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Global Ecology in Historical Perspective

Monsoon Asia and Beyond

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Preface

This book primarily examines human–animal and human–plant interactions in monsoon Asian forests (Southeast Asia and Japan) and inland waters (China). The relationship between plants, animals, and humans in Asia is quite unique from a global perspective. For example, "satoyama" in Japan means ecotone area, or the boundary between a village and a forest. There, as the number of inhabitants has declined, bears, wild boars, and other animals increasingly ravage crops, sometimes attacking humans as well.

By showing the regional nature of human–animal and human–plant interactions in Asia, this book provides for the first time a framework for understanding the world's animal and plant–human relationships. It is assumed that the relationships between humans and animals and plants have been diverse for millennia, including hunting, taming, semi-domestication, and full domestication. At the same time, for regions outside of Asia, the extent to which these diverse relationships were adapted and how diversity was formed is explained from the perspective of historical ecology. Therefore, comparative cases from Central Asia and the Americas (whales in the Arctic, sea turtles in the Caribbean, and plants in the Amazon) are also featured in this volume.

Readers can expect to derive perspectives on the coexistence of human–animal and plant–animal relationships in the near future. The conservation of rare species, diverse habitats, and biodiversity is a central theme in considering the relationship between modern civilization and the global environment. In post-industrial Japan, one focus has been the protection of iconic animals such as storks, crested ibis, dugongs, and sea turtles, while at the same time damage to crops and humans by deer, wild boars, monkeys, bears, and other common animals has become an important social issue. How can the world's 8.0 billion-plus people live in harmony with other species?

We would like to get some hints on how to solve the problems we are facing. This book collects research papers that capture the dynamics of human–animal and human–plant relationships from anthropology and adjacent disciplines. The individual papers were presented at the National Museum of Ethnology in Osaka, Japan, on March 19–21, 2018 under the international symposium entitled "Human Relationships with Animals and Plants: Perspectives of Historical Ecology." The papers are based on those reported at that international conference, with additions and corrections.

In this symposium, we were concerned primarily with Asia, a large region of the world where local, in-depth studies of human relationships with animals, plants, and environment are often lacking and/or not widely disseminated in English-language publications. In each case, the more we look, the more we can see that the grounds on which local economies, cultures, and societies have been based have also been changing, in the past and present. Under these circumstances, how is it possible to generalize about human relationships with nature, and draw any conclusions about what may happen in the future? Our approach is to make comparisons across time and space using important case studies. The contributors to this volume are experts in very diverse disciplines, time periods, and geographical areas, but are all concerned with the implications of historical-ecological research for the future of humanity and the natural—or not-so-natural—world on which we depend. The grounds are changing, and we must seek new ways of living, and new ways of looking at humans, animals, and plants.

In April 2017, the National Museum of Ethnology launched a 6-year special research project to study the challenges facing contemporary civilization. The project is called “Contemporary Civilization and the Future of Humanity: Environment, Culture and Humans.” This international conference was held in the first year of the project. In the past few decades, changes such as globalization and global warming have become threats to the future of our plane, and since 2017 those threats have only increased. At the same time, these changes are also changing the relationships between people and animals, and between people and plants. In particular, these keystone relationships in monsoon Asia provide unique facts from a global perspective.

This book aims to remedy the current status of these relationships, which have not been well documented. We hope that the book provides readers with an insight into the importance of human–nature relationship in the world, as well as exploring the unique dynamics of the relationship between creatures and people in monsoon Asia.

Osaka, Japan Kazunobu Ikeya

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The Constructed Biodiversity, Forest Management and Use of Fire in Ancient Amazon: An Archaeological Testimony on the Last 14,000 Years of Indigenous History

Laura P. Furquim, Eduardo G. Neves, Myrtle P. Shock, and Jennifer Watling

1 Introduction

The study of Amazonian biomes and their peoples has an important role in the development of modern science. Since the early eighteenth century, with Charles Marie de la Condamine, western scholars have roamed the tropics in search of answers to deeper questions, such as the emergence of biological diversity (Safier 2014). Likewise, in South America, since the first Europeans arrived on the continent in the early sixteenth century, they were confronted in the Andean highlands by centralized and hierarchical states, such as the Inca Empire. Such evidence of monumental architecture, abundant in the Andes and also along the Desert Coast of the Pacific Ocean, was employed to establish a picture of the ancient history of South America that remains strong until the present: the notion that the Desert Coast and the Andean highlands were cradles of civilization, whereas the tropical lowlands had a peripheral role in the human occupation of the continent.

Such a perspective was further reinforced by the hypothesis that the ecological conditions of the humid tropics would be inimical to the establishment of large, sedentary, and permanent settlements in the past. According to this view, environmental factors such as lack of terrestrial animal protein or the widespread distribution of nutrient-poor soils would impose a ceiling with strong limitations for human

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occupation and prevent the establishment of long-term and stable occupations. As a result of these endeavors, tropical rainforests have retained, over the years, an image of being pristine environments scarcely occupied by humans over the millennia. The underlying reasoning for this assessment was based on “degeneration” theories that considered the tropics as marginal to human history due to supposed environmental limitations (Noelli and Menezes Ferreira 2007). With neocolonialism, such perspectives eventually translated into modern public policies for the occupation of these areas, frequently fraught with significant social and ecological problems, such as those happening at this very moment.

Archaeological research carried out in the last thirty years in the Amazon has contributed to changing this picture. It is becoming clear that the Amazon was densely settled at the time of European arrival and that the societies that lived there displayed a wide variety of patterns of social and political organization (Heckenberger and Neves 2009). If, in the Andean past, stone was widely used as raw material for monumental architecture, in the Amazon, soils filled the role of construction material. As a consequence, only recently have archaeologists recognized that ditches, channels, earthworks and mounds covered by forest were built by ancient Amazonians (Prümers and Betancourt 2014; Heckenberger et al. 2003; Rostain 2012; Schaan 2010). Such new evidence shows that the Amazon was also a cradle of early cultural developments but that its ancient societies had different histories than expected by previous hypotheses. There is, therefore, room for new theories that move away from traditional classificatory typologies, as well as a new synthesis of world archaeology that incorporates such recent developments.

Archaeology in the Amazon has the potential to elucidate long environmental histories involving people, plants, animals, and landscapes in order to understand how dialectical deep history unfolded during millennia. Patterns of tree and soil distributions associated with archaeological sites can be understood as living artifacts, worked over centuries or millennia in the shaping of biomes that have a strong indigenous component, and whose intensity is yet to be better understood (Balée 2008; Levis et al. 2017; ter Steege et al. 2013; Lins et al. 2015; Souza et al. 2016a, b; Cassino et al. 2019; Clement et al. 2010). In this chapter we aim to explore some of the patterns revealed by archaeology as it studies records of human occupation in the Amazon that span most of the Holocene, particularly the continuities and changes in environmental management, accumulated in the form of knowledge among traditional populations (traditional ecological knowledge, (cf. Smith 2012) and materialized in the current floral biodiversity of the region.

2 Early Patterns of Interaction

There is still controversy regarding the age of early Indigenous occupation of South America, as well as the productive strategies and the degree of environmental impact these first settlers had (Vialou et al. 2017; Bueno et al. 2013; Boëda et al. 2016; Posth et al. 2018). It is known that the occupation of South America may have already extended to the Southern Cone of the continent at 14,147 cal. BP where people and several species of extinct mammals lived together (Dillehay et al. 2015; Politis et al. 2016).

In tropical lowland South America, occupations from the Pleistocene/Holocene transition were apparently defined by sparse populations, which renders difficult inferences about migration routes or dispersion patterns. Nevertheless an early pattern of recurrent occupation of significant places such as rockshelters and areas adjacents to major rapids can be found. Sites located many miles apart, such as Toca do Meio, Lapa do Boquete, and Pedra Pintada Cave were already occupied by about 12,000 years ago [12,440 ± 230 and 11,145 ± 135 BP (Roosevelt et al. 1991, Boëda et al. 2016)]. Just over 1,000 years later, many tropical lowland biomes were already occupied by groups with diversified food processing technologies. Remains associated with such groups include artifacts such as projectile points, hooks, flakes and axes, indicating a large spectrum generalist diet that included fish and small to medium-sized animals as well as tubers, palm fruits, and other fruits (Shock and Moraes 2019; Pereira et al. 2018; Roosevelt 1992).

Pedra Pintada cave, located adjacent to the lower Amazon floodplain, sits in a transitional environment between forests and savannas. Excavations there yielded the oldest securely dated archaeological context for Amazonia thus far (ca 12,400 BP) (Roosevelt et al. 1996). Archaeobotanical and zooarchaeological records evidence a diet based on fishing, hunting of terrestrial and aquatic animals (such as turtles), and the consumption of palm fruits, tree fruits and nuts. Large amounts of fruit pericarps from the Arecaceae family (palms) were identified, some of them widely consumed today, such as tucumã (*Astrocaryum vulgare*), buriti (*Mauritia flexuosa*), bacaba (cf. *Oenocarpus bacaba*), macaúba relatives (*Acrocomia* spp.) and other species such as *Attalea microcarpa,* and *Attalea spectabilis*. There is also evidence of the consumption of fruits such as jutaí (*Hymenaea parvifolia*), pitomba (*Talisia esculenta*), and murici (*Byrsonima* sp.). These remains represent a generalist use of resources from forested and open areas (Roosevelt 1991; Roosevelt et al. 1996; Silva 2016).

