J.S., 2005. A Formação de Montículos Artificiais: um Estudo de Caso no Sítio Hatahara, AmazonasMuseu de Arqueologia e Etnologia. Universidade de São Paulo, São Paulo.

Magalhães, M.P., 1993. O Tempo Arqueológico. Museu Paraense Emílio Goeldi, Belém, p. 196.

Magalhães, M.P., 1995. Arqueologia de Carajás. A Presença Pré-Histórica do Homem na Amazônia. Cia. Vale do Rio Doce, Rio de Janeiro.

Marengo, J.A., Nobre, C.A., Tomasella, J., Oyama, M.D., de Oliveira, G.S., de Oliveira, R., Carmargo, H., Alves, L.M., Brown, I.F., 2008. The Drought of Amazonia in 2005. Journal of Climate 21, 495–516.

Mayle, F.E., 2004. Assessment of the Neotropical dry forest refugia hypothesis in the light of palaeoecological data and vegetation model simulations. Journal of Quaternary Science 19 (7), 713–720.

Mayle, F.E., Beerling, D.J., 2004. Late Quaternary changes in Amazonian ecosystems and their implications for global carbon cycling. Palaeogeography, Palaeoclimatology, Palaeoecology 214 (1–2), 11–25.

Mayle, F.E., Beerling, D.J., Gosling, W.D., Bush, M.B., 2004. Responses of Amazonian ecosystems to climatic and atmospheric carbon dioxide changes since the last glacial maximum. Philosphical Transactions of The Royal Society, Series B. Biological Sciences 359 (1443), 499–514.

Mayle, F.E., Burbridge, R., Killeen, T.J., 2000. Millennial-scale dynamics of southern Amazonian rain forests. Science 290 (5500), 2291–2294.

Mayle, F.E., Langstroth, R.P., Fisher, R.A., Meir, P., 2007. Long-term forest-savannah dynamics in the Bolivian Amazon: implications for conservation. Philosphical transactions of The Royal Society, Series B. Biological sciences 362 (1478), 291–307.

Mayle, F.E., Power, M.J., 2008. Impact of a drier Early-Mid-Holocene climate upon Amazonian forests. Philosphical transactions of The Royal Society, Series B. Biological Sciences 363, 1829–1838.

McCann, J.M., Woods, W.I., Meyer, D.W., 2001. Organic matter and anthrosols in Amazonia: interpreting the Amerindian legacy. In: Rees, R.M., et al. (Eds.), Sustainable Management of Soil Organic Matter. CABI, New York, pp. 180–189.

McKey, D., Beckerman, S., 1993. Chemical ecology, plant evolution, and the evolution of traditional manioc cultivation systems. In: Hladik, C.M., Hladik, A., Linares, O.F., Pagezy, H., Semple, A., Hadley, M. (Eds.), Tropical Forests, People and Food. Biocultural Interactions and Applications to Development. UNESCO, Parthenon, Paris, pp. 83–112.

McKey, D., Cavagnaro, T.R., Cliff, J., Gleadow, R., 2010. Chemical ecology in coupled human and natural systems: people, manioc, multitrophic interactions and global change. Chemoecology 20, 109–133.

McMichael, C.N., Bush, M.B. and Piperno, D. (2010). Scales of pre-Columbian disturbance around western Amazonian lakes. In, Papers presented at the 95th ESA Annual Meeting.

Meggers, B.J., 1971. Amazonia: Man and Culture in a Counterfeit Paradise. Smithsonian Institution Press, Washington.

Meggers, B.J., 1995. Judging the future by the past: the impact of environmental instability on prehistoric Amazonian populations. In: Sponsel, L.E. (Ed.),

