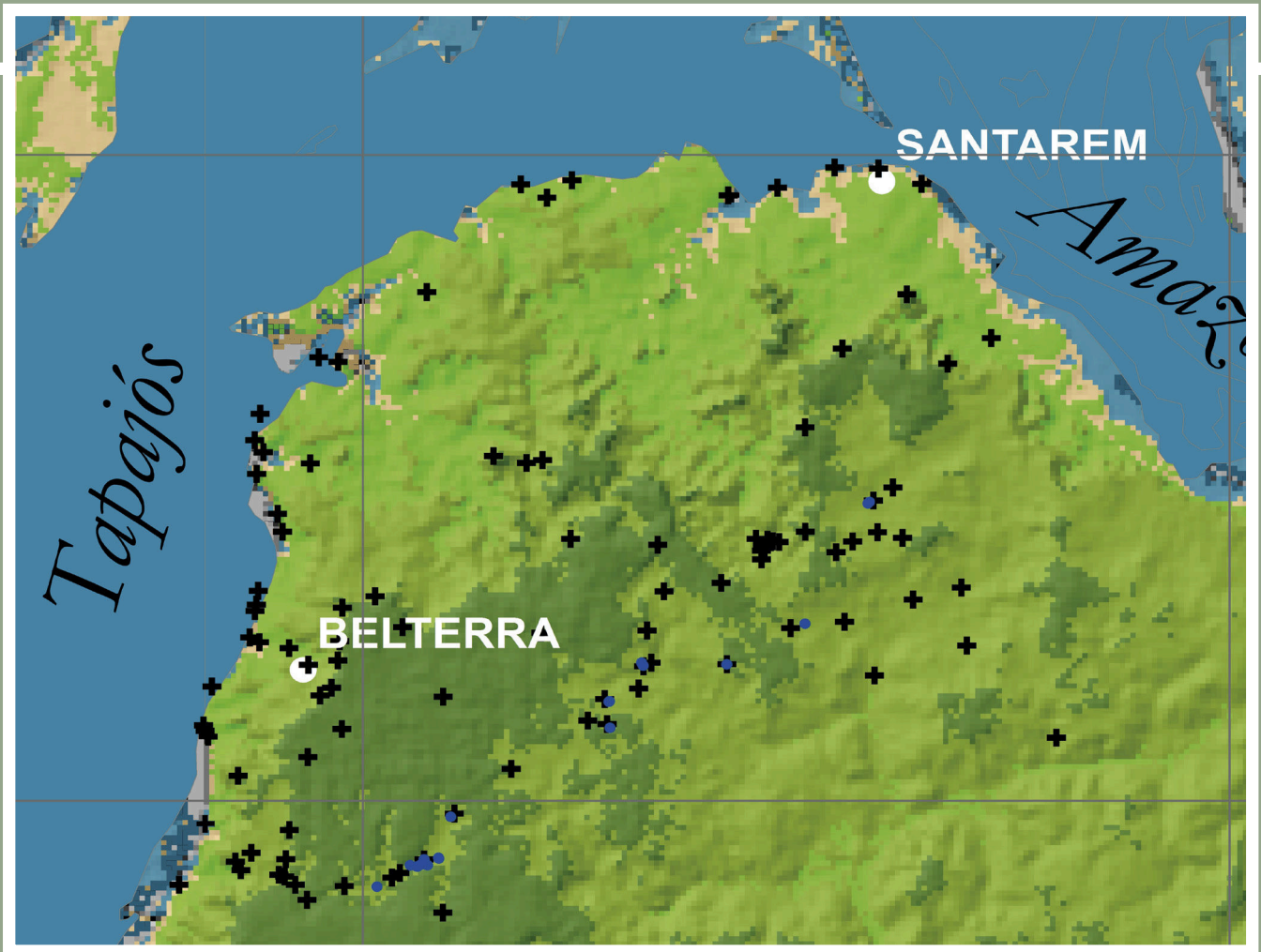
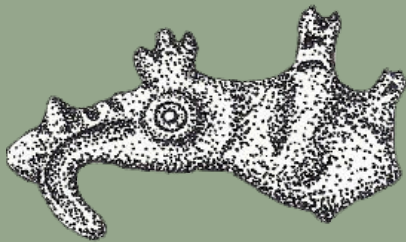


Beyond Waters

Archaeology and Environmental History of the Amazonian Inland



Edited by Per Stenborg



UNIVERSITY OF GOTHENBURG

GOTARC

Series A

Gothenburg Archaeological Studies

6

Beyond Waters

Archaeology and Environmental History of the Amazonian Inland

Editor

Per Stenborg



UNIVERSITY OF GOTHENBURG

Department of Historical Studies

Gothenburg 2016

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Editor's Preface

Per Stenborg

A short introduction to the project “Cultivated Wilderness: Socio-economic development and environmental change in pre-Columbian Amazonia”, and to the workshop “Beyond Waters: Archaeology and Environmental History of the Amazonian Inland”.

This volume is one of the outcomes of the project [“Cultivated Wilderness: Socio-economic development and environmental change in pre-Columbian Amazonia”](#) (see also, Schaan and Amaral Lima 2012; Stenborg et al. 2012, 2014; Söderström et al. 2013). The project was funded by the Bank of Sweden Tercentenary Foundation (Grant Number P10-0323:1). The project was directed by Per Stenborg at the University of Gothenburg in Sweden, while Denise Pahl Schaan at Universidade Federal do Pará, Brazil functioned as the Brazilian counterpart for the project which was made possible thanks to authorizations by the Brazilian authorities CNPq (000852/2011-2) and IPHAN (01494.000171/2011-78).

The project was organized in a bilateral/two-way manner; this allowed Brazilian researchers and students to stay in Gothenburg, Sweden, during the project's work with Amazonian material held by the Museum of World Culture in Gothenburg while Swedish researchers and students were able to participate in new archaeological and environmental research in the Santarém and Belterra areas in the State of Pará, Brazilian Amazon. The team has included archaeologists as well as soil scientists.

A crucial prerequisite for the advent of the project was the large collections of archaeological material (mainly pottery) from the Santarém area that the Museum of World Culture in Gothenburg (formerly the Gothenburg Ethnographic Museum), holds. In the 1920s, the German-born surveyor and self-made researcher Curt Unkel Nimuendajú made extensive

journeys along the Amazon River and several of its tributaries, as well as in some inland areas (including the Belterra Plateau in the Santarém-Belterra Region). The Gothenburg Museum partnered with Nimuendajú in 1922 (Rydén 2004). This cooperation should be viewed in light of the fact that the museum at that time, thanks to Erland Nordenskiöld's work, had established itself as an important institution regarding South American research (Muñoz 2011; Stenborg 2004). Nimuendajú conducted his work at a time when knowledge of the Amazon region's archaeology was almost nonexistent. The geographic extent of the region meant that his works had the character of surveys and inventories. However, the Santarém area became the part of the Amazon where he conducted most of his research and it is from this area that the largest number of objects in the collections, which today belongs to World Culture Museum in Gothenburg, have their provenance. Nordenskiöld became particularly interested in the material from Santarém; which he also had the opportunity display in the context of the 21st International Congress of Americanists, arranged in Gothenburg in 1924. The correspondence between Nordenskiöld and Nimuendajú shows that the former was unsure about the age of the Santarém pottery, (later known as Santarém Phase pottery) expressing the suggestion that it could be the result of contact between Europeans and the region's population during the contact period (from 1542 A.D.). Nimuendajú, however, convincingly argued that the pottery complex had definitely emerged before this time (Neves 2004:6; Nimuendajú 2000:73–74, 2004:151–153). As the results published in this volume shows; the Santarém Phase pottery was generally

associated with a vast expansion of human activity and settlements occurring over the last couple of centuries prior to European arrival in America (Schaan, this volume; Stenborg, this volume). Although the precise age of the Santarém material could not be determined by Nimuendajú, he correctly noted the particular dispersion of this material in the Amazonian inland (Neves 2004).

In the last two decades exploitation in the Santarém-Belterra Region has rapidly advanced. These exploitations include much needed infrastructural construction works, such as road networks, but also the expansion of mechanized agriculture (previously not practiced in the region), cattle raising and mining. An unfortunate circumstance is that archaeological sites — often associated with Terra Preta, or Amazonian Dark Earths (ADE) — constitutes the most favorable land for the introduction of mechanized agriculture. As a result the remaining archaeological sites are damaged through deforestation, leveling, ploughing, the use of artificial manure and pesticide, and so forth.

In the original application to the Bank of Sweden Tercentenary Foundation (2010) we stated our ambition to organize an international workshop related to the research issues dealt with in the project. This objective was possible to accomplish through the workshop “Beyond Waters: Archaeology and Environmental History of the Amazonian inland “ which formed part of the IX Sesquiannual Conference of the Society for the Anthropology of Lowland South America (SALSA), held in Gothenburg in June 2014. The presenters and participants at the workshop were, apart from the project members and our counterparts from Brazil, researchers from several other countries in Latin America and Europe.

The present volume includes the papers presented at our workshop, in some cases in revised or somewhat expanded form. In addition, papers by some of our key cooperation partners, who were unable to participate in the event, have been included in this book.

The contributions of the present volume span a broad range of subjects and fields, including soil science (Eriksson et al., Söderström et al.), landscape archaeology (Guarim Figueiro, Schaan, Stenborg, Troufflard), paleobotany (Alves, Iriarte),

stylistic studies (Schaan), historical information (Schaan, Stenborg) and digital mediation (Denti Gunnarsson and Castillo).

The editor expresses his gratitude to the Cultivated Wilderness crew in Sweden: Archaeologist Imelda Bakunic from the University of Gothenburg, Soil Scientists Janne Eriksson and Mats Söderström from the Swedish University of Agricultural Sciences and archaeologist Christian Isendahl from the University Uppsala, to our Brazilian counterparts and co-workers Denise Pahl Schaan at Universidade Federal do Pará, Márcio Amaral-Lima and Lilian Rebellato at Universidade Federal do Oeste do Pará. Many thanks to all the students from both Sweden and Brazil who have generously contributed to the work in Santarém, as well as in Gothenburg, and without whom much less would have been accomplished, as well as to the residents of Bom Futuro and Cedro who participated in, and supported our field work. Special thanks goes to the staff of the Museum of World Culture in Gothenburg, among others Jan Amnehäll, Adriana Muñoz and Farzaneh Bagherzade for granting us access to their collections, space to analyze the materials, as well as for their patience with our sometimes seemingly random presence. Thanks also to Mats Olvmo at the Department of Earth Sciences at the University of Gothenburg who, despite a busy schedule, helped us to understand some bits of the geology of the area and to Suzana Araújo at the Department of Soil Science, Unversidade de São Paulo for analyzing some of our samples as part of her dissertation work (Araújo 2013).

Special thanks to Bill Woods, Anna Curtenius Roosevelt, Eduardo Neves and Nigel Smith for interesting discussions and good advice and to Rich Potter for the linguistic review of the manuscript.

The publication of this book was made possible thanks to a production grant from The Swedish Foundation for Humanities and Social Sciences.

In the hope that this work will benefit not only the academic knowledge of the Amazon Region, but that it also — in one way or another — will be of value for the region and its current and future inhabitants.

Per Stenborg October 2014

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Towards a Regional History of Pre-Columbian Settlements in the Santarém and Belterra Regions, Pará, Brazil

Per Stenborg

Introduction

Studies of the human societies that existed in the Amazon Basin prior to the European expansion into this region faces, in several ways, a more difficult task than the corresponding research on most other parts of the world. Amazonian archaeology is conducted in an environment characterized by swift processes of degradation of organic material where the cycling of nutrients takes place at a high pace. Buildings and other constructions made out of perishable material leave few traces. Historians, for their part, have faced difficulties in finding historical sources that give substantial information about the conditions that prevailed prior to European contact with the region, e.g. most European chroniclers of the 16th and 17th centuries paid limited attention to Native chronologies or accounts of pre-Columbian Amazonia.

Development regarding analytical methods (in particular within Natural Science) looks promising and is sure to improve the situation over coming years (also Alves, this volume; Eriksson, this volume; Iriarte, this volume; Söderström,

this volume). The purpose of this chapter is to situate the outcome of our recent investigations in the Santarém–Belterra Region within the larger context of data on Amazonian prehistory and history. An outline of a regional periodization covering the last centuries before the European arrival and up until the early Colonial Period (post A.D. 1639) is presented along with an explanatory model for the special form of society that emerged in the Santarém–Belterra Region during the centuries preceding the European arrival. The model is an adaptation of an economic model developed for the Central Andean area (Murra 1975, 1985) to an Amazonian case study; this also takes into consideration previous anthropological and environmental research in Santarém-Belterra region (Nugent 1993; WinklerPrins 2002).