Ecotones and transitional environments between forests and savannas seem to have had a prominent role in plant management and domestication from the beginning of human occupation of the neotropics (Roosevelt et al. 1996; Piperno and Pearsal 2000). Indeed, at Pedra Pintada and other sites outside Amazonia with even earlier dates of occupation, such as Santa Elina rockshelter, evidence of the combined use of species typical of distinct biomes were found (Roosevelt et al. 1996; Bachelet and Scheel-Ybert 2015). These areas may have functioned as laboratories for the cultivation and selection of species used by Indigenous people of the past, since the transport of plant varieties out of their habitat requires a process of change and adaptation. Nowadays, however, these are the most ecologically fragile and threatened environments in the neotropics, resulting from increasing deforestation and climate change that weaken forest transitions and augment fire occurrence (Watling et al. 2018; Flores et al. 2012).

Domesticated plants known today (Clement 1999) were already consumed during the Early Holocene, whether locally or elsewhere in South America. At the Teotônio

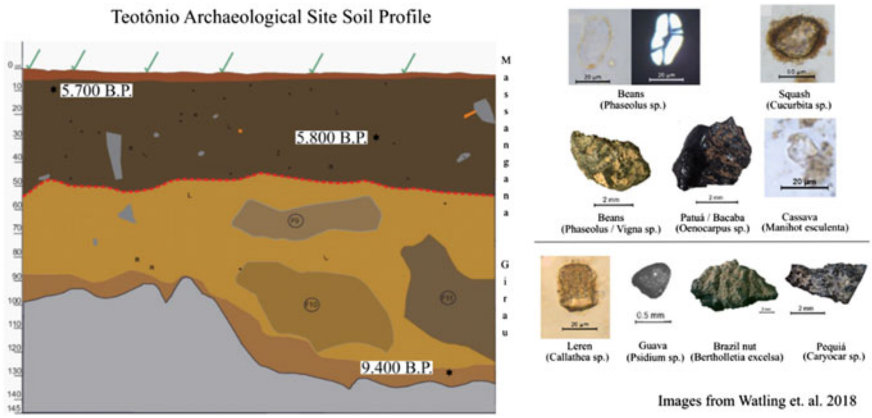

Fig. 1 ADE (Amazon Dark Earth) soil profile. Cultivated plants in the Teotônio site during Early and Middle Holocene. Upper Madeira River, Rondônia, Brazil

site, located adjacent to large rapids on the south bank of the Madeira River, SW Amazonia, lithic artifacts of the Girau phase (9,520 – 9,400 cal. BP) one finds in deposits associated with botanical remains evidence for use of palms, legumes (Fabaceae), ariá/lleren (*Calathea* cf. *allouia*) and possibly other root crops, pequiá (*Caryocar* sp.), guava (*Psidium* sp.) and Brazil nut (*Bertholettia excelsa*) (Watling et al. 2018). In subsequent occupations, bean (*Phaseolus* sp.) starch grains were identified in small quartz flakes of the Massangana phase (ca. 6,500 – 5,500 cal. BP), alongside manioc (*Manihot esculenta*) and squash (*Cucurbita* sp.) phytoliths. Such contexts show a diversified and non-specialized pattern based on management and cultivation of tree species, root crops, legumes, and squashes (Fig. 1).

The transition to the Middle Holocene (ca. 8,200 – 4,200 BP) was marked by climatic changes towards more dry conditions in southwest Amazonia, which caused the temporary shifting of ecotonal (forest/savanna) boundaries in the region (Mayle et al. 2007; Pessenda et al. 1997, 2001). Changes in species composition were accompanied by a process of anthropogenic environmental changes close to archaeological sites. Through co-evolutionary processes involving people and landscapes, indigenous peoples engaged in the controlled use of fire—aimed at clearing small areas for housing and/or cultivation—and the encouragement, fostering and introduction of useful species, involving agroforestry techniques that cultivated plants with both short and long cycles (Rindos 1983; Clement et al. 2010; Levis et al. 2018).

The Monte Castelo shell mound, in SW Amazonia, offers a record of occupation that spans the Middle Holocene, between ca. 7,000 to 4,200 BP (Miller 2013; Furquim 2018; Pugliese et al. 2017). There, the consumption of both exogenous and local plant species involved seasonal cultivation and the management of neighboring areas (Furquim et al. 2021). Subsistence involved cultivated plants such as maize (*Zea mays*), squash (*Cucurbita* sp.), sweet potato (*Ipomoea batatas*) and yams (*Dioscorea* sp.), combined with managed tree crops such as Brazil nut (*Bertholletia excelsa*),

Fig. 2 Monte Castelo Shellmound, an artificial island built around 6,000 B.P. in an ecotonal transition between flooded savannas and forests. Middle Guaporé basin, Rondônia, Brazil

cocoa/cupuaçu (*Theobroma* spp.), murici (*Byrsonima* sp.) and guava (*Psidium* sp.) (Furquim 2018; Hilbert et al. 2017; Furquim et al. 2021). There is also evidence that a local variety of wild rice (*Oryza* sp.) was brought under selection and domestication, although its cultivation was later abandoned by indigenous populations of the region (Hilbert 2017) (Fig. 2).

3 Changes in Soils: The Anthropogenic Dark Earth on Amazon

Amazonian soils are made up mainly of orange and reddish acidic soils insufficiently fertile for widespread cultivation (Quesada et al. 2011), especially of plants that require high soil nutrient content, such as maize. Around 5,500 years ago, Indigenous people began to transform soils through composting and subsequently planting small gardens next to houses on these spots (Schmidt et al. 2014), a practice that was allied to environmental management including fire use and suppression, and the selection of useful plant species (Arroyo-Kalin 2012). These same practices are carried out today by, for instance, the Nukak Indians of the Colombian Amazon (Politis 1996a, b) and the Kuikuro of the Upper Xingu Indigenous Territory (Schmidt 2013). Such modified soils, called "*Terras pretas*" or Amazonian Dark Earths (ADE), have a dark color that contrasts with adjacent natural soils, due to the accumulation of charcoal and organic matter (Schmidt et al. 2014; Arroyo-Kalin 2012; Glaser and Birk 2012). It is estimated that ADEs currently occupy 1% of the Amazon territory (Kern et al. 2004; Levis et al. 2014), or around 70.000 sq km, roughly the size of Ireland.

The oldest identified ADEs are located in the Upper Madeira River basin, SW Amazonia, at Teotonio and Garbin sites, with dates reaching back to at least 6,500 years ago (Watling et al. 2018; Zuse 2014; Caldarelli and Kipnis 2017). Compared to the typical soils of this area, these early ADEs have higher, more basic pHs and higher levels of phosphorus (P), calcium (Ca), magnesium (Mg), zinc (Zn), manganese (Mn), copper (Cu) and carbon (C) (Macedo et al. 2019; Bernardes et al. 2017). In the Central Amazon their formation appears to correspond to a process that culminated in the creation of mosaics of fertile soils inside forested areas. At the Açutuba site, located on the lower Negro River, for example, stratigraphic profiles normally show abrupt transitions between underlying strata with natural soils and overlying strata with anthropic soils with abundant presence of charcoal: from a density of 10 fragments per liter of sediment in the natural soil, to 83 fragments per liter of sediment in the occupation layers (Smith 2012; Silva et al. 2016).

The relationship between the use of fire and the formation of ADEs is related to the establishment of agroforestry systems and the opening of habitation areas. In some sites of the Central Amazon, such as Laguinho, there is an increase in the concentration of grassy species—potential indicators of open areas—such as *Setaria* sp., six varieties of grasses (Poaceae), two of Cyperaceae, and species that indicate secondary vegetation such as passion fruit (*Passiflora* sp.), two varieties each of Amaranthaceae, Solanaceae, Bromeliaceae, Cecropiaceae, Brassicaceae, Commelinaceae and three varieties of Fabaceae (Lima 2011). An increase in phytoliths from grasses and other herbs is also recorded in ADEs at Hatahara, on the lower Negro River (Cascon 2010), Teotonio (Watling et al. 2020), and the Porto site in Santarém (Alves 2016).

Around 1,000 BP, these anthropogenic soils reached a massive scale, with the effect that today they support a much richer vegetation of useful species (i.e., greater agroecological diversity) than adjacent soils (Souza et al. 2016a, b; Lins et al. 2015). The increase in the heterogeneity of anthropogenic landscapes that resulted from ADE formation possibly led to an increase in the diversity of plants grown at that time, as suggested by the archaeobotanical database (cf. Furquim 2018).

Often associated with black ADEs (*terras pretas*) are brown ADEs (*terras mulatas*) (Arroyo-Kalin 2017; Denevan 2006) which exhibit the same characteristics but on a smaller scale, with fewer cultural remains such as ceramic shards (Matos 2015). These patches have been interpreted as cultivation areas, since the much lower quantity or absence of cultural remains is not consistent with the dense occupations that formed the black ADE patches (Arroyo-Kalin 2012). In short, the archaeological record of the Amazon indicates (1) plant domestication and management since the Terminal Pleistocene/Early Holocene; (2) soil modifications resulting from daily activities in the Middle Holocene from at least about 6,500 BP, and (3) increase in density of soil and forest management from the Late Holocene, around 3,000 BP (Neves et al. 2004).