Indigenous Peoples and the Future of Amazonia: an Ecological Anthropology of an Endangered World. The University of Arizona Press, Tucson, pp. 15–43.
Meggers, B.J., 1997. La cerámica temprana en América del Sur: ¿invención independiente o difusión? Revista de Arqueología Americana 13, 7–40.
Meggers, B.J., 2001. The continuing quest for El Dorado: part two. Latin American Antiquity 12 (3), 304–325.
Meggers, B.J., Danon, J., 1988. Identification and implications of a hiatus in the archaeological sequence on Marajó Island, Brazil. Journal of the Washington Academy of Sciences 78 (3), 245–253.
Meggers, B.J., Evans, C., 1957. Archeological Investigations at the Mouth of the Amazon. Smithsonian Institution Press, Washington.
Miller, E.T., 1987. Pesquisas arqueológicas paleoindígenas no Brasil Ocidental. Estudios Atacameños 8, 37–61.
Miller, E.T., 1992a. Adaptação agrícola pré-histórica no alto rio Madeira. In: Meggers, B.J. (Ed.), Prehistoria Sudamericana: Nuevas Perspectivas. Taraxacum, Washington, pp. 219–231.
Miller, E.T., 1992b. Archaeology in the Hydrolectric Projects of Eletronorte. Eletronorte, Brasília.
Miller, E.T., 1999. A limitação ambiental como barreira à transformação do período Formativo no Brasil. Tecnologia, produção de alimentos e formação de aldeias no sudoeste da Amazônia. In: Ledergerber-Crespo, P. (Ed.), Formativo Sudamericano, una Revaluación. Abya-Yala, Quito, pp. 331–339.
Miller, E.T., 2009. Arqueologia de Rondônia In, Papers presented at the Comunicação apresentada, no XV. Congresso da Sociedad de Arqueologia, Brasileira.
Mora, S., 1991. Cultivars, Anthropic Soils, and Stability: A Preliminary Report of Archaeological Research in Araracuara, Colombian Amazonia. University of Pittsburgh, Pittsburgh, p. 87.
Mora, S., 2003a. Archaeobotanical methods for the study of Amazonian dark earths. In: Lehmann, J., Kern, D., Glaser, B., Woods, W. (Eds.), Amazonian Dark Earths: Origins, Properties and Management. Kluwer Press, Dordrecht, pp. 205–225.
Mora, S., 2003b. Early Inhabitants of the Amazonian Tropical Rain Forest: A Study of Humans and Environmental Dynamics. University of Pittsburg, Pittsburg.
Mora, S., Herrera, L.F., Cavelier, I., Rodríguez, C., 1988. Períodos y ocupación humana en Araracuara. Boletín del Museo del Oro 21, 104–108.
Moraes, C.d.P., 2006. Arqueologia na Amazônia Central Vista de uma Perspectiva da Região do Lago do LimãoMuseu de Arqueologia e Etnologia, Masters. Universidade de São Paulo, São Paulo.
Moran, E.F., 1991. Human adaptive strategies in Amazonian blackwater ecosystems. American Anthropologist 13 (2), 361–382.
Morcote-Ríos, G., Bernal, R., 2001. Remains of palms (palmae) at archaeological sites in the New World: a review. The Botanical Review 67, 309–350.
Morcote, G., Cabrera, G., Mahecha, D., Franky, C.E., Cavelier, I., 1998. Las palmas entre los grupos cazadores-recolectores de la Amazonia Colombiana. Caldasia 20 (1), 57–74.
Morcote, G., Cavelier, I., Mahecha, D., Franky, C.E., Cabrera, G., 1996. El manejo milenario de las palmas amazónicas: de los recolectores precerámicos a los Nukak. CESPEDESIA 21 (67), 89–117.
Moy, C.M., Seltzer, G.O., Rodbell, D.T., Anderson, D.M., 2002. Variability of El Nino/Southern Oscillation activity at millennial timescales during the Holocene epoch. Nature 420 (6912), 162–165.
Mühlen, G.S., Martins, P.S., Ando, A., 2000. Variabilidade genética de etnovariedades de mandioca, avaliada por marcadores de DNA. Scientia Agricola 57 (2), 319–328.
Myers, T.P., 1974. Spanish contacts and social change on the Ucayali river, Peru. Ethnohistory 21 (2), 135–137.
Myers, T.P., 2004. Dark earth in the upper Amazon. In: Glaser, B., Woods, W.I. (Eds.), Amazonian Dark Earths: Explorations in Space and Time. Springer, Berlin; London, pp. 67–94.
Neves, E.G., 1998. Paths in Dark Waters: Archaeology as Indigenous History in the Upper Rio Negro Basin, Northwest Amazon. Department of Anthropology. Indiana University, Bloomington.