The Setting

Past, as well as present people in the Santarém–Belterra Region live in an environment characterized by a tropical annual cycle of a rainy season lasting about six months and a dry season covering the other six months of the year. The

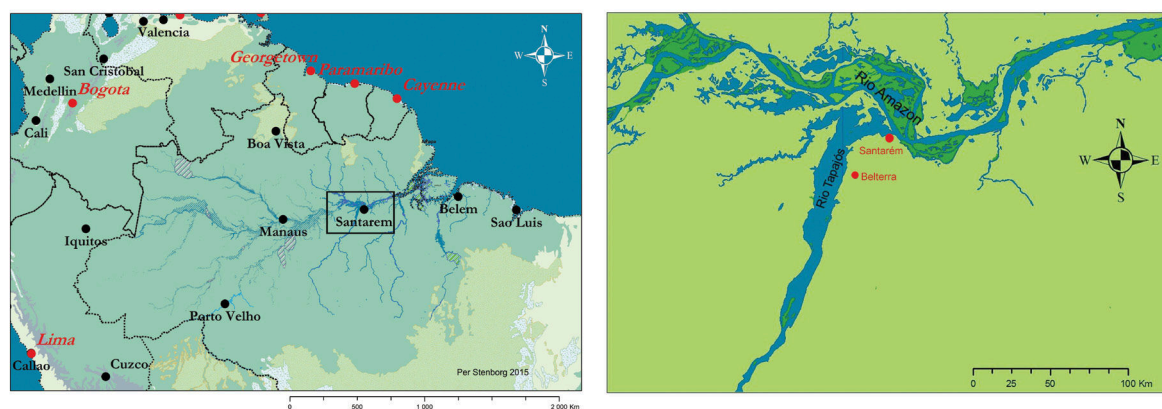


Fig. 1. Location of Santarém and Belterra. By Per Stenborg 2015.



Fig. 2. The Belterra Plateau. By Per Stenborg 2014. Background relief map is based on the SRTM 1 arc second DEM (NASA Jet Propulsion Laboratory (JPL) 2014).

Santarém–Belterra Region is also characterized by the relative proximity between riverine areas (by the Amazon and Tapajós Rivers and on islands; particularly in Amazon River) and upland areas on the Belterra Plateau (Figures 1 and 2).

Economy and subsistence

The economy of the late pre-Columbian Santarém society appears to have been primarily based on agriculture of domestic plants such as maize and manioc (cassava) (e.g. Quinn 2004; Roosevelt 1999). Some information suggests that their economy may have relied more heavily on maize than that of many other agricultural societies, including their northern neighbors the Konduri (Schaan 2012:112). Of relevance concerning subsistence and economy of the populations settled along the Amazon River as a whole, the 16th century chronicle by Carajál mentions maize and manioc (cassava, yuca), as well as fruits and nuts including chestnut; aquatic resources such as fish, turtles, manatees; birds, including parrots “ducks” and “hens” (Oviedo y Valdés 1855 [1549]). As might be expected, salt appears to have been in short supply

and was sometimes found in storage facilities.

Complementary production

WinklerPrins’ (WinklerPrins 2002) study of the Varzeiros population (Várzea is a particular riverine niche characterized by seasonal flooding) on the Ituqui island situated in the Amazon River approximately 30 km east (downstream) of Santarém City suggested that economies based on a combination of flood-recession agriculture on the island and seasonal upland (bluff) migration (as a second and different area for cultivation) observable in today’s society may have had an ancient origin. She also, however, described the present population as “smallholders who call themselves Varzeiros, residents of the várzea who have occupied the Ituqui region for at least several generations” (WinklerPrins 2002:2). This continuity, then, might only go back a couple of generations meaning that the subsistence pattern that WinklerPrins investigates could have emerged as recently as the 20th century. In its 20th century form, with significant reliance upon the production of imported plants (e.g. jute - *Corchorus sp.*), the varzeiros economy was undoubtedly a recent development. I think, however, that it would be unwise to dismiss the general idea that economies based on complementary use of riverine and upland resources and land have existed previously in the region. On the contrary this form of resource utilization may have played a critical role in the region’s economic and political development up to the time of European contact in the 16th century.

In her study of the present Varzeiros smallholders, WinklerPrins (2002:3) also noticed that the main growing season for maize and manioc on the soils seasonally flooded and nourished by the Amazon River falls between July and December. By contrast; on the uplands of the Belterra plateau seed may be sown at the onset of the rainy season, which today occurs in December or January and the growing season extends up to the start of the dry season in July or August. This means that the periods best suited for cultivation in the riverine areas and on the uplands cover almost opposite parts of the year and, accordingly, that there is potential for seasonal utilization of different ecological zones for agriculture.

A combination of agriculture practices in a dissimilar environmental zone may be compared to the “vertical” economies that emerged in various parts of the Andes (e.g. MacNeish 1977; Murra 1975). The “vertical archipelago” described and analyzed by Murra deals with cases of simultaneous occupation of areas at different heights — “floors” — in the Andes generally organized from a political center in the highlands controlling settlements situated at other altitudes. As the type of subsistence pattern found among today’s Varzeiros does not involve permanent, year-round, residence in the uplands or a hierarchy between settlements in the two environments; it is not analogous to the Andean examples of vertical economies. Murra (1985) underlines the importance of distinguishing between economies involving seasonal migration or transhumance and the kind of economies he refers to as vertical archipelagos. He also, however, points to the possibility that vertical economies historically emerged from migratory ones. Based on new archaeological data and early historical information there are good reasons to suggest that an economy organized in a manner resembling that of the vertical economies in the Andes emerged in the Santarém-Belterra region over the course of the last centuries before European contact.

Distribution of uniform material culture

A remarkably homogeneous material culture is found in the archaeological record of the Santarém-Belterra region dating from the centuries preceding European contact. The precise extension of the area of homogeneous material still remains to be determined, but recent surveys have found consistent archaeological material some 70 km south of Santarém city (Schaan 2013; Stenborg et al. 2012) as well as 50 km east of the city, confirming earlier information by Nimuendajú (Nimuendajú 2004; Stenborg 2009).

Initial European impact

It is likely that the European presence on the South American continent affected communities in the Amazonian hinterland already several decades prior to the event of the first direct encounter with the Europeans in 1541–42. The time from around 1500 up until the 1540’s may therefore

be considered to have constituted a period of indirect-, or proto-contact, between the aspiring European conquerors and the Amazonian societies.

The South American mainland on the peninsula of Paria (near the mouth of the Orinoco), as well as the islands of Trinidad and Margarita, were reached by Christopher Columbus on his third voyage in 1498 (Herrera y Tordesillas 1730a [1601-15]).

While the European presence in the Amazonian interior appears to have been minimal during the initial phase of the contact period, it is evident that a considerable number of European expeditions landed on the east coast of South America from the year 1500 onwards. To facilitate colonization, some of these expeditions left people from Europe behind (often convicts) to learn the local languages and become integrated with the local communities. Activities such as logging and transportation of timber (particularly Brazilwood, *Caesalpinia echinata*) from coastal areas back to Europe were launched by both the Portuguese and the French in the early 1500s (Hemming 1995:8–10; Metcalf 2005:19f). Rumors about meetings with Europeans, sightings of their ships and the often devastating outcome of confrontations with them must have spread far beyond the grounds where they took place and may even have given rise to some of the legends that were later recorded by European historians. Additionally, contagion would have had good potential to spread through networks, such as trade and communication routes along the Amazon and its tributaries. This may therefore have affected conditions decades before the first European traveled through the areas in question.

Orellana/Carvajal 1541-42

The famous expedition by Francisco de Orellana in 1541–1542 along the entire extension of the Amazon River – from the Andes to the Atlantic – resulted in a much debated chronicle written by a Dominican monk who participated in the journey: Gaspar de Carvajal. One issue concerning the authenticity of the chronicle has been the existence of two different manuscripts. One of these was included in the fourth volume of Oviedo y Valdés chronicle (Oviedo y Valdés 1855 [1549]) and the other was published by José Toribio Medina in the

late 19th century (Carvajal 1894). Harry Clifton Heaton, who edited an English translation of Medinas version, assumed that both versions were authentic — i.e. that Carvajal wrote his chronicle twice for different recipients (Heaton 1934). Although the differences between the two texts may be important and have been given little attention, there is considerable consistency between the two. Apart from Carvajal's apparent belief in real, rather than mythical, female Amazon warriors, researchers have questioned his description of large and densely populated settlements situated along the River, as well as his second hand reports of settlement systems that also extended inland and were connected by roads. These later claims were, nevertheless, supported by other early travelers such as Ortiguera (1909[1581–1586]), and have increasingly been substantiated through recent archaeological investigation and surveying (e.g. Heckenberger et al. 1999; Roosevelt 1999; Schaan 2012; Stenborg et al. 2012, 2014).

Carvajal described a political situation of “Señorios” (i.e. lordships, described in terms similar to those used for describing chiefdoms in other regions) covering the territories along the River with their borders often marked by fortified settlements (e.g. Oviedo y Valdés 1855[1549] vol. IV pp.545–567). Hence, at the time of the journey, such “military posts” appears to have guarded population boundaries; suggesting that some groups expanded territorially at the expense of others. Obviously things were not “standing still” as they were in the Amazon Carvajal describes. The extent to which the hostile relations between Amazonian populations arose as a result of the European rampage is difficult to evaluate – but it is clear from subsequent events that European action tended to deepen existing animosities. It is commonly assumed that a population decline resulting from the spread of diseases of the “Old World” mainly occurred in the years following Orellana's expedition. As pointed out above, it does not seem unlikely that the first waves of disease preceded Orellana's trip as consequences of the European presence in and around South America's eastern and northern coasts in the early 1500's and in the Andes from 1532 onward. Concerning the western and the central Amazonia, some information received by Carvajal

from locals indicates that strong ties had existed between populations of the Amazonian and the Andean regions. Some informants seemed familiar with stone houses, roads enclosed by walls and domestic animals resembling Andean cameloids (Ibid. p. 565). In the Machiparo Province, which is bordered in the east by the Omagua/Cambeba area — presumably by this time covering a vast region from Rio Napo to Rio Purus, the Spaniards were told that turtles were kept in special ponds (one village held as many as 1000 turtles in this manner) (Ibid. p. 553). Carvajal also described the populations in the easternmost parts as rougher and less civilized, but also increasingly affected by the European colonies to the east and north.

Most accounts dealing with the expeditions that followed Orellana (e.g. Uraúa/Aguirre 1560–1561 and Teixeira/Acuña 1637–1639) to some extent repeat details given by Carvajal. This gives the impression that the information resulting from Orellana's voyage was used by later authors as guidelines to structure and explain their own experiences.

Ursúa/Aguirre 1560–1561

In 1560 a group of disgraced conquerors were expelled from Peru and sent on an expedition organized by Pedro de Ursúa in search of El Dorado. In January 1561 Lope de Aguirre took control of the expedition through a plot leading to the assassination of Ursúa. Although opinions diverge, most historians suggest that this expedition only followed the Amazon River to the Rio Negro which they continued up until they reached the Atlantic via the Rio Orinoco. Nevertheless, Toribio de Ortiguera – the official chronicler of the expedition – describes the concluding part of the journey in his *Jornada del Río Marañón* (Ortiguera 1909[1581–1586]) in a way that indicates that this expedition may also have followed the full running of the Amazon (Marañón) River all the way to the sea. In all cases it seems reasonable to assume that information of the atrocities committed against the Native populations spread far beyond the areas directly subjected to the ravages of Lope de Aguirre and his party of 300 soldiers and 500 Natives from other parts of the Americas.