4 Biodiversity of Plants During the Holocene

An archaeobotanical database was built from published data and unpublished reports from across 188 archaeological sites in the Neotropics. We gathered in total data from 76 families and 240 species of plants identified from seeds, charcoal, phytoliths, starch grains and pollen preserved in sediments and archaeological artifacts (see complete list of references in Furquim 2018).

A broad look indicates some patterns over time. First, there is a gradual increase in the agrobiodiversity generated by indigenous peoples in the past; second, the combined use of wild and domesticated plants seems to have been consistent, including combined cultivation of plants of short and long cycles, as well as a permanent combination of fruits, tubers, grains, seeds and nuts. During the Early Holocene there is evidence that 46 genera of plants were used, while in the Middle Holocene this number increases to 75, and further to 134 during the Late Holocene. Thus, there was an increase in agrobiodiversity because there was no specialization in cultivation. Plants currently consumed as staple foods, such as maize and manioc were present, but did not occupy the predominant role they have today or during the colonial period (Roosevelt et al. 1996; Hermenegildo et al. 2017; Fausto and Neves 2018). Some of these plants (such as squash and beans) were cultivated by Indigenous people of the Americas as early as 10,000 years ago, before the beginning of ceramic production, the widespread establishment of village life, the formation of the first ADEs, showing that management and cultivation practices were an integral part of traditional Indigenous knowledge since the beginning of human occupation of South America.

There has lately been an extensive debate surrounding the construction of anthropogenic landscapes, anthropogenic forests, the increase in alpha (local) and beta (regional) biodiversity by indigenous peoples in the past, and the relationship between biodiversity and diversity of useful plants (Balée 2000; Neves 2012; ter Steege et al. 2013; Lins et al. 2015; Clement et al. 2015; Junqueira et al. 2010; Arroyo-Kalin 2018). In the Amazon, these processes are manifest bothin the creation of anthropogenic forest patches near archaeological sites—in which agrobiodiversity is higher than in other places—as in creating a situation of species hyperdominance in the Amazon as a whole. The effects of these processes are long lasting and appear to be dispersed in "waves" of human disturbance, with housing sites as central points, spreading through gardens, clearings, areas of management, hunting and collection, and encompass various environments, between rivers banks, terraces, floodplains and lowlands.

Anthropic forests are landscapes with palimpsests of stories connecting people and plants which can emerge through many processes that may or not include human action—such as plant succession, ending the seed dormancy through fire, the removal of vegetation, or the management of competing plants (Politis 1999; Caromano et al. 2016; Lins et al. 2015) (Fig. 3).

The Amazon has about 16,000 species of trees, of which only 227 (1.4%) account for half of the total number of individuals. Among these hyperdominant species (ter

Fig. 3 Meliponid apiary in the middle of an açaí orchard, community Ponta da Castanha, Tefé Lake, Middle Solimões River, Amazonas, Brazil

Steege et al. 2013) there are about 20 species of domesticated or managed plants, whose dispersion and concentration was possibly influenced by human action in the past (Levis et al. 2017). In the graph below (Fig. 4) we selected these 20 hyperdominant domesticated plants to explore how they help us in understanding the antiquity of Amazonian landscape construction.

Among the hyperdominant species of palms (Arecaceae) with some degree of domestication are açaí-do-mato (*Euterpe precatoria*) and açaí-do-Pará (*Euterpe oleracea*), patauá (*Oenocarpus bataua*), and murumuru (*Astrocaryum murumuru*), these having the larger populations and total concentration at present. Their chronological distribution in the archaeological record, however, is quite different. Despite the documented use of the genus *Euterpe* sp. since the Early Holocene it is not possible to assess which of the açaí species is present in the sites from this period. It is known that açaí was managed since about 2,000 years BP, and it is linked to forest areas in the Brazilian and Colombian Amazon where there is occurrence of sites with black earths (ADEs). The same can be seen with bacaba (*Oenocarpus bacaba*), the genre which is represented from ca. 11,000 BP, but whose species remains dated only from the Middle Holocene. Other palm trees, such as patauá and murumuru were managed since the Early Holocene, about 11,000 years ago, and are present in several sites, such as rockshelters and open air sites, with or without anthropogenic soils. Needles to say, absence of evidence is not evidence of absence, given the problems involved in identifying specific palm species in the archaeobotanical record, since much of the only genus (macroremains) or family/subtribe (phytoliths) can be identified.

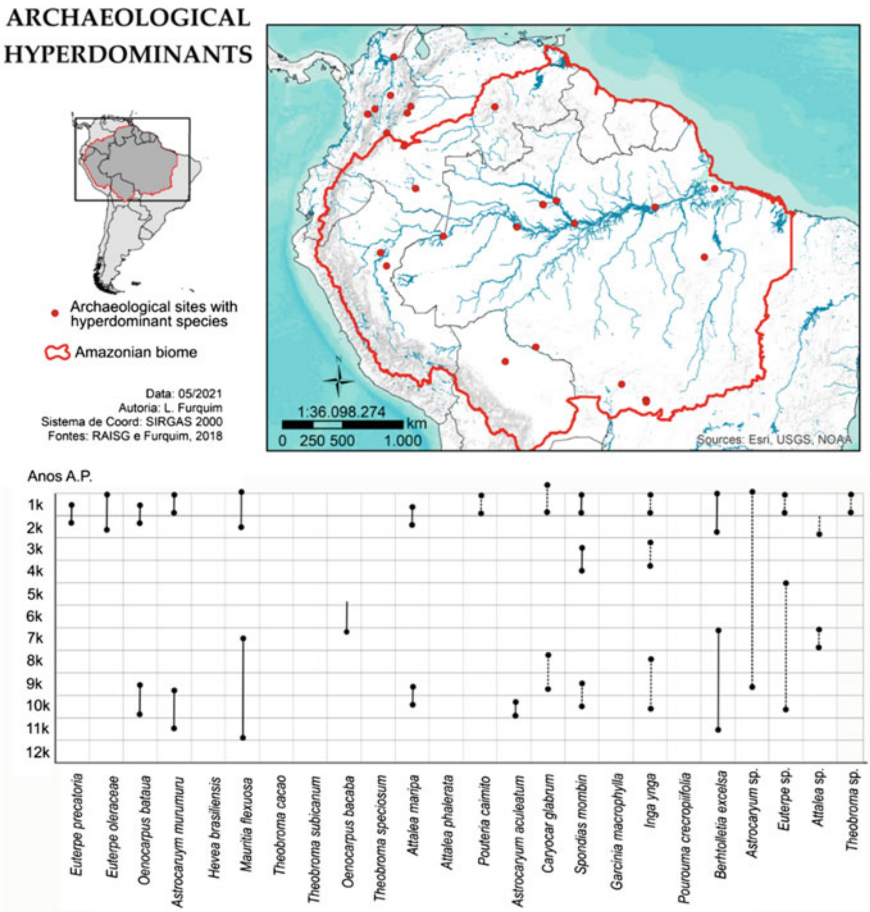

Fig. 4 Chronological distribution of the domesticated hyperdominant species of the Amazon forest. Discontinuous lines indicate that the distribution along the period is estimated (Furquim 2018)

There is less accurate information about fruit trees. Taperebá (*Spondias mombin*) was identified only in the Middle Orinoco River about c. 4,000 BP, and in the Middle Solimões River about 1,000 BP, associated with ADEs. There is no evidence yet that shows the antiquity of the specific use of the rubber tree (*Hevea brasiliensis*), cupuí (*Theobroma subincana*) cacauí (*Theobroma speciosum*), abiu (*Pouteria caimito*) pequiarana (*Caryocar glabrum*), bacupari (*Garcinia macrophylla*), inga (*Inga edulis*) or Amazon tree grape (*Porouma cecropifolia*), due to difficulties in taxonomic identification of many archaeological remains. We have evidence of the use of the chocolate genus *Theobroma* in the above mentioned Monte Castelo shell mound about 4,500 BP, and at the São João site, located in the Middle Solimões at about 1,000 BP, as well as of *Theobroma cacao* in the Western Amazon around 5,200 BP (Zarrillo et al. 2018). Seeds of the genera *Caryocar* sp. and *Spondias* sp. have dates of the Late

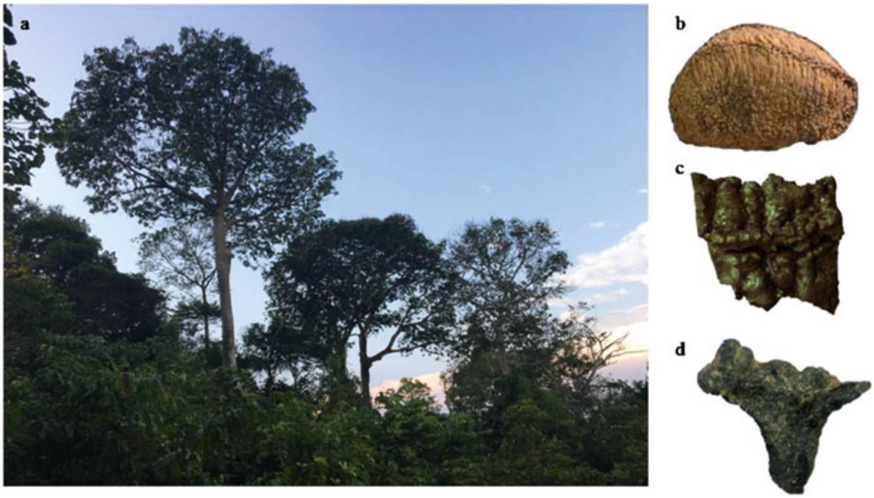

Fig. 5 (**a**) A Brazil nut orchard over the ADE (Amazon Dark Earth) archaeological site Ponta da Castanha (Solimões River basin). Brazil nut modern seed (**b**), experimental burned seed bark for archaeobotanical reference collection (**c**), and archaeological seed bark from Sol de Campinas site (**d**)

Holocene in Colombian amazon and Southwestern Amazonia (Watling et al. 2018), while *Pouteria* sp. and *Inga* sp. are dated about c. 10,000 BP in Santa Elina rock shelter, southwest of the Amazon. The Fabaceae family in general (which includes >1,200 species of leguminous trees and herbs in Amazonia, including *Inga* sp.) is frequently found in early and mid-Holocene contexts throughout the South American continent, and likely comprised an important early resource long before the common bean (Phaseolus sp.) was adopted into lowland economies.