Neves, E.G., 2001. Levantamento arqueológico da área de confluência dos rios Negro e Solimões, estado do Amazonas. FAPESP, São Paulo, p. 100.
Neves, E.G., 2003. Levantamento Arqueológico da Área de Confluência dos rios Negro e Solimões, Estado do Amazonas: Continuidade das Escavações, Análise da Composição Química e Montagem de um Sistema de Informações Geográficas. FAPESP, São Paulo.
Neves, E.G., 2004. The relevance of Curt Nimuendajú's archaeological work. In: Stenborg, P. (Ed.), In Pursuit of a Past Amazon. Archaeological Researches in the Brazilian Guyana and in the Amazon region, 45. Värlskulturmuseet i Göteborg, Gothenburg, pp. 2–8.
Neves, E.G., 2005. Vestígios da Amazônia pré-colonial. Scientific American Brasil 10 (special edition), 54–61.
Neves, E.G., 2007. El Formativo que nunca terminó: la larga historia de estabilidad en las ocupaciones humanas de la Amazonía central. Boletín de Arqueología PUCP 11, 117–141.
Neves, E.G., 2008. Ecology, ceramic chronology and distribution, long-term history, and political change in the Amazonian floodplain. In: Silverman, H., Isbell, W. (Eds.), Handbook of South American Archaeology. Springer, New York, pp. 359–379.
Neves, E.G., Petersen, J.B., 2006. The political economy of pre-Columbian Amerindians: landscape transformations in central Amazonia. In: Balée, W., Erickson, C.L. (Eds.), Time and Complexity in Historical Ecology: Studies in the Neotropical Lowlands. Columbia University Press, New York, pp. 279–310.
Neves, E.G., Petersen, J.B., Bartone, R., da Silva, C.A., 2003. Historical and socio-cultural origins of Amazonian dark earths. In: Lehmann, J., Kern, D.C., Glaser, B., Woods, W. (Eds.), Amazonian Dark Earths: Origin, Properties, Management. Kluwer Academic Publishers, Dordrecht, pp. 29–50.
Neves, E.G., Petersen, J.B., Bartone, R.N., Heckenberger, M.J., 2004. The timing of terra preta formation in the central Amazon: archaeological data from three sites. In: B.Glaser, Woods, W.I. (Eds.), Amazonian Dark Earths: Explorations in Space and Time. Springer, Berlin; London, pp. 125–134.
Nimuendajú, C., 1949. Os Tapajó. Boletim do Museu Paraense Emílio Goeldi 10, 93–106.
Oliver, J.R., 2001. The archaeology of forest foraging and agricultural production in Amazonia. In: McEwan, C., Barreto, C., Neves, E.G. (Eds.), Unknown Amazon. Culture in Nature in Ancient Brazil. The British Museum Press, London, pp. 50–85.
Oliver, J.R., 2008. On the road to agriculture in Amazonia: an overview. In: Silverman, H., Isbell, B. (Eds.), Handbook of South American Archaeology. Springer, New York, pp. 185–216.
Olsen, K.M., Schaal, B.A., 1999. Evidence on the origin of cassava - phylogeography of Manihot esculenta. Proceedings of the National Academy of Sciences of the United States of America 96 (250–251), 5586–5591.
Oyuela-Caycedo, A., Bonzani, R.M., 2005. San Jacinto I: A Historical Ecological Approach to an Archaic site in Colombia. The University of Alabama Press, Tuscaloosa, p. 222.
Pearsall, D.M., 2003. Plant food resources of the Ecuadorian Formative: an overview and comparison to the Central Andes. In: Raymond, J.S., Burger, R.L. (Eds.), Archaeology of Formative Ecuador. Dumbarton Oaks Research Library and Collection, Washington DC, pp. 213–257.
Perota, C., 1992. Adaptação agrícola no baixo Xingu. In: Meggers, B.J. (Ed.), Prehistoria Sudamericana: Nuevas Perspectivas. Taraxacum, Washington, pp. 211–218.
Perota, C., Botelho, W.C., 1992. Les 'sambaquis' de Guará et des varaiations climatiques pendant l'Holocene. In: Prost, M.-T. (Ed.), Evolution des littoraux de Guyane et de la Zone Caraïbe Méridionale Pendant le Quaternaire. Orstom, Paris, pp. 379–395.