Neither Carvajal, nor the authors of

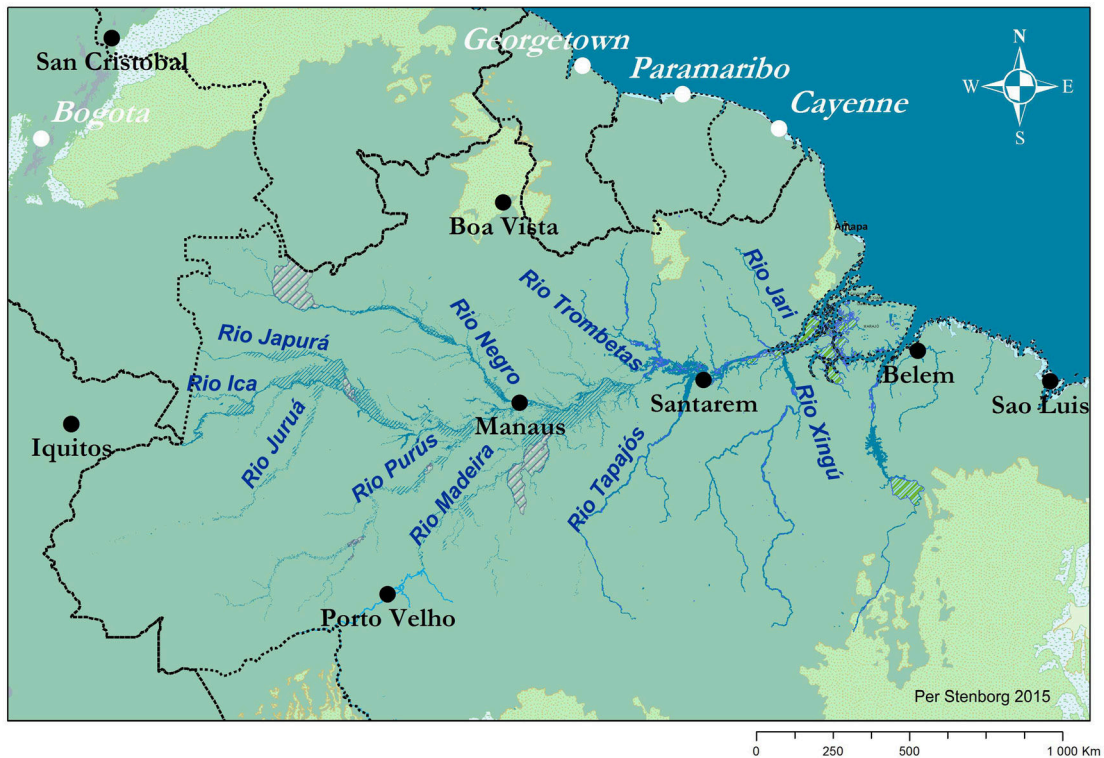


Fig. 3. Map showing the tributaries of the Amazon River. By Per Stenborg 2015.

the accounts of the Ursúa/Aguirre journey, showed much interest in regional history or in understanding the socio-cultural processes that had led up to the reality that they met during their expeditions along the Amazon. Notwithstanding, it appears evident from their accounts that societies practicing comparably large scale agriculture were still in control of large continuous sections along the Amazon River and several of its tributaries by the mid-1500s. Apparatus for storage and redistribution of products, as well as for transport and communication, were still maintained (e.g. Oviedo y Valdés 1855[1549] vol. IV pp. 556–558, 561–562; Ortiguera 1909[1581–1586] p. 341).

Teixeira/Acuña 1637–1639

Almost a century after Orellana, Pedro Teixeira lead a Portuguese expedition which crossed the Amazon in the opposite direction — from the Atlantic coast to Ecuador. This expedition was primarily undertaken as a reaction to the presence of other European colonial powers in the Amazonian inland (in 1637 two Spanish missionaries and a group of soldiers had travelled from Quito to Pará, an event that aroused Portuguese concerns regarding their own plans for

colonization of the region). For the return trip, the Spanish Jesuit Cristóbal de Acuña accompanied the Portuguese group. In his chronicle (2009 [1641]) Acuña frequently refers to Orellana's previous expedition, but it is uncertain whether he had actually read Carvajál's account. Several of the better known chroniclers (e.g. Garcilaso de la Vega 1966 [1609]; Herrera y Tordesillas 1730b [1601–1615]) had included shorter descriptions of the events in 1542 which may have served as sources for Acuña.

The fact that chroniclers often assumed that they describe a reality and situation that essentially had remained unchanged over centuries is a particular problem and means that we should pay attention to any hints about social, political and economic history that may hide behind the descriptions of such things as the 'nature' and attitudes populations displayed when encountering Europeans, as well as of their relationships to other communities. Studies of written sources indicate that sweeping social, economic and political changes occurred among the Amerindian communities during the 16th and 17th centuries. These changes are primarily to be interpreted as direct or indirect consequences

of European involvement. This, however, does not exclude the possibility that large and radical changes also occurred at other times during Amazonian history. Though our studies shows that remarkably radical changes occurred over the period A.D. 1300–1500, we may suggest, nevertheless, that developments prior to 1500 were of other types than those reflected through historical writings.

Description of the populations of the Santarém area and the Tapajós River

Carvajal's description of the latter part of Orellana's expedition contains little details about populations and societies. This was primary due to the fact that the expedition met strong resistance from local populations and often had to escape whole fleets of canoes. Carvajal had also been severely injured as an arrow hit his eye. Some confusion concerning dates and distances occur after this incident, which is why the more precise borders between Carvajal's provinces "La Punta de Sanct Johan" (The point of Saint John's Day) or San Juan (according to informants covering 150 leguas ruled by an overlord called Couynco or Quenyuc who served a queen named Coñuri) (Cavajal et al. 1934:219–221), to the east bordering on a province of "tall people" ruled by an overlord named "Arripuna" (Cavajal et al. 1934:223), and the "Provincia de la hierba" (Prov. of the Herbs) still further east, ruled by a chief "Ichipayo" (Cavajal et al. 1934:226), are difficult to decipher. The names have been preserved as Konduri (a term used for the archaeological complex found at sites in the area of Rio Nhamundá and Trombetas, two northern tributaries to the Amazon), Arrapiuns (a river branch in the east discharging into the Tapajós River, near its estuary into the Amazon), and Tapajós. A particular threat from the Provincia de la hierba (Ichipayo/Tapajós) and downstream was that populations used arrows prepared with a deadly poison (Oviedo y Valdés (1855 [1549] vol. IV, pp. 564–566).

By the time of Teixeira's double voyage through the Amazon in 1637–1639, several European countries had established colonies of their own along the stretch of the Amazon River. The Dutch had established a fort in the area of Gurupá in the early 1600s and had subsequently fought with

the Portuguese for control of the area situated east of the mouth of the Xingú. As a result of the expeditions of Thomas Roe in 1610 and Roger North in 1620, both English and Irish settlements had been established. Bernardo O'Brian, an Irishman who participated on North's expedition, founded an Irish colony between the Xingu and the Tapajós. He also continued upstream to a place which in all probability was near today's Santarém, where further westward movement was prevented by a particularly hostile population (O'Brian 1970 [1634]). This suggests that polities capable of putting up strong unified resistance remained in control of the Santarém–Belterra territory into the early 1630s.

While Acuña's account regarding the return trip of Teixeira in 1638–1639 has been published in many editions, archival information on the 1637–1638 outward voyage was published by La Espada (1889) and more recently by Cuesta (1993). A digital copy of the document kept in the archive of the National Library of Spain has since been made available online (Rojas, dated 1639). In this source the name "Estrapajosos" is used in reference to the populations in the Santarém–Tapajós Región: "Estos mismos soldados y dos religiosos, cuando bajaron el río, llegaron a unas muy dilatadas provincias, cuyos habitantes llaman los portugueses los Estrapajosos" (Ibid. P. 21). Oviedo y Valdés (1855 [1549] vol. IV p. 389) already mentions two similar names; "Topayo" and "Rapio", which according to this author were the names of two chiefs whom were subjects to the Queen Conori (Coñuri). In the version of Carvajal's chronicle published by Medina and Heaton, the chief of the "Province of the Poison" is named "Ichipayo" (Carvajal et al. 1934:226). Acuña (2009 [1641]:154) employs the name "Tapajosos" for both the population and the river. The Tapajós group was still feared for their use of poisonous arrows up to Teixeira's and Acuña's voyages in 1637–1639. In 1639 they were subjugated by the Portuguese Sergeant Benito Maciel (Acuña 2009 [1641]:155).

Development of the floodplain-hinterland relationship

As mentioned above, WinklerPrins (2002) studied contemporary examples of complementary

subsistence patterns based on seasonal migration between the floodplain and upland areas in the Santarém region. She suggested that similar economies may have prevailed in this area prior to European contact. The primary basis of such economies would be flood-recession agriculture, while the seasonal occupation of upland areas would have been complementary.

In the case of the Varzeiros the upland sites were usually located some 10 to 15 km away from the Amazon River. A site such as Bom Futuro is about three times that distance from Santarém City; while sites with ceramic in a Santarém-style have been found as far as 60 km south of the city (Schaan 2013). The easiest way to go from Santarém to many of the sites situated on the Belterra Plateau would have been to travel up the Tapajós River, which would reduce the distance that had to be covered overland considerably. Possibilities to stay in contact with a “home” settlement located in the area of today’s Santarém City would have been problematic during the rainy (i.e. the growing-) season – particularly as a consequence of the inundation of water which also hampers communications today due to frequent interruptions of the region’s road system. Seasonal migrants to agricultural settlements on the Belterra Plateau would have faced periods of isolation; land transportation of produce and tools would have been considerably easier after and before the actual growing season. Therefore one driving force behind the development of permanent settlements on the Plateau may have been a need for more efficient and reliable use of the area for rainy season agriculture, also requiring presence of settlers over the dry season. Furthermore, the competition between neighboring lordships and populations described by Carvajal; which might have included questions of control over inland resources, could have increased the need for permanent presence in such areas.

Carvajal also described a place that he interpreted as a repository of primary as well as processed products. According to Heaton’s estimations this place was situated between the mouths of the Madeira and Tapajós tributaries, near Rio Uatumã (Heaton 1934:48). This suggests that an organized management of goods and products existed at a level above that of the

individual villages.

“Sinkholes” on the Belterra Plateau

The Belterra Plateau — situated south of present day Santarém city and east of the Tapajós River — form an upland area characterized by its considerable “flatness” and an absence of permanent watercourses (Figure 02). The lack of water supply during the dry season, as well as frequent inundations during the rainy part of the year constitute difficulties that residents here have had to cope with through all times.

A hitherto overlooked factor of critical importance for human settlement on the Belterra Plateau is the frequent occurrence of sinkholes or “enclosed depressions” (Figure 04). Such formations are the result of the presence of deep underground drainage which can dissolve underlying rocks and undermine bedrock. When layers above sink down to fill voids formed through water dissolution and transportation, depressions may form in the landscape. The depressions found on the Belterra Plateau vary in size and shape — some measuring more than 200 m across with others considerably smaller. Once formed, the filtering of surface water through the upper soil layer of these depressions results in a process of slow leaching that leads to the formation of a superficial layer of fine-grained clay of low permeability known locally as Tabatinga. Hence, over time the capacity of these depressions to retain water will increase. Of great importance here, therefore, is that these natural processes produced natural reservoirs in an area where water is otherwise a scarce resource during the dry season.

Our investigations at a number of sites on the plateau, as well as our previous surveys and the recording of more than 110 sites in the Santarém – Belterra regions, suggests that people settling on the plateau in pre-Columbian times chose to locate their settlements in areas where depressions of the type described above are met with. Important limitations of our work have been that it has been restrained to areas outside the Floresta Nacional do Tapajós (FLONA), and that the initial surveying was undertaken as part of rescue archaeological work related to a major road construction project, the BR-163, and



Fig. 4. Two examples of large depressions at Ramal do Funil (left) and Bom Futuro (right). Photo by Per Stenborg.

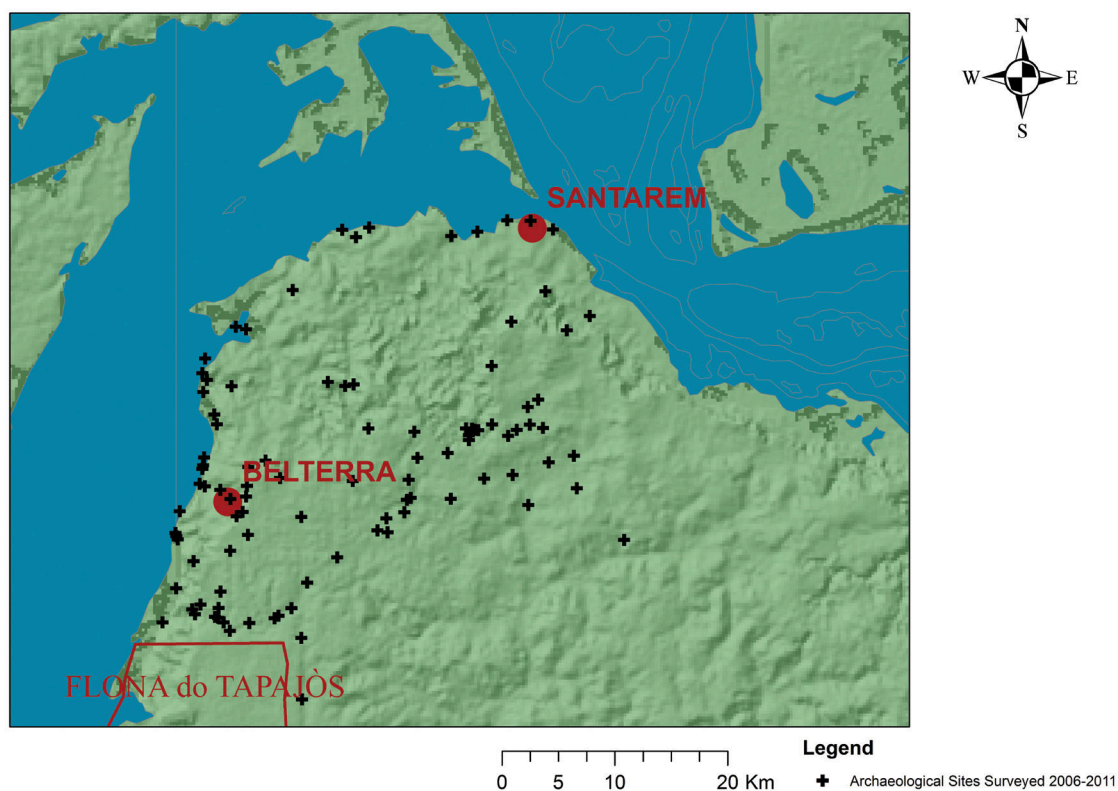


Fig. 5. Distribution of the sites encountered during the surveys 2006–2010. By Per Stenborg. Background relief map is based on the SRTM 1 arc second DEM (NASA Jet Propulsion Laboratory (JPL) 2014).

therefore primarily focused on the areas directly or indirectly affected by this exploitation. In spite of these limitations, 112 sites were located in surveys between 2006 and 2010 (Figure 05). Only 26 of these sites are situated within a distance of 1 km from either the Amazon or the Tapajós River banks while 50 % of the sites are located 10 km or more away from the rivers.