It has been ethnographically shown that even small groups of hunter-gatherers can change the configuration of useful species in their surroundings and create more productive environments (Balée 2008; Posey and Balée 1989; Politis 1996a, b). Such practices are part of agroforestry practices (Denevan 2006), reviewed by Levis et al. (2018). The evidence presented here, albeit preliminary, indicates that the hyperdominant effect seen in the composition of the Amazon flora developed as part of a co-evolutionary process between people and plants that started at the beginning of its occupation.

From Brazil Nut to Brazil Nut Orchards

The Brazil nut tree (*Bertholletia excelsa*) is the tree species with the most ancient and widespread use in Amazonia. There are traces of the use of Brazil nut seeds from about 11,000 BP at Pedra Pintada cave, from about 9,000 BP in southwestern Amazonia at Teotônio site, and around 7,000 BP at the Monte Castelo shell mound, also in southwestern Amazonia. Brazil nut is a species that benefits from clearings in the forest for its growth (Mori and Prance 1990). The presence of large Brazil nut groves associated with archaeological sites is a constant pattern throughout the Amazon basin, and has been identified by many researchers as one of the main indications of human presence in the past (Balée 2008; Shepard 2011; Cassino et al. 2019) (Fig. 5). This association is due to the combination of a cyclical practice of plant and animal management, in which the opening of forested areas for cultivation also created spaces for the development of seeds, probably carried and buried by dispersers such as the agouti (*Dasyprocta leporina*), which were attracted to the areas. The agouti themselves would be attracted by the presence of the Brazil nut orchards, then used as a hunting ground by indigenous peoples, completing the cycle. Knowledge of these succession cycles between fields, cultivation fields and Brazil nut trees is widespread among many contemporary groups such as the Wajãpi, who recognize these plants as cultigens of the agoutis (Oliveira 2016), and perform management activities and periodic cleanings of the stands.

The greatest spread of the Brazil nut tree seems to have occurred, however, during the Late Holocene, when it occupied vast areas of the Amazon basin, including the Negro, Solimões, Madeira, and Amazon river basins, in regions both with and without ADEs (Thomas et al. 2015). In the Central Amazon, some of these contemporary Brazil nut orchards (dated by dendrochronology) are more than 400 years old (Andrade et al. 2019; Scoles and Gribel 2015), confirming the resilience of these landscapes and management practices.

5 Palaeoenvironment, Paleofires, and Agroforestry Management in the Past

In the Neotropics the management of plants and the use of fire had key roles in the construction of landscapes (Piperno and Pearsall 2000). The use of fire in environmental management was already practiced by humans long before the colonization of the Americas, probably embedded in basic systems of natural resource management (Boivin et al. 2016; Roberts et al. 2017). The management systems of contemporary indigenous peoples provide the baseline used for archaeology to identify the presence of such systems in the past (Cassino et al. 2019). Among past agroforestry management practices, the use of fire played an important role, whether in the open fields, to release nutrients trapped in plant matter into the soil, in the extermination of pests and weeds, or in preventing more severe fires (“controlled burning”) (Levis et al. 2018). The existence of domesticated plants can be used as indirect evidence of these management strategies.

In the Amazon, Clement identified 140 plant species that exhibit some degree of domestication, i.e., whose phenotypes and genotypes were modified by human selection. For such changes to be established and maintained, it was a necessary and concomitant process of landscape transformation in which whole plant populations—and the gene flow within them—were managed (Clement 1999). The richness and diversity of domesticated plants, as a result of co-evolution among people, plants, and landscapes (Rindos 1983; Clement et al. 2010) is an important aspect of past and present environmental management history.

Genetic data show, for example, that manioc was domesticated between 10,000 and 8,000 years ago in Southwestern Amazonia (Isendahl 2011). It is important to remember that wild manioc does not reproduce vegetatively (by clone/stake) as the domesticated species does. It is likely that this feature was selected by Indigenous people so that other advantageous traits could become perennial more effectively, such as the presence of larger and more productive roots (Rival and Mckey 2008). Therefore, in the beginning, selection involved the removal and isolation of individuals to avoid crossing with wild populations, operating derived landscape changes. These practices form the basis of agroforestry systems today, and were already under way in the early Holocene.

In Teotônio and Monte Castelo sites, the recovery of carbonized palm seeds, along with traces of other fruit species having populations domesticated at present (e.g., Brazil nut, pequiá, guava, and biribá) in occupation layers dating from ca. 9,000 and 7,200 years BP provides indirect evidence of agroforestry since the first occupations of the area (Furquim 2018; Watling et al. 2018). Guava (*Psidium* sp.), identified in both sites, as well as the early presence of root crops, suggests the use of fire in these systems, these species being associated with highly disturbed/ secondary forest areas (Fig. 6).

Fig. 6 Hearth feature dating from 6.000 B.P., associated with an ADE (Amazon Dark Earth) layer in the Teotônio site, Rondônia, Brazil

As agroforestry systems extend far beyond inhabited areas, the evidence of their existence in the past can also be identified by paleoecological studies that reconstruct the history of vegetation and fire beyond the archaeological site, allowing a correlation between human presence and ecological changes on a larger scale (Mayle and Iriarte 2014).

The most widely used proxy for detecting fire in the past is charcoal, which can be quantified and dated from sediments, soils, and lake coress. Identifying anthropogenic paleofires, however, requires an association with human activity areas, due to the possible occurrence of natural outbreaks of fire during periods of drier climate and in regions with savanna vegetation. In the savannas of Central Brazil, for example, evidence from Lake Comínia contained carbon dated to ca. 32,000 years BP, prior to human presence in the region (Ledru 2002) (but see also (Vialou et al. 2017; Araujo 2013; Parenti 2001). Many species of the savanna have evolved with fire. From the arrival of humans, however, fire probably began to be used to stimulate the production of edible fruits, control pests, and help in hunting (Mistry 1998).

The paleoenvironmental record, however, can also contain traces of fires caused by farming practices and other human activities. Lake cores in the eastern Amazon (Comprida (Bush et al. 1989), Geral, Santa Maria, Saracuri (Bush et al. 2007) Curuá (Behling and da Costa 2000), Crispin (Behling and Lima da Costa 2001) Tapajós (Irion et al. 2006) and Carana (Maezumi et al. 2018), in the state of Pará), and in the southwest (Gentry and Parker, Peru (Bush et al. 2007), and Chaplin, Bella Vista (Burbridge et al. 2004), Chalalán, Santa Rosa (Urrego et al. 2013) and Rogaguado (Brugger et al. 2016), in Bolivia) record charcoal since at least 8,000 cal. yr BP, when most of these lakes were formed. Amazon forests very rarely catch fire naturally, even in places with longer dry seasons (Nepstad et al. 2004), which is why some researchers (Bush et al. 2007; Mayle and Power 2008), attribute this charcoal to human presence. In addition, charcoal input in many of these records is higher during the Middle Holocene (ca. 8,200—4,200 cal BP) than during the Late Holocene (from 4,2000 cal BP.)—a shared pattern in the savanna (Vernet 1994). The higher incidence of fire during this time could be the effect of a drier climate, which would have resulted in unmanaged anthropogenic fires (as seen recently in Acre (Aragão et al. 2007)). A similar pattern occurs in the Late Holocene, where more intense periods of El Niño correlate with higher incidence of charcoal in lakes and soils of the Amazon (Bush et al. 2008, 2017). When accompanied by pollen analysis, some of these records register the opening of the forest to plant crops (notably maize) since at least 6,320 cal. BP in the southwestern (Bush et al. 2016), and 4,300 cal. BP in the eastern (Bush et al. 2000) Amazon.

Direct evidence of the management of perennial plants, however, is scarce in the paleoecological record, depending on the taxonomic resolution permitted by fossil pollen, which is often restricted to genus. Generally, a genus containing species used by people also contains species that are not used. However, a paleoecological study in Santarém (PA) quantified the abundance of annual economic genera (maize, manioc, and squash) over 8,500 years of history, and showed that they increased with the use of fire in the region from 4,500 cal. BP (Maezumi et al. 2018). Archaeobotanical studies at archaeological sites in the region also showed the intensification of these

Fig. 7 Maize and peanut crushed by mortar in a wooden pestle for chichi production in the Palhal Village, Tupari indigenous people, Branco River, Rondônia, Brazil

agroforestry systems over time (Alves 2016). In eastern Acre, another paleoecological study found an increase in regional fires from ca. 4,000 cal. BP and subsequent proliferation of palm also interpreted as the proliferation of agroforestry practices in the Late Holocene (Watling et al. 2017). In archaeological sites located in this region, such as Sol de Campinas site, dating from ca. 1,000 to 1,600 BP, there are traces of the use of these palm trees—like the uricuri (*Syagrus coronata*) —in fires probably related to cooking and or daily activities together with large amounts of maize kernels (Neves et al. 2016; Watling et al. 2015) (Fig. 7).