Pessenda, L.C.R., Boulet, R., Aravena, R., Rosolen, V., Gouveia, S.E.M., Ribeiro, A.S., Lamotte, M., 2001. Origin and dynamics of soil organic matter and vegetation changes during the Holocene in a forest-savanna transition zone, Brazilian Amazon region. Holocene 11 (2), 250–254.
Piperno, D.R., 1990. Aboriginal agriculture and land usage in the Amazon basin, Ecuador. Journal of Archaeological Science 17, 665–677.
Piperno, D.R., 2006a. Identifying Manioc (Manihot esculenta Crantz) and other crops in pre-Columbian tropical America through starch grain analysis. In: Zeder, M., Bradley, D.G., Emshwiller, E., Smith, B.D. (Eds.), Documenting Domestication: New Genetic and Archaeological Paradigms. University of California Press, Berkeley and Los Angeles, pp. 46–67.
Piperno, D.R., 2006b. Quaternary environmental history and agricultural impact on vegetation in Central America. Annals of the Missouri Botanical Garden 93, 274–296.
Piperno, D.R., 2009a. Identifying crop plants with phytoliths (and starch grains) in Central and South America: a review and an update of the evidence. Quaternary International 193 (1–2), 146–159.
Piperno, D.R., 2009b. The origins of plant cultivation and domestication in the new world tropics. Current Anthropology 52 (S4) 0.
Piperno, D.R., Becker, P., 1996. Vegetational history of a site in the central Amazon basin derived from phytolith and charcoal records from natural soils. Quaternary Research 45 (1), 202–209.
Piperno, D.R., Flannery, K.V., 2001. The earliest archaeological maize (Zea mays L.) from highland Mexico: new accelerator mass spectrometry dates and their implications. Proceedings of the National Academy of Sciences of the United States of America 98 (4), 2101–2103.
Piperno, D.R., Holst, I., 1998. The presence of starch grains on prehistoric stone tools from the humid neotropics: indications of early tuber use and agriculture in Panama. Journal of Archaeological Science 25 (8), 765–776.
Piperno, D.R., Pearsall, D., 1998. The Origins of Agriculture in the Lowland Neotropics. Academic Press, San Diego.
Piperno, D.R., Ranere, A.J., Holst, I., Hansell, P., 2000. Starch grains reveal early root crop horticulture in the Panamanian tropical forest. Nature 407 (6806), 894–897.
Politis, G., 1996. Nukak. SINCHI Instituto Amazónico de Investigaciones Científicas, Bogotá.
Politis, G., 1999. Plant exploitation among the Nukak Hunter-gatherers of Amazonia: between ecology and ideology. In: Gosden, C., Hather, J. (Eds.), Prehistory of Food: Appetites for Change. Routledge, London, pp. 99–126.
Pope, K.O., Pohl, M.E.D., Jones, J.G., Lentz, D.L., von Nagy, C., Vega, F.J., Quitmyer, I.R., 2001. Origin and environmental setting of ancient agriculture in the lowlands of Mesoamerica. Science 292 (5520), 1370–1373.
Porras, P., 1987. Investigaciones Arqueológicas a las Faldas del Sangay. Centro de Investigaciones Arqueológicas, Quito.
Power, M.J., Marlon, J., Ortiz, N., Bartlein, P.J., Harrison, S.P., Mayle, F.E., Ballouche, A., Bradshaw, R., Carcaillet, C., Cordova, C., Mooney, S., Moreno, P., Prentice, I.C., Thonicke, K., Tinner, W., Whitlock, C., Zhang, Y., Zhao, Y., Anderson, R.S., Beer, R., Behling, H., Briles, C., Brown, K.J., Bush, M., Camill, P., Chu, G.Q., Clark, J., Colombaroli, D., Connor, S., Daniels, M., Daniau, A.-L., Dodson, J., Doughty, E., Edwards, M.E., Fisinger, W., Foster, D., Gaillard, M.-J., Gil-Romera, G., Gavin, D.G., Gobet, E., Haberle, S., Hallett, D.J., Higuera, P., Hope, G., Horn, S., Impagliazzo, S., Inoue, J., Kaltenrieder, P., Kennedy, L., Kong, Z.C., Larsen, C., Long, C.J., Lynch, J., Lynch, B., McGlone, M., Meeks, S., Mensing, S., Meyer, G., Minckley, T., Mohr, J., Nelson, D., New, J., Newnham, R., Noti, R., Oswald, W., Pierce, J., Richard, P.J.H., Rowe, C., Sanchez Goñi, M.F., Shuman, B.J., Takahara, H., Toney, J., Turney, C., Umbanhower, C., Vandergoes, M., Vanniere, B., Vescovi, E., Walsh, M., Wang, X., Williams, N., Wilmshurst, J., Zhang, J.H., 2008. Changes in fire regimes since the