Water management at a local level

Our investigations have revealed that, apart from

these natural supplies of water, smaller ponds were constructed within the confines of settlements and may have been managed by particular households or groups of households at an organizational level below that of the village (see Stenborg, this volume).

Dates and temporal relationship between Upland and Riverine settlements

Dates from large riverine settlements, particularly the Porto site in Santarém, suggest that some

of these areas may have been inhabited by human populations over several millennia. An intensification of human activity is seen around A.D. 1300; over the following centuries this development led to the establishment of a large population center in the riverine area of present day Santarém city and the emergence of a characteristic material culture (the Santarém pottery complex or phase) (Gomes 2002; Quinn 2004; Schaan 2012, see also Schaan, this volume).

Less has been known about the age of settlements in the upland, or hinterland, — although reports of such settlements became known through the fieldwork of Curt Nimuendajú in the 1920s (Linné 1928; Nimuendajú 1949, 2004; Nordenskiöld 1930; Palmatary 1939).

The new dates from these settlements indicate that permanent occupation of areas on the Belterra plateau emerged much later than those along the Amazon and Tapajós Rivers. The settlements seem to have been the most extensive during the centuries that preceded the European arrival, while many settlements may have remained inhabited well into the contact period.

Analyses of samples from three sites (Bom Futuro, Amapá and Cedro) all situated on the Belterra Plateau have yielded consistent results indicating that occupation of these sites began in the about A.D. 1300 and continued into the 17th century (Stenborg et al. 2014, see also Stenborg, this volume).

Discussion of the implications of our result

In terms of the Santarém region our results substantiate early historical claims that not only were the riverine areas inhabited, but that a significant population also lived inland. The historical sources tell us nothing about the time-period in which the establishment of the interior occurred, but through dating of archaeological material from sites on the Belterra Plateau (pottery and charcoal) we have been able to show that this expansion most likely took place over the last few centuries before the European arrival and therefore in a late stage in the history of human presence in the Santarém region. Equally important, however, is the conclusion that this expansion period was part of the region's pre-Columbian history.

These inland settlements may at a later stage

— and as an outcome of increasing European involvement — have gained other significances. They would have offered populations the option to stay away from the rivers and thus avoid risky dealings with the various European colonial powers that sought to gain control of the region, but mainly stuck to the rivers.

Concerning the depressions of varying sizes found in the region — these are today locally referred to as poços (or poços de água) — i.e. wells. It may be recalled that the same term was used by Carvajal to describe ponds in western Amazonia (in what he named the Machiparo-province, which bordered on the region of the Homaga [Omagua/Cambeba]) in the east (Oviedo y Valdés 1855 [1549]). The riverine Machiparo population used these ponds to store living turtles — suggesting that ponds could serve purposes other than those directly linked to human water supply. Although limited access to water during the dry season in an inland area such as that on the Belterra plateau strongly suggests that the main function of water reservoirs was that of providing the possibility of permanent residence, it should be noted that access to water during other parts of the year was much better and it should therefore not be ruled out that these depressions/reservoirs may also have served several purposes.

Reflections on the relation between regional and supra-regional perspectives

In this context it is necessary to consider the limitations of any strictly regional periodization. A region's history is linked to a variety of “internal”, as well as “external” factors. Above all, history takes place in interaction with surroundings. To Amazonia, where interregional contacts are reflected by material culture (e.g. ceramic traditions); this may apply to an even greater extent than to many other parts of the earth (also, of course, recognizing the fact that the whole basin is interconnected through waterways). There is certainly also a variety of indications suggesting some forms of connections between pre-Columbian cultures in Amazonia and those existing in other parts of South America, as well as on the Caribbean islands (or West Indies); although the nature and temporal scope of these connections still remain relatively poorly charted

and differentiated. Acknowledging the partiality of a regional periodization and its limited ability to encompass causal relations beyond the extent of the region; there are still plenty of arguments favoring the development of such periodizations:

- Given the size of the Amazon Basin (c. 6.915.000 km²) and its often overlooked geological and ecological diversity; it should come as little surprise that research based on data from one part, or region of Amazonia, arrives at conclusions that contrast sharply to those based on data from other regions. The longstanding dispute as to whether — or not — socio-politically complex societies existed in the Amazon prior to the European arrival can partly be deduced from this diversity and variation (e.g. Meggers 1954, 1992; Roosevelt 1999). This dichotomy has hampered the development of regionally substantiated models of Amazonian (pre-) history by nourishing notions of a pan-Amazonian homogeneity; something which essentially lacks empirical support. (The mentioned dichotomy can — of course — also be regarded as a conflict between evolutionary and cyclical understandings of history.)
- While the wide distribution of stylistic traits of pottery shows that societies in various parts of Amazonia influenced one another in some way, this does not mean that those societies as wholes must have been very similar. Quite different societies may well affect and influence each other; while at the same time preserving many of their differences. As regards Amazonia; it is of particular importance to develop chronologies and periodizations that consider parameters beyond those directly related to ceramic typologies. Such factors may be forms of production, settlement structures, technology and so forth.
- Despite its limited geographic scope; a regional periodization should, as far as possible, consider external and interregional factors as relevant for the history of the region in question. This is obvious when dealing with regions directly affected by for example the Roman

expansion in Europe or the Inca expansion in the Andes. Even in such cases, however, the regional situation during the time of the expansion cannot be described in a satisfactory way as merely an outcome of the expansion itself. When comparing the Santarém region with a neighboring region such as that by the confluence of Rio Negro and Rio Amazon (Rio Solimoes) further west (in the Central Amazon) (Heckenberger et al. 1999; Petersen et al. n.d.) a diachronic picture emerges as regards the way that human activity is reflected through series of dates from the two regions. Petersen et al. (n.d.) convincingly associate the Modeled-Incised or Incised Rim Complex in the Negro/Solimoes region with the timespan from c. 360 B.C. to c. A.D. 850; a period almost devoid of dates in the Santarém region (cf. Quinn 2004; Schaan 2012b). The fact that the two regions appear out of phase may well reflect a shift or drift, over time, concerning the economic importance (or prosperity) of the two regions. Thus Schaan's use of center-periphery model has obvious empirical support (Schaan, this volume). A shift of the position of the epicenter would have taken place as the previous peripheral Santarém Region established itself as a center in terms of economy, political power and population density. This shift, however, was only possible through the development of new and innovative technologies for water management, agriculture and networks of communication and logistics. Notwithstanding; the period of the dissemination of the Santarém-phase pottery across the Santarém region (c. A.D. 1300–1500) (Quinn 2004; Schaan 2012a, 2012b, this volume) seems partly contemporary with the emergence of the "Guarita" ceramic complex in the Negro/Solimoes region (c. A.D. 900–1440) (Petersen et al. n.d.). Regional models should not be seen as incompatible with inter-regional or global models; but as a complement to and resources for further

development of such broader models.

Outline of a regional chronology and periodization

The following is an outline of a regional (sub-) periodization covering the period from c. 500 up to Colonial times (approximately corresponding to the era of the pan-Amazonian Incised-Punctuated macro tradition) in the Santarém-Belterra area

While a considerable number of dates suggest that humans may have been present in the Amazon Region as early as Late Pleistocene (Miller 1987, Roosevelt et al. 1996), the record becomes more solid concerning Early Holocene occupation; even suggesting that an early intensification in respect of such activity could have occurred during the eleventh millennium before present (Bueno 2010; Miller 1987, Roosevelt et al. 1996).

In the Santarém Region, dates of material associated with cultural layers excavated in the Caverna da Pedra Pintada, a sandstone cave situated approximately 70 km North-east of Santarém on the northern side of the Amazon River, suggested that it has been inhabited by humans for several periods. The earliest covers the period from about 11.000 B.P to 10.000 B.P. (9.000–8.000 B.C.) (Roosevelt et al. 1996; see also Kipnis et al. 2005; Schaan 2012:12–13).

Of primary importance to the topics discussed in this article is an intensification in human activity that appears to emerge in many parts of the Amazon by the middle of the first millennium our era: approximately A.D. 600 according to several series of radiocarbon dates (e.g. Brochado et al. 1969; Heckenberger et al. 1999; Hilbert 1962, 1968; Petersen et al. 2004; Perota 1992) and associated with, for example, the Marajoara pottery from the Amazon estuary and the Manacapuru pottery in the Central Amazon. Strikingly, this intensification is not evident in dates from the Santarém Region, where only a couple of dates exist for this period (see Schaan, this volume). Quinn (2004) published 16 dates acquired from samples taken from the Riverine Porto site in Santarém. 14 of these fell within the time period 1300–1550, while two were dated to the last millennium B.C. Six radiocarbon dates on material from our excavations at the Bom Futuro site on the Belterra Plateau all fall within

the period A.D. 1300 to 1550 and thus show that Bom Futuro was inhabited during the period in which the Porto-settlement expanded into a large centra-site. The OSL-dates from Bom Futuro reinforce the image of an occupation of the area concentrated to the last two centuries before European contact, but also suggests that the area may have remained populated during the Contact Period (1542–1639).

In the Santarém-Belterra Region the relative scarcity of dates from the middle of the first millennium is followed by a period of evident and ample increase in human activity in the area. From about 1300 A.D. up to the time of contact with the Europeans, at least one large population centra emerged in riverine settings (Santarém) and systems of settlements — some of them sizable — were established on the Belterra Plateau, probably also at node-locations along the communication routes between riverine settlements and hinterland (Belterra) sites.

It is possible that particular geological and environmental conditions found in the Santarém-Belterra Region were of importance for a somewhat divergent regional development compared with the general trends that can be discerned through the archaeological record from surrounding parts of the Amazon. These divergent features include a later, but — on the other hand — more radical expansion of human settlement in late pre-contact times including a large-scale establishment in hinterland areas. It may be significant to note that in the Santarém-Belterra Region (as well as in the neighboring Konduri Region, north-west of Santarém, on the northern side of the Amazon River (see Schaan, this volume)) the pottery shows peculiar stylistic traits setting it apart from certain aesthetical conventions that are otherwise found widely distributed over large parts of the Amazon (and often referred to as revelatory of cultural interconnections) (e.g. Hilbert 1968; Lathrap 1977; Meggers and Evans 1957; Petersen et al. 2004). The initially mentioned relative proximity between riverine areas and upland areas which characterize the Santarém-Belterra Region may have slowed the construction of socio-political structures as the conditions for human settlement in different parts of the region are very contrasting. However, as the techniques of

water management, cultivation, production and transportation improved, the differences between the sub-regions, which also comprised potential benefits such as the prospects of gaining access to natural resources from different habitats and combining different growing seasons, appear to have turned into driving forces speeding up and increasing the process of expansion of populations and settlements in the hinterland. From about 1300 A.D. up to the 16th century this line of development, which reinforced the emergence of a regional organization (politically either segmentary or centralized in character) overshadowed other patterns of change that may have proceeded alongside it. Even so; this comparably newly established system was among the first to collapse as a result of the European expansion into this region in the 16th century.

An outline of a periodization for the segment of history during which a development towards an economy based on a combination of production in several environmental settings occurred in the region of study:

- **-A.D. 1300.** Before A.D. 1300, the region seems to have been a sparsely populated and peripheral area in relation to both the central parts of the Amazon to the west, and the coastal areas to the east. Populations mainly inhabited areas near the rivers

and flood-recession agriculture may have emerged as part of the economy.