From Agroforestry to Pasture: Acre After 500 Years of Colonization

The Brazilian state of Acre, on the border with Bolivia and Peru, has a long history of territorial disputes centered on the debate about models of farming/conservation proposed by different groups. Data from 2017 tell us that about 45% of the total territory consists of protected areas, among which 14% are Indigenous Lands, and indicate that the number of cattle herds and areas for temporary crops (especially corn and sugarcane) have increased in recent years (SEPLAN 2017). The gradual removal of vegetation cover since the 1980s has revealed the presence of several archaeological sites consisting of earthern structures such as mounds, ditches, and roads, whose archaeobotanical and paleoenvironmental remains point to a long history of agroforestry.

The study of Watling et al. (2017) found that the region of the so-called geoglyphs, which began to be built around 2,500 years ago (Saunaluoma and Schaan 2012), was covered by bamboo (*Guadua* sp.). Forest clearance to build the geoglyphs appears to have been restricted to areas of occupation. However human presence is correlated

Fig. 8 Archaeological site Sol de Campinas do Acre. Aerial view of the mounds in circular shape (**a**) (Photo: Sana Saunaluoma), ceramic vessel fragments (**b**) and excavation profile (**c**), Acre, Brazil.

with a significant increase in palm trees in the same locations. Traces of these anthropogenic forests can be found today near these archeological sites, like the geoglyph Três Vertentes (Balée et al. 2014).

Sol de Campinas, a site consisting of mounds arranged in a circular shape, was occupied intermittently between 1,000 and 300 yrs B.P. represents an indigenous space usage model of this region 400 years BP. Like neighboring, similar sites, it is located on a small plateau close to water sources, clearly to take advantage of this natural resource. A variety of maize was cultivated with a slightly larger grain (2 mm) and used in combination with species indicative of secondary forests such as passion fruit and murici, and perennial species such as Brazil nut, tucumã, urucuri (*Attalea palerata*) and other palms (Neves et al. 2016; Furquim 2017) (Fig. 8).

There are reports about indigenous peoples who lived in this region until the nineteenth century, when the first rubber tappers began to occupy the area, triggering the migration, murder, and enslavement of many indigenous people (Labre cited. in Rocha 2016). In the 1970s, the Brazilian Federal Government sponsored a colonization project in the area. Due to the low productivity of the soils and the inexperience of the settlers (most originating from outside of the area) these forests gradually became transformed into cattle pastures.

Based on paleoenvironmental records of Watling et al. (2017), a comparative look between the past and the present shows that, while past indigenous management led to the maintenance and transformation of forested environments, current land use practices are characterized by deforestation on a spatial and temporal scale never seen before. Over 500 archaeological structures have been identified in Acre, the vast majority located in cattle grazing areas. The removal of anthropogenic forest formed over 2000 years favors a rapid exhaustion of the soil, which in about two years is unproductive for agriculture. A look at the past can not only enhance indigenous history, but also point to new agroforestry and water management strategies that enable cultivation, coupled with environmental conservation.

6 Conclusions

The landscapes bequeathed by Indigenous societies that occupy the Amazon for millennia are perceived and incorporated by modern traditional communities and integrate part of their traditional ecological knowledge (TEK, cf. Smith 2012) and of their daily management and cultivation practices. ADEs, plants, and landscapes are often used as resources (Rocha et al. 2014) in the construction of gardens, yards, and modern agroforestry systems. The construction of traditional ecological knowledge undergoes a direct correlation between knowledge accumulated through generations and creative engagement, uniting tradition and innovation (Ingold 2000) through a learning process that is inscribed in the territory. For instance, current agrobiodiversity is positively correlated to the history of human occupation, and corresponds to past sociocultural variability, buts its preservation is also favored by the continued use of anthropogenic soils and their associated landscapes by Indigenous and traditional communities in the present.

Studies on fertility of soil have indicated the presence of archaeological materials. Similarly, community gardens on ADE sites in the Urubu River (Amazonas state), show that sites occupied by more than one cultural group support greater heterogeneity and diversity in their plant composition (Lins et al. 2015). There is, however, a homogenizing effect, wherein gardens with higher proportions of exotic plants have a lower variability of native species, suggesting that the introduction of such species neutralizes an ancient process of succession, formation of seed banks, and correlations between past and present plants. In addition, exotic species are those most in need of the improved conditions provided by ADEs, since they are not adapted to Amazonian acidic soils (Junqueira et al. 2016a, b), which is the reason why ADEs are sought for their cultivation (Fig. 9).

This chapter aimed to show that Indigenous agroecological practices have contributed over the millennia to transform Amazonian biomes. Such practices are still alive and their ancient record can be found in archaeological sites and contemporary landscapes. The conversion of forests into pasture, together with the catastrophic social and ecological consequences it brings, also erases, in a few days, biomes that co-evolved with humans over millennia. The Amazon rainforest and its traditional inhabitants were never as threatened as they are today and Indigenous lands play an important role in preventing further deforestation. It is impossible, therefore, to disentangle nature conservation from the protection of the livelihoods of traditional societies as we hope to have shown here.

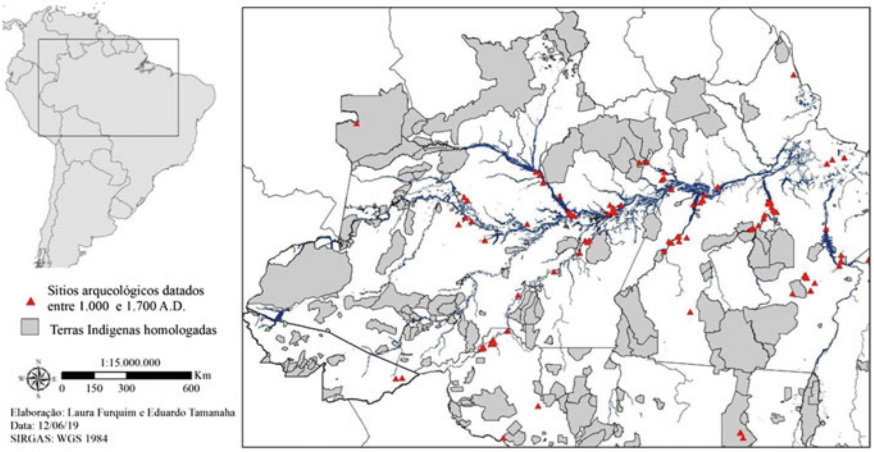

Fig. 9 Archaeological sites dated from the last 500 years before European conquest (*Source* Eduardo Tamanaha), with approved indigenous lands (*Source* Funai Database)

References

Alves D (2016) Plant food consumption and the origin of Amazonian dark earth in the lower Tapajós Region". In Beyond Waters. Archaeology and Environmental History of the Amazonian Inland, 61–70. Gothenburg: Per Stenborg.

Andrade C, Victor, Flores B, Levis C, Clement C, Roberts P, Schöngart J (2019) Growth rings of Brazil nut trees (Bertholletia excelsa) as a living record of historical human disturbance in Central Amazonia. PLoS ONE 14(abril):e0214128. https://doi.org/10.1371/journal.pone.0214128

Aragão L, Malhi Y, Román-Cuesta RM, Saatchi S, Anderson L, Yosio Shimabukuro Y (2007) Spatial patterns and fire response of recent Amazonian droughts. Geophys. Res. Lett 34(abril). https://doi.org/10.1029/2006GL028946

Araujo A, Feathers J, Arroyo-Kalin M, Tizuka M (2008) Lapa das Boleiras rockshelter: stratigraphy and formation processes at a Paleoamerican site in Central Brazil. J Archaeol Sci 35(dezembro). https://doi.org/10.1016/j.jas.2008.07.007

Araujo A (2013) Geomorfologia e paleoambientesno leste da América do Sul: implicaçõesarqueológicas. In: Geoarqueologia. Goiânia, GO: PUC

Arroyo-Kalin M (2012) Slash-Burn-and-Churn: landscape history and crop cultivation in pre-Columbian Amazonia. Quat Int 249(fevereiro). https://doi.org/10.1016/j.quaint.2011.08.004

Arroyo-Kalin M (2017) Human niche construction and population growth in pre-Columbian Amazonia. Archaeol Int 20(dezembro):122. https://doi.org/10.5334/ai.367

Arroyo-Kalin M (2018) Human Niche construction and population growth in pre-Columbian Amazonia. Archaeol Int 20. https://doi.org/10.5334/ai-367

Bachelet C, Rita Scheel-Ybert R (2015) Landscape and firewood selection in the Santa Elina rock shelter (Mato Grosso, Brazil) during the Holocene. Quat Int, Janeiro. https://doi.org/10.1016/j.quaint.2015.12.019

Balée W (2000) Antiquity of traditional ethnobiological knowledge in Amazonia: The Tupí-Guaraní family and time. Ethnohistory 47(2):399–422

Balée W (2008) Sobre a Indigeneidade das Paisagens. Revista De Arqueologia, x 21:9–23

Balée W, Schaan D, James Whitaker J, Holanda R (2014) "Florestas Antrópicas no Acre: inventário florestal no geloglifo Três Vertentes, Acrelândia". Amazônica, Revista de Antropologia 6(1). https://doi.org/10.18542/amazonica.v6i1.1752.