Last Glacial Maximum: an assessment based on a global synthesis and analysis of charcoal data. Climate Dynamics 30 (7–8), 887–907.
Prous, A., 1991. Arqueologia Brasileira. Editora UnB, Brasília, p. 605.
Pujol, B., David, P., McKey, D., 2002. Germination ecology of cassava (*Manihot esculenta* Crantz, Euphorbiaceae) in traditional agroecosystems :seed and seedling biology of a vegetatively propagated domesticated plant. Economic Botany 56, 366–379.
Pyne, S.J., 1998. Forged in fire: history, land, and anthropogenic fire. In: Balée, W. (Ed.), Advances in Historical Ecology. Columbia University Press, New York, pp. 64–103.
Rival, L., 1998. Domestication as a historical and symbolic process: wild gardens and cultivated forests in the Ecuadorian Amazon. In: Balée, W. (Ed.), Advances in Historical Ecology. University of Columbia Press, New York, pp. 232–250.
Rival, L., 2002. Trekking Through History: The Huaorani of Amazonian Ecuador. Columbia University Press, New York.
Roosevelt, A.C., 1989. Resource management in Amazonia before the conquest: beyond ethnographic projection. In: Posey, D., Balée, W. (Eds.), Resource Management in Amazonia: Indigenous and Folk Strategies, 7. New York Botanical Garden, Bronx, NY, pp. 3–62.
Roosevelt, A.C., 1993. The rise and fall of the Amazon chiefdoms. L'Homme 33 (2–4), 255–283.
Roosevelt, A.C., 1995. Early pottery in the Amazon: twenty years of scholarly obscurity. In: Barnett, W.K., Hoopes, J.W. (Eds.), The Emergence of Pottery: Technology and Innovation in Ancient Societies. Smithsonian Institution, Washington, pp. 115–131.
Roosevelt, A.C., 1999a. The development of prehistoric complex societies: Amazonia, a tropical forest. In: Bacus, E.A., Lucero, L.J. (Eds.), Complex Polities in the Ancient Tropical World, 9. American Anthropological Association, Arlington, pp. 13–33.
Roosevelt, A.C., 1999b. The maritime, highland, forest dynamic and origins of complex culture. In: Salomon, F., Schwartz, S.B. (Eds.), The Cambridge History of the Native Peoples of the Americas: South America, 2. Cambridge University Press, Cambridge, pp. 264–349.
Roosevelt, A.C., 2000. The lower Amazon: a dynamic human habitat. In: Lentz, D.L. (Ed.), Imperfect Balance: Landscape Transformations in the Precolumbian Americas. Columbia University Press, New York, pp. 455–491.
Roosevelt, A.C., 2002. Late Amazonian. In: Peregrine, P.N., Ember, M. (Eds.), Encyclopedia of Prehistory. V.7 South America. Kluwer, Dordrecht, pp. 196–199.
Roosevelt, A.C., Douglas, J., Brown, L., 2002. The migrations and adaptations of the first Americans: Clovis and Pre-Clovis viewed from South America. In: Jablonski, N.G. (Ed.), The First Americans: The Pleistocene Colonization of the New World, 27. California Academy of Sciences, San Francisco, pp. 159–223.
Roosevelt, A.C., Housley, R.A., Da Silveira, M.I., Maranca, S., Johnson, R., 1991. Eighth millennium pottery from a prehistoric shell midden in the Brazilian Amazon. Science 254 (5038), 1621–1624.
Roosevelt, A.C., Lima da Costa, M., Lopes Machado, C., Michab, M., Mercier, N., Valladas, H., Feathers, J., Barnett, W., Imazio da Silveira, M., Henderson, A., Silva, J., Chernoff, B., Reese, D.S., Holman, J.A., Toth, N., Schick, K., 1996. Paleoindian cave dwellers in the Amazon. The Peopling of the Americas Science 272 (5260), 373–384.