- Over the period c. **A.D. 1300–1500** new forms of agriculture emerged, enabling an expansion of areas for permanent settlement to the Belterra Plateau. The period appears to have been associated with major transformations of the prehistoric societies, significant population growth and the development of new types of water management and agriculture.
- **c. 1500–1639.** As discussed above, the region was probably affected indirectly by the European arrival in South America also some time before the first direct encounter; which occurred in 1542. Hence, an abandonment of previously densely populated areas around the rivers and withdrawal to more secure inland areas may have commenced prior to this encounter. From 1542 onwards this development was accelerated.
- In early colonial times (**A.D. 1639–**) a gradual resettlement in river areas (partly in missionary villages or “Aldeas”) and increasing trade with Europeans occurred.

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Discussing Centre-Periphery Relations within the Tapajó Domain, Lower Amazon

Denise P. Schaan

Abstract

Ethnohistorical sources indicate that the Tapajó occupied a large area on the lower Amazon in the 16th century, the present day location of the city of Santarém. Curt Nimuendaju found 41 archaeological sites containing the same types of artefacts that were also found in the hinterland in the 1920s, attesting that the Tapajó dominated a much larger territory. In the past seven years, regional surveys, surface collection of artefacts, and excavations at selected sites have provided information on the extension of the Tapajó domain, from the riverside to the adjacent plateau, covering an area of about 2,000 sq km. Excavations in the Port site (in Santarém, the political centre), and in four plateau sites, revealed cultural features related to ceremonial and domestic activities, workshops, and chronology, allowing for comparisons between sites from different locations in the landscape. This paper compares centre and periphery sites, presenting some hypotheses on the Tapajó's regional organization.

Introduction

According to early travelers, on the eve of the European conquest a large region of the Amazon basin around the lower reaches of the Nhamundá, Trombetas and Tapajós rivers was occupied by culturally related indigenous groups (Carvajal et al. 2002). Scholars later documented the similarities between archaeological sites in the region, which are characterized by the presence of ADE (Anthropogenic Dark Earth) soils, ceramics of the Incised and Punctate tradition, and green stone objects (Barbosa-Rodrigues 1875; McCann et al. 2000; Nimuendajú 1949; Smith 1980). In

addition to the wide distribution of this ceramic tradition in the lower Amazon, similar styles occur in the Orinoco Basin and the Caribbean suggesting long term contact between these areas (Meggers and Evans 1961; Palmatary 1960). In the lower Amazon, two sub-styles of the Incised and Punctate tradition, called Santarém phase and Konduri phase, are believed to mark the presence of two distinct ethnohistorical indigenous groups: the Tapajó, located at the confluence of the Tapajós and Amazonas rivers where the city of Santarém today lies, and the Konduri, who lived at the mouth of the Trombetas River (Guapindaia 1993; Hilbert and Hilbert 1980). It is possible that they dominated these two areas which were also inhabited by other ethnic groups that are also mentioned in ethnohistorical sources (Bettendorff 1990 [1698]; Menéndez 1981).

Until recently scholars believed that the Amazon River was the main divide between Konduri and Santarém pottery styles, however, ceramics collected during surveys and excavations in the lower Tapajós River tell a different story. Konduri phase ceramics have been found in the hinterland south of the Amazon River, and Santarém ceramics have been found north of the Amazon in Monte Alegre (Roosevelt et al. 1996; Schaan 2012). More than 200 sites have been identified in the whole region, but there is still no working hypothesis on the social, political, and economic relations between all these sites. Although some attempts have been made to understand settlement patterns (Stenborg et al. 2012), and sites from different landscape locations have been studied, diagnostic types have been used to characterize sites as belonging to one or another phase. We clearly need more contextual ceramic

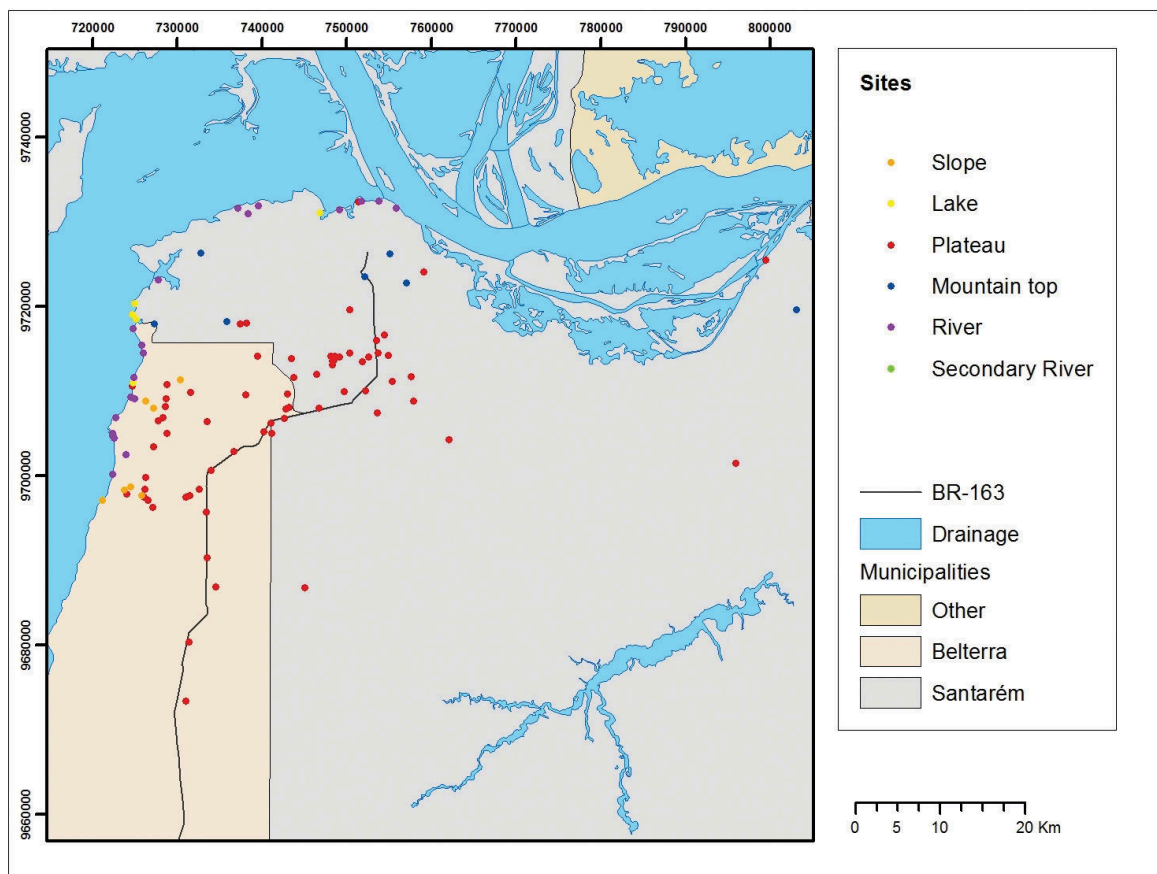


Fig. 1. Location of archaeological sites in the Santarém/Belterra region.

studies to understand cultural variability and to build hypotheses on social organization.

This paper aims to discuss relations between centre and periphery in the Tapajó area, where the diagnostic sherds of the Santarém phase prevails. In the last eight years we have conducted surveys and excavations in the Santarém lowlands and the Belterra plateau where we have identified 111 archaeological sites. Ceramics were collected from surface and test-pit excavations and later analyzed regarding their paste composition, decoration, and iconographic style. In this paper we compare data on ceramics collected from several sites and propose a hypothesis for the relationships between sites within the Tapajó domain.

Surveys, preliminary landscape archaeology data, and chronology

Systematic and non systematic surveys were conducted over an area of circa 12,000 hectares along the lower Tapajós River right shore, and the Belterra plateau. More than a hundred sites

| Location | Amount | Freq. |
|-----------------|--------|---------|
| Plateau | 68 | 62,96% |
| River | 20 | 18,52% |
| Slope | 7 | 6,48% |
| Mountain top | 7 | 6,48% |
| Lake | 5 | 4,63% |
| Secondary river | 1 | 0,93% |
| Total | 108 | 100,00% |

Table 1. Landscape location of archaeological sites in the Tapajó area.

were located, most of them impacted by modern towns, farming, pasture, and roads. The state of preservation imposed limits on our ability to measure and estimate both the site size and the depth of the archaeological strata. Based on geomorphological features of the site locations we were able to determine five categories of sites: riverine, upland, mountain top, slope, and lake side (Figure 1, Table 1).

Wells were identified at 27 sites, 26 of them situated on the plateau and only one on the slope; 36% of the plateau sites have wells. Data for site size are available for only 31 sites, or about 28%

| No. | Site | Area (hec) | Location |
|-----|------------------------|------------|----------|
| 1 | Aldeia/Porto | 16,36 | River |
| 2 | Vila Americana | 7,80 | Plateau |
| 3 | Lavras 1 | 4,49 | Plateau |
| 4 | Cuiarana | 3,99 | Plateau |
| 5 | Comunidade Terra Preta | 3,26 | Plateau |
| 6 | Boa Fé | 2,11 | Plateau |
| 7 | Jacú | 2,05 | Plateau |
| 8 | Lavras 7 | 1,94 | Plateau |
| 9 | Lavras 9 | 1,92 | Plateau |
| 10 | Lavras 4 | 1,70 | Plateau |
| 11 | Guaraná | 1,66 | Plateau |

Table 2. Site size and location of the 11 largest archaeological sites.

| Lab. No./ Sample | Location | Site | Prov. | Radiocarbon Convenc. Age | Cal 2 Sigma |
|------------------------|----------|------------|------------------------------|-----------------------------|--------------------------------------|
| Beta-324176 AMP-001 | Plateau | Amapá | Unit 1 - 70-80 cm | 300 ± 30 AP | Cal AD 1490-1600 Cal AD 1610-1650 |
| Beta-324178 BFT-001 | Plateau | Bom Futuro | Unit 1 - 20-25cm | 350±30 AP | Cal AD 1450-1640 |
| Beta-324192 CDR-001 | Plateau | Cedro | Unit 1 - 18 cm | 550 ± 30 AP | Cal AD 1320-1350 Cal AD 1390-1430 |
| Beta-324193 CDR-003 | Plateau | Cedro | Unit 3 - Trench 1 - 23 cm | 240 ± 30 AP | Cal AD 1640-1670 Cal AD 1780-1800 |
| Beta-324179 FDS-002 | River | Iruçanga | Unit 2 - 150-160 cm | 1220 ± 30 AP | Cal AD 690-750 Cal AD 760-890 |

Table 3. Chronology for four plateau sites.

of them. Site size varies between 0.01 and 16 hectares. The largest site is Porto/Aldeia¹, located at the Tapajós river mouth. The 2nd (7.8 hec) to the 11th (1.6 hec) largest sites are located on the plateau. Sites measuring less than 1.4 hectares are located by the river, on the plateau, on the slope, or by a lake (Table 2).

Surface collection of artifacts was performed where possible. Some sites were so impacted by constructions and the removal of the anthropogenic soil that surface collections only produced a few sherds, none of them diagnostic. We were able to collect ceramics from 59 sites, however, only 20 of them allowed for a sample of more than 70 sherds.

Seven sites were excavated: the site of Porto (the largest one), and six plateau sites of different

sizes (Amapá 1, Bom Futuro, Cedro, Iruçanga, Miguel das Freiras, and Tabocal). Porto and Cedro were more intensively excavated; similar features were found here such as prepared floors, bell-shaped garbage pits, and urn burials of crushed bones. Ceramics collected from all sites were very similar and affiliated to the Incised and Punctate tradition. The presence of typical zoomorphic adornos, fragments of figurines, and mat-impressed ceramics at almost all sites also reinforces the idea of close ties between Santarém (Porto site) and the plateau sites.

Chronology shows that the Porto site was occupied earlier than the plateau sites. The calibrated dates for the Tapajó occupation of the Porto site fall within the interval between 900 and 1600 AD. Dates between cal AD 1320 and 1650 for the Bom Futuro, Amapá, and Cedro sites suggest that the Tapajó were expanding throughout the plateau. The early date for the site of Iruçanga (690–890 AD) implies that some sites

1. Porto and Aldeia were registered as two separate sites because they were partially separated by a small lake in the past, despite both of them constituting the Tapajós main settlement in Santarém.



Fig. 2. The three types of vessels identified by Barata: (A) caryatid vessel (height: 19 cm; MAE/USP); (B) neck vessel (height: 18,9 cm, MPEG); (C) globular vessel (MAE/USP).

might have been occupied in a pre-Tapajó period (Table 3). In the Porto site, there are dates that go back to 3,000 PB that are also related to a pre-Tapajó occupation (Alves 2012).

In conclusion, it seems that the Tapajó first occupied the river mouth and later expanded their settlements to the plateau, probably looking for farming land.