Behling H, Lima da Costa M (2000) Holocene environmental changes from the Rio Curuá Record in the Caxiuanã Region, Eastern Amazon Basin. Quatern Res 53(3):369–377. https://doi.org/10.1006/qres.1999.2117
Behling H, Lima da Costa M (2001) Holocene vegetational and coastal environmental changes from the Lago Crispim record in northeastern Pará State, eastern Amazonia. Rev Palaeobot Palynol 114(3):145–155. https://doi.org/10.1016/S0034-6667(01)00044-6
Bernardes K, Ruivo M, Pedroso A, Rodrigues P, Okumura R (2017) Chemical attributes of archaeological black earth soils in Brazilian Amazon. Australian J Crop Sci 11(outubro):1334–38. https://doi.org/10.21475/ajcs.17.11.10.pne611
Boëda E, Rocca R, da Costa A, Fontugne M, Hatté C, Clemente-Conte I, Santos JC et al. (2016) New data on a Pleistocene archaeological sequence in South America: Toca do Sítio do Meio, Piauí, Brazil. PaleoAmerica: J Early Human Migrat Dispersal 247:16–21. https://doi.org/10.1080/20555563.2016.1237828
Boivin NL, Zeder MA, Fuller DQ, Crowther A, Larson G, Erlandson JM, Denham T, Petraglia MD, MD, (2016) Ecological consequences of human niche construction: examining long-term anthropogenic shaping of global species distributions. Proc Natl Acad Sci 113(23):6388. https://doi.org/10.1073/pnas.1525200113
Brugger SO, Gobet E, van Leeuwen JFM, Ledru MP, Colombaroli D, van der Knaap WO, Lombardo U et al (2016) Long-term man–environment interactions in the Bolivian Amazon: 8000 years of vegetation dynamics. Quatern Sci Rev 132:114–128. https://doi.org/10.1016/j.quascirev.2015.11.001
Bueno L, Dias AS, Steele J (2013) The late Pleistocene/Early Holocene archaeological record in Brazil: a geo-referenced database. A Late Pleistocene/early Holocene archaeological 14C database for Central and South America: Palaeoenvironmental contexts and demographic interpretations 301 (julho):74–93. https://doi.org/10.1016/j.quaint.2013.03.042
Burbridge R, Mayle F, Killeen T (2004) Fifty-thousand-year vegetation and climate history of Noel Kempff Mercado National Park, Bolivian Amazon. Quatern Res 61(março):215–30. https://doi.org/10.1016/j.yqres.2003.12.004.
Bush M, Piperno D, Colinvaux P (1989) A 6,000 year history of maize Amazonian cultivation. Nature 340:303–305
Bush M, Miller M, Oliveira P, Colinvaux PA (2000) Two histories of environmental change and human disturbance in eastern lowland Amazonia. The Holocene 10(setembro):543–54. https://doi.org/10.1191/095968300672647521
Bush M, Silman M, de Toledo M, Listopad C, Gosling W, Williams C, Oliveira P, Krisel C (2007) Holocene fire and occupation in Amazonia: Records from two lake districts. Philos Trans R Soc Lond. Ser B, Biol Sci 362 (março):209–18. https://doi.org/10.1098/rstb.2006.1980
Bush M, Silman M, Mcmichael C, Sassan Saatchi S (2008) Fire, climate change and biodiversity in Amazonia: A Late-Holocene perspective. Philos Trans R Soc Lond. Ser B, Biol Sci 363(junho):1795–1802. https://doi.org/10.1098/rstb.2007.0014
Bush M, Correa-Metrio A, Mcmichael C, Sully S, Shadik C, Valencia B, Guilderson T, Kannan M, Overpeck J (2016) A 6900-year history of landscape modification by humans in lowland Amazonia. Quatern Sci Rev 141(junho):52–64. https://doi.org/10.1016/j.quascirev.2016.03.022
Bush M, Correa-Metrio A, Woesik AV, Shadik C, Mcmichael C (2017) Human disturbance amplifies Amazonian El Niño-Southern Oscillation signal. Global Change Biol 23(março). https://doi.org/10.1111/gcb.13608
Caldarelli S, Kipnis R (2017) A ocupação pré-colonial da Bacia do Rio Madeira: novos dados e problemáticas associadas. Especiaria: Cadernos de Ciências Humanas, Territórios e Culturas no Brasil Pré-Colonial 17(30):229–289
Caromano C, Cascon L, Murrieta R (2016) A Roça Asurini e o Fogo Bonito de Aí. Habitus 14(outubro):131. https://doi.org/10.18224/hab.v14.1.2016.131-140
Cascon L (2010) Alimentação na Floresta Tropical: um estudo de caso no sSítio Hatahara, Amazônia Central, com base em microvestígios botânicos. Dissertação de Mestrado, Rio de Janeiro: UFRJ/MN

Cassino M, Alves R, Watling J, Junqueira A, Shock M, Ferreira MJ, Andradre V, et al (2019) Ethnobotany and ethnoecology applied to historical ecology. In: Methods and techniques in ethnobiology and ethnoecology. Springer protocols handbooks. Humana Press, New York

Clement C (1999) 1492 and the loss of Amazonian crop genetic resources. ii. Crop biogeography at contact. Econ Bot 53(2):203–216. https://doi.org/10.1007/BF02866499

Clement C, Denevan W, Heckenberger M, Junqueira A, Neves E, Teixeira W, Woods W (2015) The domestication of Amazonia before European conquest. Proc B of the R Soc 282:9. https://doi.org/10.1098/rspb.2015.0813

Clement C, Cristo-Araújo M, d'Eeckenbrugge G, Pereira A, Doriane Picanço-Rodrigues D (2010) Origin and domestication of native Amazonian crops. Diversity 2(março). https://doi.org/10.3390/d2010072

Corteletti R, Dickau R, DeBlasis P, Iriarte J (2015) Revisiting the economy and mobility of southern proto-Jê (Taquara-Itararé) groups in the southern Brazilian highlands: starch grain and phytoliths analyses from the Bonin site, Urubici, Brazil. J Archaeol Sci 58(março). https://doi.org/10.1016/j.jas.2015.03.017

Denevan W (2006) Pre-European forest cultivation in Amazonia. In: Time and complexity in historical ecology: studies in the neotropical lowlands. Balée e Erickson, New York, pp 153–164

Dillehay TD, Ocampo C, Saavedra J, Sawakuchi AO, Vega RM, Pino MM, Collins MB et al (2015) New archaeological evidence for an early human presence at Monte Verde, Chile. PLoS ONE 10(11):e0141923. https://doi.org/10.1371/journal.pone.0141923

Fausto C, Neves EG (2018) Was there ever a Neolithic in the Neotropics? Plant familiarisation and biodiversity in the Amazon. Antiquity 92(366):1604–1618. https://doi.org/10.15184/aqy.2018.157

Flores B, Nelson B, Piedade MT (2012) Fire disturbance in Amazonian blackwater floodplain forests. Plant Ecol Divers 7(janeiro). https://doi.org/10.1080/17550874.2012.716086

Furquim L, Watling J, Hilbert L, Shock M, Prestes-Carneiro G, Calo M, Py-Daniel A, Brandão K, Pugliese F, Zimpel C, Silva C, Neves E (2021) Fancing change through diversity: diversification of plant management strategies during the Mid to Late Holocene transition at the Monte Castelo Shellmound. SW Amazonia. Quatern 4(8). https://doi.org/10.3390/quat4010008

Furquim L (2017) Nem tudo que reluz é milho: manejo agroflorestal no interflúvio Purus - Madeira (Acre, Brasil). Apresentação Oral em Simpósio Temático apresentado em IV Encontro Internacional de Arqueologia Amazônica, Trinidad, Bolívia

Furquim L (2018) Arqueobotânica e Mudanças Socioeconômicas no Sudoeste da Amazônia durante o Holoceno Médio. Mestrado, São Paulo: USP

Glaser B, Birk J (2012) State of the scientific knowledge on properties and genesis of Anthropogenic Dark Earths in Central Amazonia (terra preta de Indio). Geochimica et Cosmochimica Acta 82 (abril):39–51. https://doi.org/10.1016/j.gca.2010.11.029

Guimarães PR, Jr GM, Jordano P (2008) Seed dispersal anachronisms: rethinking the fruits extinct Megafauna Ate. PLoS ONE 3(3):e1745. https://doi.org/10.1371/journal.pone.0001745

Heckenberger M, Neves E (2009) Amazonian archaeology. Annu Rev Anthropol 38:251–266

Heckenberger MJ, Kuikuro A, Kuikuro UT, Russell JC, Schmidt M, Fausto C, Franchetto B (2003) Amazonia 1492: pristine forest or cultural Parkland? Science 301(5640):1710. https://doi.org/10.1126/science.1086112

Hermenegildo T, O'Connell TC, Vera Guapindaia VLC, Neves EG (2017) New evidence for subsistence strategies of late pre-colonial societies of the mouth of the Amazon based on carbon and nitrogen isotopic data. Forests Plenty 448(agosto):139–149. https://doi.org/10.1016/j.quaint.2017.03.003

Hilbert L (2017) Investigating plant management in the Monte Castelo (RO-Brazil) and Tucumã (PA-Brazil) Shell Mounds using phytoliths analysis. University of Exeter, Doutorado, Exeter