Rostain, S., 1999. Secuencia arqueológica en montículos del valle de Upano en la Amazonía Ecuatoriana. Bulletin de l'Institute Français d'études Andines 28 (1), 53–89.
Rostain, S. (submitted for publication). Between Sierra and Selva: landscape transformations in the upper Ecuadorian Amazonia. Quaternary International.
Saldarriaga, J.G., 1994. Recuperación de la Selva de "Tierra Firme" en el Alto Río Negro, Amazonía Colombiana-Venezolana. TROPENBOS/Presencia, Bogotá, p. 201.
Saldarriaga, J.G., West, D.C., 1986. Holocene fires in the northern Amazon basin. Quaternary Research.
Saldarriaga, J.G., West, D.C., Tharp, M.L., Uhl, C., 1988. Long-term chronosequence of forest succession in the upper Rio Negro of Colombia and Venezuela. Journal of Ecology 4, 938–958.
Salick, J., Cellinese, N., Knapp, S., 1997. Indigenous diversity of cassava: generation, maintenance, use and loss among the Amuesha, Peruvian Upper Amazon. Economic Botany 51, 6–19.
Sandweiss, D.H., Maasch, K.A., Burger, R.L., Richardson, J.B., Rollins, H.B., Clement, A., 2001. Variation in Holocene El Nino frequencies: climate records and cultural consequences in ancient Peru. Geology 29 (7), 603–606.
Sanford, R.L., Saldarriaga, J., Clark, K.E., Uhl, C., Herrera, R., 1985. Amazon rain-forest fires. Science 227 (4682), 53–55.
Santos, G.M., Gomes, P.R.S., Anjos, R.M., Cordeiro, R.C., Turcq, B.J., Sifeddine, A., di Tada, M.L., Cresswell, R.G., Fifield, L.K., 2000. C-14 AMS dating of fires in the central Amazon rain forest. Nuclear Instruments & Methods in Physics Research Section B- Beam Interactions with Materials and Atoms 172, 761–766.
Schmidt, M.J., 2010. Historical landscape in the Neotropics: a model for prehistoric anthrosol (terra preta) formation in the upper Xingu. In: Pereira, E., Guapindaia, V. (Eds.), Arqueologia Amazônia. MPEG/IPHAN/Secetaria de Estado de Cultura do Pará, Belém, pp. 853–878.
Sifeddine, A., Frohlich, F., Fournier, M., Martin, L., Servant, M., Soubies, F., Turcq, B., Suguio, K., Volkmerribeiro, C., 1994. La sèdimentation lacustre indicateur de changements des palèoenvironnments au cours des 30000 dernièrs années (Carajás, Amazonie, Brésil). Comptes Rendus De L'Académie des Sciences, Serie II 318 (12), 1645–1652.
Sifeddine, A., Martin, L., Turcq, B., Volkmer-Ribeiro, C., Soubies, F., Cordeiro, R.C., Suguio, K., 2001. Variations of the Amazonian rainforest environment: a sedimentological record covering 30,000 years. Palaeogeography, Palaeoclimatology, Palaeoecology 168 (3–4), 221–235.
Silva, F.A., Rebellato, L., 2004. Use of space and formation of Terra Preta: the Asuriní do Xingu case study. In: Glaser, B., Woods, W.I. (Eds.), Amazonian Dark Earths: Explorations in Space and Time. Springer, Berlin, pp. 159–167.
Simões, M.F., 1969. The Castanheira site: new evidence on the antiquity and history of the Ananatuba phase (Marajó Island, Brazil). American Antiquity 34 (4), 402–410.
Simões, M.F., 1981. Coletores-pescadores ceramistas do litoral do Salgado (Pará). Boletim do Museu Paraense Emílio Goeldi 78, 1–26.
Smith, H., 1879. Brazil. The Amazonas and the Coast. Scribner's Sons, New York.