The Incised and Punctate Horizon

In a 1961 article, Meggers and Evans offered an “experimental formulation of horizon styles” for the tropical forest. Horizon style, after Kroeber, was defined as “one showing definably distinct features, some of which extended over a large area” (Kroeber 1944, cited by Meggers and Evans 1961: 372). Among the four horizon styles proposed², the incised and punctate occupy a late position and is found distributed over a large area including the Orinoco and Amazon River basins, as well as the Brazilian and British Guianas. Its main characteristics are the use of incision, punctuation and modeling; filling of areas with parallel incised lines; the use of zoomorphic and anthropomorphic adornos; and red slipping (ibid., 381). According to Meggers and Evans, the Santarém style excelled in the modeling technique used for vessels’ adornos.

Among the few attempts made to classify vessel forms for the Tapajó style, Barata’s is the most useful and has been adopted by archaeologists and museums (Barata 1950, 1953a, 1953b). He identified three main types of vessels: caryatid, neck, and globular (Figure 2). These vessels are richly decorated with incision, painting, and profusions of zoomorphic and anthropomorphic

appendages and appliqués. Because they are so patterned, the identification of its broken pieces among collections is easy, thus such sherds can be considered to be diagnostic of the style.

Konduri ceramics have been less studied and are frequently compared to Santarém ceramics (Guapindaia and Lopes 2011; Hilbert 1955). Surface collections and excavations provided the bulk of material for ceramic analysis, with only a small number of entire vessels. Carelessly executed incised lines (in a fish bone style), nubbins next to rims, rudimentary adornos, profuse punctuation, and the absence of painting are the most notable characteristics (Hilbert 1955:32). Hilbert identified two sub-styles among the Konduri ceramics: the true Konduri, and the globular style. The globular sub-style is identified by modeled rim adornos decorated with incisions and perforated nubbins, some of which could have been handles (ibid., 65–66). Such adornos are probably zoomorphic, but there are insufficient details to identify the animal. The general appearance is of a little globe to which other half globes are attached.

Both Konduri and Santarém ceramics are tempered with a freshwater sponge called cauxi. The higher amounts of cauxi temper in the Konduri ceramics also distinguish it from Santarém’s.

Ceramic Analysis

We analyzed the ceramics collected from 58 sites³, excluding the Cedro site which is currently under analysis. Ceramics from all sites were subjected to the same type of analysis. Ceramics from the Porto site were part of a different project and were not analyzed for temper, only for decorative technique.

2. Zone-Hatched, Incised Rim, Polychrome, Incised and Punctate.

3. For the quantitative analysis, we did not use data from sites with less than 70 sherds.

Temper

Sherds were observed using a magnifying microscope in order to identify temper materials. Cauixi and grog are the main temper materials (cauixi alone or cauixi with grog). They are sometimes found mixed with crushed hematite, sand, caraipé, and charcoal in different combinations. Data for 18 sites are organized in Table 4.

Table 4 shows that although cauixi is present in the ceramics of all sites, the amount of cauixi varies since it is often mixed with other temper materials meaning that either a mixture was a preference or cauixi was not available in the amount needed.

If we split the sample between plateau sites on one hand and riverine/lake sites on the other, it is possible to notice that the use of grog in the mixture with cauixi is more common on the plateau than next to rivers and lakes. This is probably because cauixi is collected in river and lakes and therefore availability in the plateau demands traveling to the shore to obtain it or trade with riverine peoples. Figures 3 and 4 illustrate this point by comparing sites regarding the frequency of temper materials.

Although the use of cauixi is common in all ceramics, as a cultural marker its use decreases as

one moves away from the sources (rivers and lakes), suggesting that availability was determinant when choosing a ceramic temper. The use of cauixi in the plateau implies a close connection to riverine people, either from travelling to the river and lakes or trading with them to obtain the desired temper.

Surface treatment and decorative methods

Very often more than one decorative technique is found on a single ceramic sherd. The decorative technique of each sherd was recorded in a spreadsheet. Initially, the presence of two different techniques was recorded as one, for example, red slipped and punctation. This generated a very large number of combinations which made it impossible to compare one site to another. So we tabulated the data again recording each technique separately; for example, one sherd decorated with orange slip, grooving and incision was recorded three times, as orange slipped, grooved and incised.

For each site we tabulated the frequency of each decorative technique. For example, although the Bom Futuro site had 187 decorated sherds, counting decorative techniques individually gave us a 205 sample size, as Table 5 shows.

| No. | Site | Cauixi (%) | Cauixi & grog (%) | Cauixi & other (%) | Other (%) | Amount of sherds | Site location |
|-----|------------------|------------|-------------------|--------------------|-----------|------------------|---------------|
| 1 | Caxambú | 43,68 | 6,90 | 47,13 | 2,29 | 87 | Lake |
| 2 | Cajutuba 1 | 39,02 | 8,54 | 37,81 | 14,63 | 82 | River |
| 3 | Ram. do Limão | 38,32 | 36,86 | 20,04 | 4,78 | 274 | Plateau |
| 4 | Iruçanga | 33,23 | 20,43 | 43,60 | 2,74 | 573 | River |
| 5 | Km 42 | 32,93 | 38,21 | 27,23 | 1,63 | 246 | Plateau |
| 6 | Murarema | 29,94 | 8,38 | 28,15 | 33,53 | 167 | River |
| 7 | Amapá 1 | 29,50 | 31,78 | 37,20 | 1,52 | 1051 | Plateau |
| 8 | Amapá 2 | 25,58 | 50,00 | 21,51 | 2,91 | 172 | Plateau |
| 9 | Vila Americana | 24,55 | 35,33 | 38,33 | 1,79 | 167 | Plateau |
| 10 | Genipapo | 24,1 | 63,86 | 12,04 | 0,00 | 83 | Plateau |
| 11 | Santa Maria 1 | 22,89 | 40,96 | 33,72 | 2,43 | 89 | Plateau |
| 12 | Mig. das Freiras | 20,33 | 34,51 | 43,64 | 1,52 | 1333 | Plateau |
| 13 | Barreto | 16,09 | 58,62 | 21,84 | 3,45 | 87 | Plateau |
| 14 | São Martinho | 15,69 | 27,06 | 57,25 | 0,00 | 255 | Plateau |
| 15 | Bom Futuro | 11,53 | 46,86 | 37,68 | 3,93 | 685 | Plateau |
| 16 | Tabocal | 7,92 | 40,93 | 49,53 | 1,62 | 1036 | Plateau |
| 17 | Zinha | 7,87 | 34,18 | 57,61 | 0,34 | 7227 | Plateau |
| 18 | Açuzal | 1,41 | 45,07 | 45,07 | 8,45 | 71 | Plateau |

Table 4. Frequencies of temper materials in ceramic samples of 18 sites.

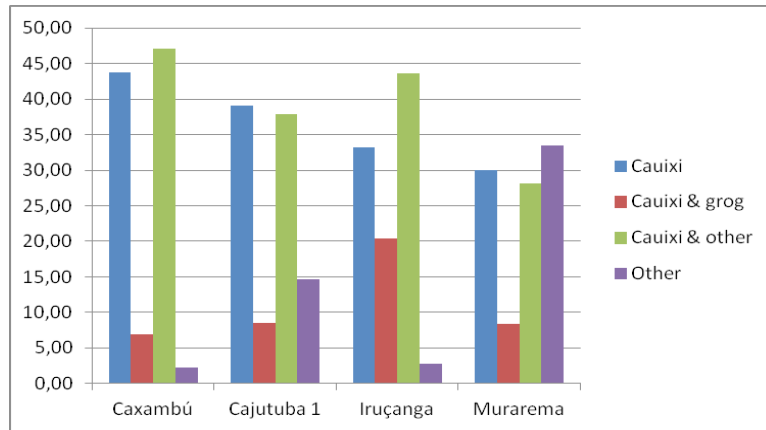


Fig. 3. Proportions of temper materials in sherds collected in four riverine/lake sites. Note that the use of grog (in red) is in lower frequency compared to other tempers.

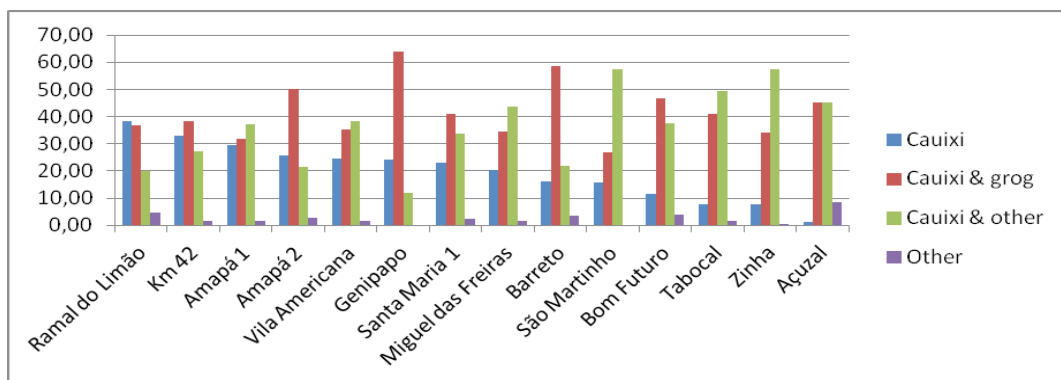


Fig. 4. Proportions of temper materials in sherds collected in 14 plateau sites. Note that the use of grog (in red) is in high frequency.

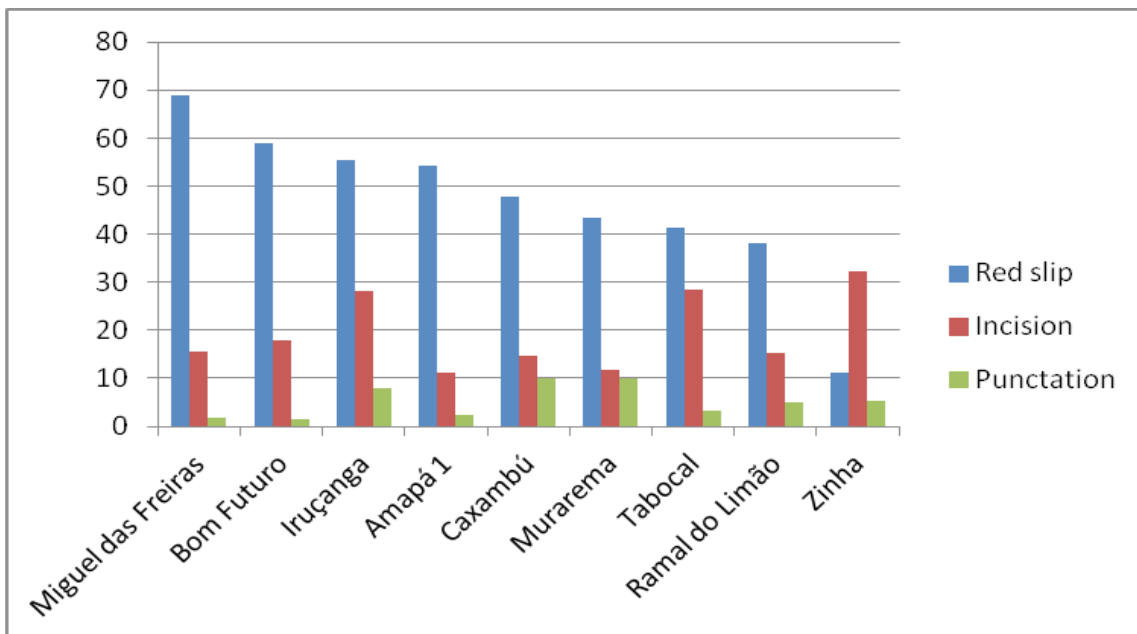


Fig. 5. Comparison between nine sites regarding the three main decorative techniques.

| Decorative technique | Amount | Freq. | | Incision | Red slip |
|----------------------|--------|--------|--------------------|----------|----------|
| Red slip | 121 | 59,02 | No. of Cases | 9 | 9 |
| Incision | 37 | 18,05 | Minimum | 11,05 | 11,24 |
| Modeling | 35 | 17,07 | Maximum | 32,35 | 69,01 |
| Grooved | 3 | 1,46 | Range | 21,3 | 57,77 |
| Orange slip | 2 | 0,98 | Median | 15,49 | 47,71 |
| Mat-impressed | 2 | 0,98 | Arithmetic Mean | 19,487 | 46,627 |
| Punctuation | 3 | 1,46 | Standard Deviation | 7,991 | 16,399 |
| Fillet appliqué | 2 | 0,98 | Variance | 63,853 | 268,925 |
| Total | 205 | 100,00 | Total | 205 | 100,00 |

Table 5. Amount of decorative techniques on Bom Futuro ceramic sherds.