Hilbert L, Neves EG, Pugliese F, Whitney BS, Shock M, Veasey E, Zimpel CA, Iriarte J (2017) Evidence for mid-Holocene rice domestication in the Americas. Nat Ecol Evol 1(11):1693–1698. https://doi.org/10.1038/s41559-017-0322-4

Iriarte J, Behling H (2007) The expansion of Araucaria forest in the southern Brazilian highlands during the last 4000 years and its implications for the development of the Taquara/Itararé Tradition. Environ Archaeol 12(outubro). https://doi.org/10.1179/174963107x226390

Irion G, Bush M, Mello J, Stüben D, Neumann T, Müller G, de JO, Junk JW (2006) Multiproxy record of Holocene lake sediments from the Rio Tapajós, eastern Amazonia. Palaeogeograph Palaeoclimatol Palaeoecol. Palaeogeography, Palaeoclimatol, Palaeoecol 240(outubro):523–535. https://doi.org/10.1016/j.palaeo.2006.03.005

Isendahl C (2011) The domestication and early spread of Manioc (Manihot Esculenta Crantz): a brief synthesis. Latin Am Antiquity 22(dezembro):452–468. https://doi.org/10.2307/23072569

Junqueira A, Souza N, Stomph T, Clement C, Struik P (2016a) Soil fertility gradients shape the agrobiodiversity of Amazonian homegardens. Elsevier Agricult, Ecosyst Environ 221:270–281

Junqueira A, Shepard G, Clement C (2010) Secondary forests on anthropogenic soils in Brazilian Amazonia conserve agrobiodiversity. Biodivers Conserv 19(junho):1933–1961. https://doi.org/10.1007/s10531-010-9813-1

Junqueira A, Stomph TJ, Clement CR, Struik P (2016b) Variation in soil fertility influences cycle dynamics and crop diversity in shifting cultivation systems. Agricult, Ecosyst Environ 215(janeiro):122–132. https://doi.org/10.1016/j.agee.2015.09.015

Kern D, D'aquino G, Rodrigues T, Frazao F, Sombroek W, Myers T, Neves EG (2004) Distribution of Amazonian dark earths in the Brazilian Amazon. In: Amazonian dark earths: origin, properties, management, pp 51–75. https://doi.org/10.1007/1-4020-2597-1_4

Ledru MP (2002) "Late Quaternary history and evolution of the cerrados as revealed by palynological records". In , 33–50.

Levis C, Costa FRC, Bongers F, Peña-Claros M, Clement CR, Junqueira AB, Neves EG et al (2017) Persistent effects of pre-Columbian plant domestication on Amazonian forest composition. Science 355(6328):925. https://doi.org/10.1126/science.aal0157

Levis C, Flores BM, Moreira PA, Luize BG, Alves RP, Franco-Moraes J, Lins J et al (2018) How people domesticated Amazonian forests. Front Ecol Evol 5:171. https://doi.org/10.3389/fevo.2017.00171

Levis C, Silva MS, Silva MA, Moraes C, Neves EG, Tamanaha E, Flores B, Clement CR (2014) What do we know about the distribution of Amazonian dark earth along tributary rivers in Central Amazonia? III Encuentro Internacional De Arqueologı´a Amazónica, janeiro 305–311

Lima L (2011) Feições: vestígios antrópicos na Amazônia Central. Iniciação Científica. São Paulo: Museu de Arqueologia e Etnologia, USP

Lins J, Lima H, Baccario F, Knupp V, Shepard G, Clement C (2015) Pre-Columbian floristic legacies in modern homegardens of Central Amazonia. PLoS ONE 10(6):1–10

Macedo, RS, Teixeira WG, Lima HN, Gil de Souza AC, Silva FWR, Encinas OC, Neves EG (2019) Amazonian dark earths in the fertile floodplains of the Amazon River, Brazil: an example of non-intentional formation of anthropic soils in the Central Amazon region. Boletim do Museu Paranaense Emílio Goeldi. Ciências Humanas. https://doi.org/10.1590/1981-81222019000100013

Maezumi SY, Alves D, Robinson M, de Souza JG, Levis C, Barnett RL, de Oliveira EA, Urrego D, Schaan D, Iriarte J (2018) The legacy of 4,500 years of polyculture agroforestry in the eastern Amazon. Nat Plants 4(8):540–547. https://doi.org/10.1038/s41477-018-0205-y

Matos C (2015) Análise micromorfológica dos depósitos arqueológicos do sítio Conjunto Vilas, Tefé (AM). Universidade Federal do Rio de Janeiro, Dissertação de Mestrado, Rio de Janeiro

Mayle F, Iriarte J (2014) Integrated palaeoecology and archaeology–a powerful approach for understanding pre-Columbian Amazonia. J Archaeol Sci 51(novembro):54–64. https://doi.org/10.1016/j.jas.2012.08.038

Mayle F, Power M (2008) Impact of a drier Early-Mid-Holocene climate upon Amazonian forests. Philos Trans R Soc Lond. Ser B, Biol Sci 363(junho):1829–1838. https://doi.org/10.1098/rstb.2007.0019

Mayle FE, Langstroth RP, Fisher RA, Meir P (2007) Long-term forest-Savannah dynamics in the Bolivian Amazon: implications for conservation. Philos Trans R Soc Lond. Ser B, Biol Sci 362(1478):291–307. https://doi.org/10.1098/rstb.2006.1987

Miller E (2013) Algumas Culturas Ceramistas, do Noroeste do Pantanal do Guaporé à Encosta e Altiplano Sudoeste do Chapadão dos Parecis. Origem, Difusão/Migração e Adaptação – do Noroeste da América do Sul ao Brasil. Linguística Antropológica 5(2):355–383

Mistry J (1998) Fire in the cerrado (savannas) of Brazil: an ecological review. Progr Phys Geography: Earth Environ 22(4):425–448. https://doi.org/10.1177/030913339802200401

Mori S, Prance GT (1990) Taxonomy, ecology and economic botany of the Brazil nut (Bertholletia excelsa Humb. & Bonpl.:Lecythidaceae). Adv Econ Botany 8(janeiro):130–150

Nakamura C, Melo Jr J, Ceccantini G (2010) Macro-restos vegetais: uma abordagem paleoetnobotânica e paleoambiental. In: Lapa das Boleiras: Um sítio paleoíndio do carste de Lagoa Santa, MG, Brasil.. São Paulo: ARAUJO, A. G. M., NEVES, W. A, pp 163–190

Nepstad D, Lefebvre P, Júnior US, Tomasella J, Schlesinger P, Solorzano L, Moutinho P, Guerrero J (2004) Amazon drought and its implications for forest flammability and tree growth: a basin-wide analysis. Global Change Biol 10(maio). https://doi.org/10.1111/j.1529-8817.2003.00772.x

Neves EG, Petersen J, Bartone R, Silva C (2004) Historical and socio-cultural origins of Amazonian dark earth, pp 29–50. https://doi.org/10.1007/1-4020-2597-1_3

Neves, EG, Furquim L, Zimpel C, Pugliese F, Shock M (2016) Pesquisa e Formação nos sítios Espinhara e Sol de Campinas do Acre. Relatório Final de Atividades. Rio Branco, AC: IPHAN

Neves EG (2012) Sob os Tempos do Equinócio: oito mil anos de História na Amazônia Central (6.500 AC – 1.500 DC). Livre-Docência, São Paulo: USP

Noelli F, Ferreira LM (2007) A persistência da teoria da degeneração indígena e do colonialismo nos fundamentos da arqueologia brasileira. Historia Ciencias Saude-manguinhos 14 (dezembro). https://doi.org/10.1590/S0104-59702007000400008

Oliveira JC (2016) Mundos de roças e florestas. Boletim Do Museu Paraense Emilio Goeldi 11(1):115–131. https://doi.org/10.1590/1981.81222016000100007

Parenti F (2001) Le gisement quaternaire de la Pedra Furada (Piaui, Brésil). Stratigraphie, chronologie, evolution culturelle

Pereira E, Barreto C, Py-Daniel AR, Moraes C, Arenz K, Nascimento H (2018) Monte Alegre uma história de longa duração

Pessenda LCR, Gouveia SEM, Aravena R, Gomes BM, Boulet R, Ribeiro AS (1997) 14C dating and stable carbon isotopes of soil organic matter in forest-savanna boundary areas in the Southern Brazilian Amazon region. Radiocarbon 40(2):1013–1022. https://doi.org/10.1017/S0033822200018981

Pessenda LCR, Boulet R, Aravena R, Rosolen V, Gouveia SEM, Ribeiro AS, 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. The Holocene 11(2):250–254. https://doi.org/10.1191/095968301668898509

Piperno DR, Pearsal D (2000) "The Origins of Agriculture in the Lowland Neotropics". Latin American Antiquity 11 (março): 104. https://doi.org/10.2307/1571684.

Politis G (1996a) Nukak: ethnoarchaeology of an Amazonian people. Left Coast Press, California

Politis GG (1996b) Moving to produce: Nukak mobility and settlement patterns in Amazonia. World Archaeol 27(3):492–511. https://doi.org/10.1080/00438243.1996.9980322

Politis G, Guitiérrez M, Rafuse D, Blasi A (2016) The Arrival of Homo sapiens into the Southern Cone at 14,000 years ago. PLoS ONE 11(9):1–27. https://doi.org/10.1371/journal.pone.0162870

Politis G (1999) "Plant exploitation among the Nukak hunter-gatherers of Amazonia: Between ecology and ideology". The Prehistory of Food: Appetites for Change, janeiro, 99–126.