Smith, N.K.H., 1980. Anthrosols and human carrying capacity in Amazonia. Annals of the Association of American Geographers 70 (4), 553–566.
Sombroek, W.G., 1966. Amazon Soils: A Reconnaissance of the Soils of the Brazilian Amazon Region. Centre for Agricultural Publications and Documentation, Wageningen.
Soubies, F., 1979–80. Existence d'une phase sèche en Amazonie Bresilienne datée para la présence de charbons dans les sols (6.000-3.000 ans BP). Cahiers du ORSTOM. série Géologie 9 (1), 133–146.
Stahl, P.W., 1996. Holocene Biodiversity: An Archaeological Perspective from the Americas. Annual Review of Anthropology 25, 105–206.
Steward, J., 1948a. Culture areas of the tropical rainforest. In: Steward, J. (Ed.), Handbook of South American Indians: the Tropical Forest tribes, 3. Bureau of American Ethnology, Smithsonian Institution, Washington DC, pp. 883–903.
Steward, J.H., 1948b. Tribes of the Montaña and Bolivian east Andes. In: Steward, J.H. (Ed.), Handbook of South American Indians: the Tropical Forest Tribes, 3. Bureau of American Ethnology, Smithsonian Institution, Washington DC, pp. 507–656.
Vacher, S., Jérémie, S., Briand, J., 1998. Amérindiens du Sinnamary (Guyane): Archéologie en forêt équatoriale. Éditions de la Maison des Sciences de l'Homme, Paris, pp. 300.
Valdez, F., Guffroy, J., de Saulieu, G., Hurtado, J., Yepes, A., 2005. Découvert d'un site cérémoniel formatif sur le versant oriental des Andes. Comptes Rendus Palevol 4, 369–374.
van der Hammen, M.C., 1992. El manejo del mundo: naturaleza y sociedad entre los Yukuna de la Amazonía Colombiana. Tropenbos, Colombia, Bogotá, p. 376.
van der Hammen, T., Hooghiemstra, H., 2000. Neogene and Quaternary history of vegetation, climate, and plant diversity in Amazonia. Quaternary Science Reviews 19 (8), 725–742.
Walsh, R.P.D., 1998. Climate. In: Richards, P.W. (Ed.), The Tropical Rain Forest. Cambridge University Press, Cambridge.
Weng, C.Y., Bush, M.B., Athens, J.S., 2002. Holocene climate change and hydrarch succession in lowland Amazonian Ecuador. Review of Palaeobotany and Palynology 120 (1–2), 73–90.
Wilson, W.M., Dufour, D., 2002. Why bitter cassave? Productivity of 'bitter' and 'sweet' cassava in a Tukanoan Indian settlement in the northwest Amazon. Economic Botany 56 (1), 49–57.
WinklerPrins, A.M.G.A. (2006). Creating terra preta in home gardens: a preliminary assessment. In: Papers Presented at the 18th World Congress of Soil Science.
Woods, W., Teixeira, W., Lehmann, J., Steiner, C., WinklerPrins, A., Rebellato, L., 2008. Amazonian Dark Earths: Wim Sombroek's Vision. Kluwer, Dordrecht.
Woods, W.I., 1995. Comments on the black earths of Amazonia. Papers and Proceedings of the Applied Geography Conferences 18, 159–165.
Woods, W.I., 2002. Perspectives on Terra Preta Soils. Papers Presented at the 'Perspectives and Reflections on the Anthropogenic Amazon' Panel. 98th Annual Meeting of the Association of American Geographers.
Woods, W.I., 2003. Development of anthrosol research. In: Lehmann, J., Kern, D., Glaser, B., Woods, W. (Eds.), Amazonian Dark Earths: Origins, Properties and Management. Kluwer Press, Dordrecht, pp. 3–14.
Zeidler, J.A., 1983. La etnoarqueología de una vivienda Achuar y sus implicaciones arqueológicas. Miscelánea Antropológica Ecuatoriana 3, 155–193.