That made it possible to compare sites regarding the proportions of decorative techniques used. The chart of Figure 5 compares nine sites regarding the proportions of red slip, incision and punctuation, the most prevalent decorative techniques.

We compared the number of cases for the incision and red slip techniques for the same nine sites as these were the two prevalent decorative techniques that mark important differences between Miguel das Freiras and Zinha sites on each end of the chart. Table 6 shows the descriptive statistics for the two techniques.

Incision is found on average in 19.48% of the samples, while red slip occurs on average in 46.63% of the samples. The standard deviation for the red slip sample is almost double the standard deviation for the incision sample. That means that incision has a more homogenous distribution across all

Table 6. Descriptive statistics for the occurrence of incision and red slip (in %) in nine archaeological sites.

sites, while red slip, although in high numbers, has a more heterogeneous distribution. As a result, red slip can be used as a marker to measure differences between sites in their ceramic assemblages. The sites of Zinha, Miguel das Freiras and Amapá 1 appear to be very distinct from each other regarding the amounts of sherds with red slip and incision. The meaning of this is still unknown.

When we add more decorative techniques to our chart, we can see that the decrease of red slip is not related to an increase of any particular decorative technique. At all sites, except Zinha, red slip is the most frequent decoration. Incision was more important at Zinha (see Figure 6).

Finally, we examined the relationship between decorative technique and temper, but did not find any patterns that would point to a possible relationship between these two variables.

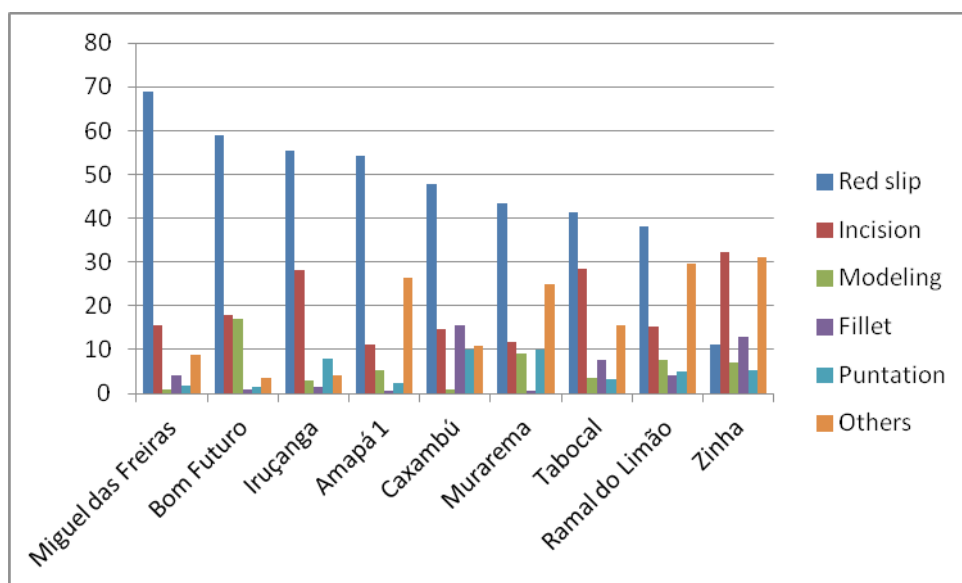


Fig. 6. Comparison between nine sites regarding the five main decorative techniques.



Fig. 7. Pottery figurines.



Fig. 8. Mat-impressed texture on pottery sherds.



Fig. 9. Parts of caryatid vessels.



Fig. 10. Modeled vulture heads from broken vessels.



Fig. 11. Hematite spindle whorls.

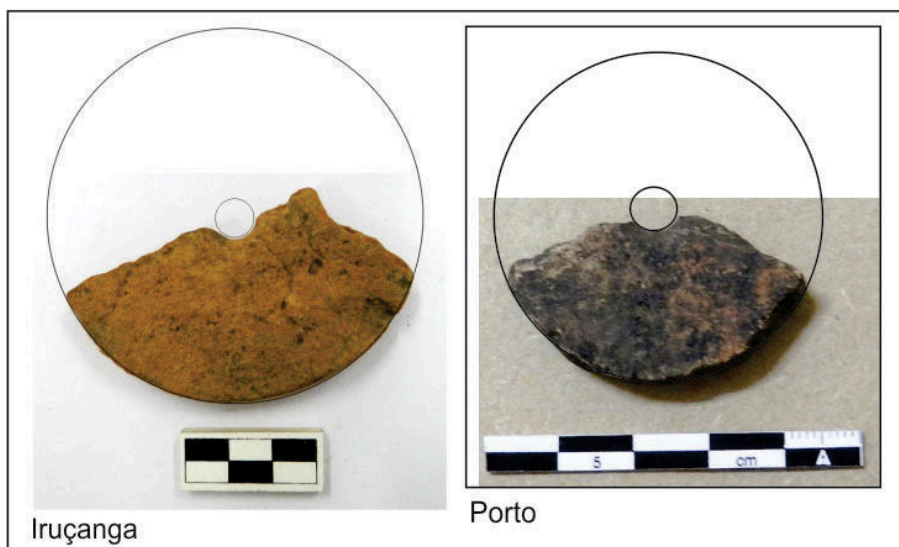


Fig. 12. Pottery spindle whorl from sites of Porto and Iruçanga.



Fig. 13. Globular style adornos.



Fig. 14. Incised decoration fish bone style (Barreto site), and profusion of punctation (Iruçanga site).

Vessel type, typical objects and style

We have performed a qualitative comparison between sites regarding the presence of diagnostic traits of Santarém, konduri and globular styles.

Fragments of figurines were present at 19 sites, including the Porto and plateau sites (see Figure 7). They are very similar and can be compared to typical Santarém figurines found in museum collections (Corrêa 1965; Gomes 2001).

Mat-impressed ceramics, another characteristic of Santarém pottery, were present at 13 sites (Figure 8).

Parts of caryatid vessels were present at 17 sites (Figure 9).

Vulture heads, usually part of a neck vessel or a caryatid vessel were also very common in the Porto and other plateau sites (we do not have quantitative data on their occurrence) (Figure 10).

Spindle whorls were found at 18 sites, most of them a hematite disk decorated with fine line incisions forming spirals and delimitating hatched fields. Plain pottery disks were also common (Figures 11 and 12).

The little rim adornos found at five sites (Amapá 1, Barreto, Bom Futuro, Ramal do Limão and Santa Maria 1) are typical of the globular style which was first identified in the Konduri area and has been

reported in museum collections where Santarém material predominates (Figure 13).

Influence of Konduri style was noticed at four sites (Barreto, Iruçanga, Murarema and São Martinho), in the form of profuse punctation and fish bone incisions (Figure 14).

Summary of results from ceramic analysis

Our surveys indicated the presence of Santarém diagnostic sherds at 74 sites. The analysis of ceramics collected at 58 sites showed: (1) differences between sites regarding the amount of cauxi used; higher in riverine and lake sites; (2) differences between sites regarding preferences for one or another decorative technique which was emblematic of the preference for incision at the Zinha site and red slip in Miguel das Freiras site; (3) similarities in the iconographic style of figurines, adornos, and diagnostic vessels and sherds; (4) absence of a clear hierarchy between sites regarding potters' skills.

Ceramics at the Porto site are not higher in quality when compared to plateau sites. Excavations at the Cedro and Porto site show similar features, despite differences in site size.

It is possible that a study focused on domestic vessels would establish other terms for comparison and help to understand the daily activities that could count for differences between settlements.

Conclusion

According to Roosevelt's interpretation of ethnohistoric sources, ceramic iconography, and settlement patterns, the Tapajó was a "warlike complex chiefdom", with a "moderately centralized political hierarchy that claimed some tribute" (Roosevelt 1999:27). Chronicles written by Friar João Felipe Bettendorff (1990 [1698]), a jesuit friar who built the first Mission at the mouth of the Tapajós River in 1669, and Maurício de Heriarte (1964 [1663]), a judge who visited the mission a year later, do not support such interpretation however. Archaeological data remains the only reliable source to access the Tapajó's social organization.

Our survey data suggests a site size hierarchy, where Porto/Aldeia is the largest site and perhaps an important center. Other large sites are found on the plateau, where our surveys located sites of different sizes. Some sites are located very close

to each other, such as the Lavras cluster, and can therefore be interpreted as large villages or groups of villages.

Site location can account for functional differences between villages. We suppose that settlements on the plateau produced crops and cloth (presence of spindle whorls), while sites at rivers and lakes were fishing stations.

Ceramic analysis did not point to any hierarchy between sites. The widespread use of the same type of ceramics, despite local variability, indicates close ties between settlements. Ceramics collected at the Porto site are not technically superior or iconographically different from the ceramics used at other sites meaning that the “style” was not a prerogative of the assumed political center.

In other parts of the Amazon, such as Marajo Island, site size hierarchy is accompanied by a clear hierarchy regarding the use of festive-ceremonial ceramics and the use of secondary inhumation (Meggers and Evans 1957; Schaan 2005, 2008). Signs of stratification are clear. At the Tapajó's domain, however, feasting and ceremonies appear pervasive pointing to social equality and solidarity instead of a rigid hierarchy.

Carneiro had predicted that the process of chiefdom formation in the Amazon demanded environmental circumscription as well as social circumscription (Carneiro 1970, 1998). According to him, competition for the best agricultural lands at the *varzea* would produce stratification and centralization (environmental circumscription), while the defeated peoples would become subordinates since they had no place to settle in the hinterland (social circumscription). This was certainly not the case for the Tapajó. Agriculture was likely practiced both next to the river (in Porto/Aldeia) and on the plateau. There is also no evidence for dense sedentary settlements before the occupation of the river mouth. Both radiocarbon dates and the depth of archaeological strata suggest an initial occupation of the Santarém area followed by an expansion throughout the plateau.

Opposed to Carneiro's circumscription theory, Roosevelt suggests “that the existence of poorer *terra firme* rainforests around the floodplains might retard the development of political centralization and hierarchical social stratification by serving as a refuge for homesteaders reluctant to submit to strong, top down political authority” (Roosevelt 1999:19). It is possible that large inhabited areas would in fact retard the growing of demographically dense and centralized polities, which might have happened to the Tapajó.

Two hundred years before the European conquest, the Tapajó were growing in numbers and territory, but it is more likely that a social system based on exchange (between villages and long distance trade), feasting, religious rituals, and alliances against common enemies held settlements together. Economy likely depended on the work of farmers and fishermen who did not need a managerial government to organize production. Erickson (2006) argues that a political economy perspective usually denies agency to farmers, while making assumptions that are not always supported by archaeological and ethnographic data. As an alternative, he proposes a landscape archaeology approach and a historical ecology perspective.

We still need more data on landscape features (and their historical changes), and more excavations in selected sites of different landscape locations. A study of the domestic wares can also help to determine what kind of activities were performed at each site, as well as how the sites relate to each other. Geochemical and mineralogical studies of pottery sherds could also bring information about possible ceramic trade, as well as identify loci of production. For now, based on the available data, our hypothesis is that the Tapajó were not centralized and stratified, but were tied together by a built environment that involved a common cultural history based on specialization in economic activities, both internal and external exchange, and religious ritual.

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Well Builders of the Belterra Plateau, Lower Tapajós: Preliminary Data

Joanna Troufflard

Introduction

The recent increase in archaeological research in the Lower Tapajós region has demonstrated how this part of the Eastern Amazon was one of the most significant places in terms of the emergence of complex societies in the Brazilian Amazon. While most of archaeological research done in this region focuses on the study of settlements at the mouth of the Tapajós River and their material culture (Alves 2012; Gomes 2002, 2010, 2013; Gomes and Luiz 2011; Guapindaia 1993; Quinn 2004; Roosevelt 1989, 1993, 2009; Schaan and Alves 2015; Symanski and Gomes 2012), recent surveys in the Santarém region suggest many archaeological sites are also present upland (Schaan 2012, 2014; Stenborg et al. 2012, 2014).

This chapter aims to present the preliminary results of archaeological research done at the Belterra plateau, located in the southern bank of the lower Tapajós River, and questions that will need to be answered by future research in the area. It uses historical ecology, which is an interdisciplinary research program studying interactions between humans and the environment enhancing human agency in environmental transformations (Balée 2006), as a theoretical framework. We therefore look at archaeological sites as part of a domesticated landscape formed by “all intentional and non-intentional practices and activities of humans that transform the environment into a productive landscape for humans and other species” (Erickson 2008:158). Thus, the presence of Amazonian Dark Earths (ADE) and structures such as wells, mounds, and roads in archaeological sites demonstrates landscape modifications interpreted in the light of socio-economic purposes.