Posey D, Balée W (1989) Resource Management in Amazonia: Indigenous and Folk Strategies. New York Botanical Garden Pr Dept: Edition Unstated.

Posth C, Nakatsuka N, Lazaridis I, Skoglund P, Mallick S, Lamnidis TC, Rohland N et al (2018) Reconstructing the deep population history of Central and South America. Cell 175(5):1185-1197.e22. https://doi.org/10.1016/j.cell.2018.10.027

Prümers H, Betancourt CJ (2014) 100 años de investigaciones arqueológicas en los Llanos de Mojos. Arqueoantropológica 4(4):11–53

Pugliese F, Zimpel C, Neves EG (2017) Los concheros de la Amazonía y la historia indígena profunda de América del Sur.

Quesada C, Lloyd J, Anderson L, Fyllas N, Schwarz M, Czimczik C (2011) Soils of Amazonia with particular reference to the RAINFOR sites. Biogeosciences 8(junho). https://doi.org/10.5194/bg-8-1415-2011

Rindos D (1983) The origins of agriculture: an evolutionary perspective. Academic, New York

Rival L, Mckey D (2008) Domestication and diversity in Manioc (Manihot esculenta Crantz ssp. esculenta , Euphorbiaceae). Current Anthropol 49(dezembro):1119–1128. https://doi.org/10.1086/593119

Roberts P, Hunt C, Arroyo-Kalin M, Evans D, Boivin N (2017) The deep human prehistory of global tropical forests and its relevance for modern conservation. Nat Plants 3(agosto). https://doi.org/10.1038/nplants.2017.93

Robinson M, de Souza JG, Maezumi S, Cárdenas M, Pessenda L, Prufer K, Corteletti R et al. (2018) Uncoupling human and climate drivers of late Holocene vegetation change in southern Brazil". Sci Rep 8(maio). https://doi.org/10.1038/s41598-018-24429-5

Rocha B, Belletti J, Moraes C, Py-Daniel A, Oliveira VH (2014) Na margem e à margem: Arqueologia Amazônica em territórios tradicionalmente ocupados. Amazônica, Revistra De Antropologia 6(2):358–384

Rocha H (2016) Coronel Labre. 1a ed. Vol. 1. São Carlos, SP: Scienza.

Roosevelt A (1991) Moundbuilders of the Amazon: geophysical archaeology on Marajo Island. Academic, Brazil

Roosevelt A, Costa M, Machado C, Michab M, Mercier N, Valladas H, Feathers J et al (1996) Paleoindians Cave-Dweelers in the Amazon: the peopling of Americas. Sci, New Series 272:373–384

Roosevelt A (1992) Arqueologia Amazônica. In: História dos Índios no Brasil. São Paulo: Manuela Carneiro da Cunha

Rostain S (2012) Where the Amazon River meets the Orinoco River. Archaeology of the Guianas. Amazônica, Revista de Antropologia 4(1):10–28. http://dx.doi.org/https://doi.org/10.18542/amazonica.v4i1.880

Safier N (2014) The tenacious travels of the torrid zone and the global dimensions of geographical knowledge in the eighteenth century. J Early Modern Hist 18(fevereiro):141–172. https://doi.org/10.1163/15700658-12342388

Saunaluoma S, Schaan D (2012) Monumentality in Western Amazonian formative societies: geometric ditched enclosures in the Brazilian state of Acre. Antiqua 2(fevereiro). https://doi.org/10.4081/antiqua.2012.e1

Schaan D (2010) Long-term human induced impacts on Marajó Island Landscapes, Amazon Estuary. Diversity 2(fevereiro). https://doi.org/10.3390/d2020182

Schmidt M, Py-Daniel AR, Moraes C, Valle R, Caromano C, Teixeira W, Barbosa C et al. (2014) Dark earths and the human built landscape in Amazonia: a widespread pattern of anthrosol formation. J Archaeol Sci 42(fevereiro):152–165. https://doi.org/10.1016/j.jas.2013.11.002

Schmidt M (2013) Amazonian dark earths: pathways to sustainable development in tropical rain-forests? Boletim do Museu Paraense Emilio Goeldi 8(abril): 11–38. https://doi.org/10.1590/S1981-81222013000100002

Scoles R, Gribel R (2015) Human influence on the regeneration of the Brazil Nut Tree (Bertholletia excelsa Bonpl., Lecythidaceae) at Capan Grande Lake, Manicor,, Amazonas, Brazil. Human Ecol 43(novembro). https://doi.org/10.1007/s10745-015-9795-4

Seplan (2017) O Acre em números." Rio Branco, AC: Secretaria do Estado de Planejamento

Shepard G (2011) Made in Brazil: human dispersal of the Brazil Nut (Bertholletia excelsa, Lecythidaceae) in Ancient Amazonia 1. Econ Botany 65(março):44–65. https://doi.org/10.1007/s12231-011-9151-6

Shock M, Moraes C (2019) A floresta é o domus: a importância das evidências arqueobotânicas e arqueológicas das ocupações humanas amazônicas na transição Pleistoceno/Holoceno. Boletim Do Museu Paraense Emilio Goeldi, Ciências Humanas 14(2):263–289. https://doi.org/10.1590/1981.81222019000200003

Silva FM, Shock M, Neves EG, Scheel-Ybert R (2016) Vestígios Macrobotânicos Carbonizados na Amazônia Central: o que eles nos dizem sobre as plantas na Pré-História? Cadernos do LEPAARQ 13(25)

Silva FS (2016) Um estudos paleoetnobotânico no Baixo Amazonas: o caso do sítio arqueológico da Caverna da Pedra Pintada, Monte Alegre - PA. Trabalho de Conclusão de Curso. Santarém, PA: Universidade Federal do Oeste do Pará

Smith B (2012) A cultural Niche construction theory of initial domestication. Biol Theory Tematic Issue Article: Cult Niche Constr. 10.1007/s13752-012-0028-4

Steege H, Pitman NCA, Sabatier D, Baraloto C, Salomão RP, Guevara JE, Phillips OL et al (2013) Hyperdominance in the Amazonian Tree Flora. Science 342(6156):1243092. https://doi.org/10.1126/science.1243092

Thomas E, Caicedo CA, McMichael CH, Corvera R, Loo J (2015) Uncovering spatial patterns in the natural and human history of Brazil nut (Bertholletia excelsa) across the Amazon Basin. J Biogeogr 42:1367–1382. https://doi.org/10.1111/jbi.12540

Tim I (1993) The temporality of the landscape. World Archaeol 25(2):152–174. https://doi.org/10.1080/00438243.1993.9980235

Urrego D, Bush M, Silman M, Niccum B, Rosa P, Mcmichael C, Hagen S, Palace M, Vetaas O (2013) Holocene fires, forest stability and human occupation in south-western Amazonia. J Biogeography 40(março). https://doi.org/10.1111/jbi.12016

Vernet JL (1994) Fire, climate and vegetation in central Brazil during the Holocene: data from a soil profile with charcoal, Salitre, Minas Gerais. Comptes Rendus - Academie des Sciences. Serie II: Sciences de la Terre et des Planetes 319(janeiro):1391–1397

Vialou D, Benabdelhadi M, Feathers J, Fontugne M, Vialou A (2017) Peopling South America's centre: the late Pleistocene site of Santa Elina. Antiquity 91(358):865–884

Villagran X, Strauss A, Miller C, Ligouis B, Oliveira R (2016) Buried in ashes: site formation processes at Lapa do Santo rockshelter, East-Central Brazil. J Archaeol Sci 77(julho). https://doi.org/10.1016/j.jas.2016.07.008

Watling J, Saunaluoma S, Pärssinen M, Schaan D (2015) Subsistence practices among earthwork builders: phytolith evidence from archaeological sites in the southwest Amazonian interfluves. J Archaeol Sci Rep 4:542–551

Watling J, Shock M, Mongeló G, de Almeida FO, Kater T, de Oliveira PE, Neves EG (2018) Direct archaeological evidence for Southwestern Amazonia as an early plant domestication and food production centre. PLoS ONE 13(7):1–28

Watling J, Iriarte J, Mayle F, Schaan D, Pessenda L, Loader N, Street-Perrott FA, Dickau R, Damasceno A, Ranzi A (2017) Impact of pre-Columbian 'geoglyph' builders on Amazonian forests. Proc Natl Acad Sci 114(fevereiro): 201614359. https://doi.org/10.1073/pnas.1614359114

Watling J, de Almeida FO, Kater T, Shock M, Mongeló G, Neves EG (2020) Arqueobotânica de ocupações ceramistas na Cachoeira de Teotônio. Boletim do Museu Paraense Emílio Goeldi: Ciências Humanas 15(2)

Zarrillo S, Gaikwad N, Lanaud C, Powis T, Viot C, Lesur I, Fouet O et al (2018) The use and domestication of Theobroma cacao during the mid-Holocene in the upper Amazon. Nat Ecol Evol 2(12):1879–1888. https://doi.org/10.1038/s41559-018-0697-x

Zuse S (2014) Variabilidade cerâmica e diversidade cultural no alto rio Madeira, Rondônia. Tese de Soutorado, São Paulo: Museu de Arqueologia e Etnologia, USP