Archaeological sites of the Belterra plateau

1. Sources

Ethnohistory

There are several ethnohistorical accounts from early colonial and post-colonial periods that provide descriptions concerning daily and religious life of indigenous people in the Lower Tapajós region (e.g. Acuña 1641; Bates 2005 [1863]; Bettendorf 1910 [1661]; Carvajal 2011 [1542]; Daniel 2004 [1722-1776]; Heriarte 1964 [1874]; La Condamine 2000; La Espada 1889; Marcoy 2001 [1847]; Martius 1823-1850; Rodrigues 1875; Teixeira 1950 [1639]). Information about ethnicity, language, and socio-political organization provided by ethnohistorical accounts are of special interest for archaeologists. However, most of the early accounts were written by explorers, colonial officers, and missionaries and for this reason they cannot be considered as a true reflection of indigenous past but as an additional source to study culture change in the “longue durée” (Lightfoot 1995:204).

Furthermore, the use of ethnohistorical accounts in Amazonian archaeology has been tied to the debate concerning change and continuity in indigenous history. Three main perspectives compose this debate; while Meggers (1993) stated the unreliability of ethnohistorical accounts and emphasized similarities between past and present indigenous people, Roosevelt (1989, 1993) acknowledged the devastating effects of the European conquest on indigenous societies and stressed discontinuities between past and present populations. Based on her research in Santarém, Roosevelt formulated a model about social complexity; she argued that the region was inhabited by centralized and warlike complex chiefdoms

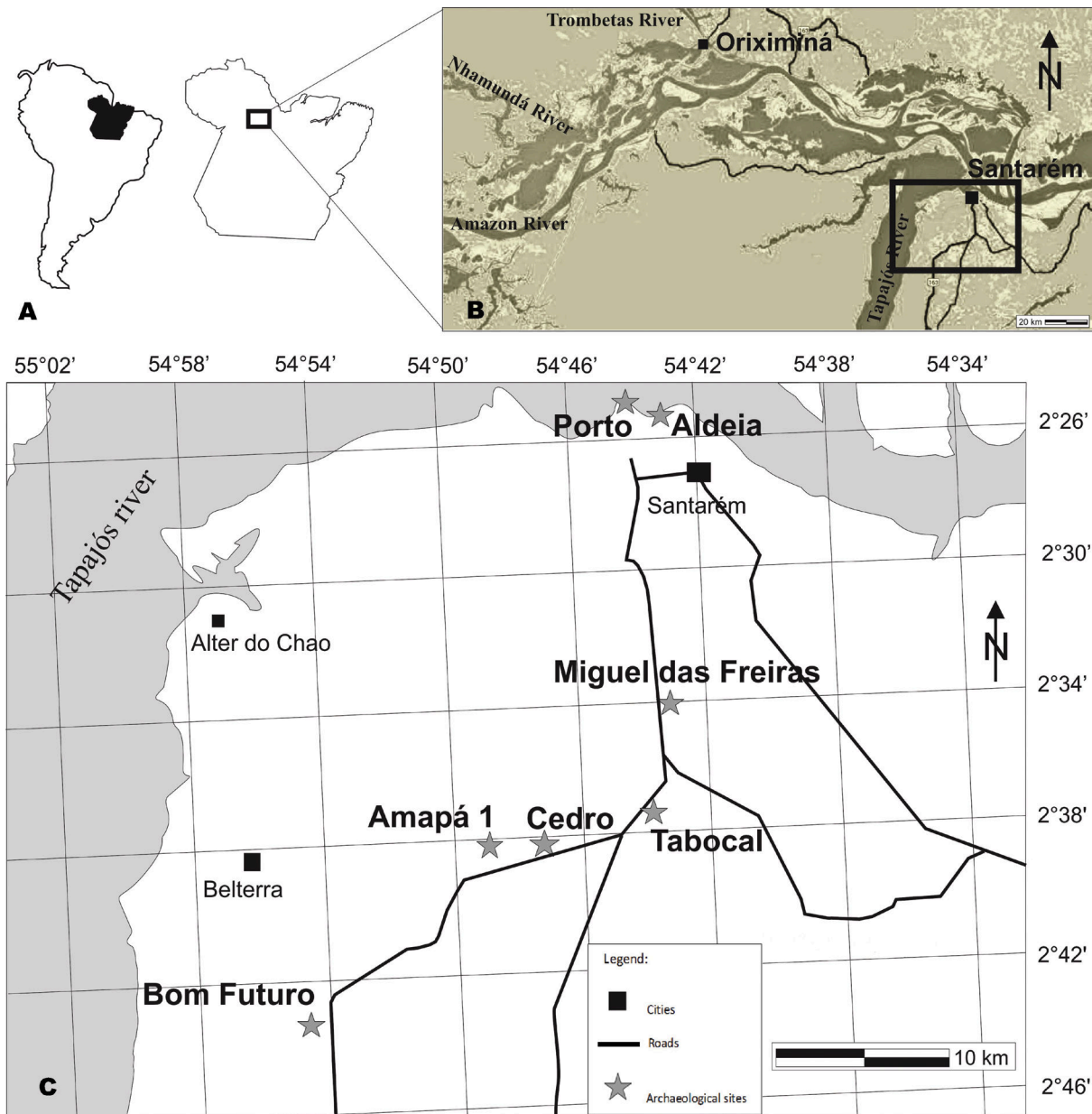


Fig. 1. Maps of the study region: A: location of the Pará state in Brazil, B: Nhamundá and Trombetas rivers and Lower Tapajós River with study area, C: archaeological sites mentioned in this chapter.

(Roosevelt 1989, 1993, 2000; this model have been criticized by Gomes 2007, 2009). A recent perspective looks at ethnohistory, archaeology, and ethnology as complementary sources that should be use together in order to construct an indigenous history (Gomes 2007, 2012; Viveiros de Castro 1996). This vision also criticizes the dangers of both “ethnographic projection” and “archaeological perversion”; while the former denies changes among indigenous societies, the latter can prejudice present political claims, especially about land rights, by distancing indigenous people from their ancestors (Viveiros de Castro 1996:193).

First Research

The presence of ADE in the Lower Amazon region was noticed by several scientists at the end of the 19th century, Rodrigues (1875), Orton (1875), Hart (1885), Katzer (1903 apud Woods and Denevan 2009), Farabee (1921), and Nimuendajú (1952 [1939], 2004). All of these scientists except Orton associated these soils to the ancient human occupation in the region. At the beginning of the 20th century, the German-Brazilian ethnologist Curt Nimuendajú conducted surveys and excavations in the region. He was associated to the Emilio Goeldi Museum

in Belém and the Ethnographical Museum of Gothenburg in Sweden. Between 1923 and 1926, he registered 65 archaeological sites located in the South of Santarém, in the region of Alter do Chao and Samahuma, Arapixuna, on the South bank of the Lago Grande of Vila Franca and on the right bank of the Amazon, between the Lago Grande of Vila Franca and Arapixuna (Nimuendajú 1952 [1939]: 9). He was the first to recognize the significant concentration of ADE in the modern city of Santarém, which covers the Aldeia and Porto sites. In Belterra plateau, he first noticed the presence of artificial wells, mounds, and roads (Nimuendajú 1952 [1939], 2004). He also created an ethnolinguistic map of Brazil based on his ethnohistorical research where he mentioned the Tapajó group living in the Santarém area in the 17th century (Nimuendajú 1981 [1944]).

Recent Projects

Archaeological research in the Belterra plateau started in 2006 with a survey conducted by Denise P. Schaan in the BR-163 between the Santarém and Rurópolis sections. Based on this survey, a rescue archaeology project led by Denise P. Schaan was conducted in the same sections of the BR-163 between 2006 and 2012. The aim of this project was to collect information about sites along the road BR-163 that was going to be paved. In addition to the impacts of the road, most archaeological sites located in the area are strongly impacted by mechanized agriculture. In 2011, another project called “Cultivated Wilderness: Socio-economic development and environmental change in pre-Columbian Amazonia” started under the supervision of Per Stenborg and Denise P. Schaan. This interdisciplinary project conducted by a Swedish-Brazilian team aims to study relationships between human and environment through the pre- and post- contact periods. In this way, it has two focus, to study artefacts coming from the Santarém region that were collected by Nimuendajú in the 1920’s and are currently curated at the Museum of World Culture in Gothenburg and to do new fieldwork in the region (Stenborg et al. 2014). Through this two projects, 111 archaeological sites were registered, among which seven were excavated, one located at the mouth of the Tapajós River (Porto site) and five

upland (Amapá 1, Bom Futuro, Cedro, Miguel das Freiras, and Tabocal) (figure 1). Among these 111 archaeological sites, 68 sites were found in the Belterra plateau. This plateau is part of the Amazon high plain, which dates from the Plio-Pleistocene age (Sombroek 1966:274). It rises between 60 and 180 m above sea level (masl); its altitude is 175 masl at Belterra Estate, 180 masl at Curuáuna center, and 60 masl between Nhamundá and Trombetas rivers, and it is relatively flat (Sombroek 1966:21). This plateau provides an impressive view to the Tapajós River and offered a strategic location for its past inhabitants, especially during the European conquest.

2. Preliminary data

Soils

There are two main types of soils in the Lower Tapajós region, one is natural and the other one is anthropic. The dominant soil is Kaolinitic Yellow Latosol that is formed by clay soil called “Belterra clay,” which originated from the erosion of uplifted kaolinitic deposits coming from the Andes and that spread through Amazonia (Sombroek 1966:275). The Belterra plateau presents three categories of latosols, Kaolinitic Latosolic Sand, Kaolinitic Yellow Latosol medium textured, and Kaolinitic Yellow Latosol very heavy textured (Sombroek 1966:275).

All the archaeological sites registered in the Belterra plateau present Amazonian Dark Earths (i.e. Black Earth and Brown Earth) (Embrapa 2001, Schaan 2013, Smith 1980, Sombroek 1966, Woods and McCann 1999, Woods and Denevan 2009). These anthrosols are characterized by high levels of carbon (C), phosphorus (P), calcium (Ca), magnesium (Mg), zinc (Zn), and manganese (MN) (Kern et al. 2003:51). While the formation of Black Earth is explained through ancient human habitations (i.e. household waste deposition), Brown Earth is related to long-term soil management practices (i.e. intensive agriculture) (Woods and McCann 1999).

Excavated sites show ADE layers that vary between 20cm (Bom Futuro site) to 50cm deep (Tabocal site). However, the extension of ADE at most of the sites is not yet known, except for 31 of them (Schaan 2013). For example, the Cedro site has been estimated to cover 6 ha (Schaan and



Fig. 2. Well at Bom Futuro site (photograph by the author 8/12/2010).

Martins 2012:13). This site has large areas of ADE separated by smaller areas of Brown Earth. Based on excavations and test-pit data, archaeologists suggest that Brown Earth areas at the Cedro site could be related to domestic structures, such as floors (Schaan and Martins 2012:13).

Structures

Among the 68 sites located in the Belterra plateau, 28 contain structures such as wells locally called *buracos*, artificial mounds known by locals as *cacimba* or *mudurú* (Schaan 2010), and roads that link these sites to the Tapajós River situated several kilometers away. Although wells are located in places far away from the Tapajós River, they are close to many smaller watercourses called *igarapés* (Figure 2). There are two types of wells, natural and artificial. While the former type shows a natural water-holding depression with circular form and large dimension, the latter presents an elongated shape with a smaller size, between 15 to 30m in diameter (Schaan 2013; Stenborg et al. 2014). Differences in size and form may certainly relate to different functions.

Excavations of wells occurred in Amapá 1, Cedro, and Bom Futuro sites (see Stenborg et al. 2014 for the results of excavations done at Bom Futuro site). Amapá 1 contains two wells, the larger one is 15m in diameter and is 3m deep. It has a horseshoe shaped reinforcement wall and is associated with two small artificial mounds. Archaeologists excavated the well and one of the artificial mounds. The results demonstrated that the mound probably originated from the soil removed during the construction of the well. As such, the well and the mound are likely contemporaneous.

The well excavated at the Cedro site is 12m in diameter and its original depth was around 110cm (Schaan and Martins 2012:26). Moreover, a floor area excavated near the well could have served as an access point to the well (Schaan and Martins 2012:16).

The presence of roads that link sites from the Belterra plateau to those at the mouth of the Tapajós River illustrates the presence of social and commercial networks in the region during precolonial times. Carvajal was the first person

to describe the existence of roads in the Amazon during the Orellana expedition in 1542 (Carvajal 2011 [1542]:39-41). Upland surveys showed a group of archaeological sites connected by what seems to be an ancient road; this road is located in the Estrada da Revolta, which is the name of the ancient road that is currently used. It connects the archaeological sites of Revolta 1, Revolta 2, and Revolta 3 (Schaan 2010:277). According to a local inhabitant that cultivate in the area, the ancient indigenous road connects several other sites and terminates close to the Tapajós River. Another indigenous road impacted by present-day activities was also identified linking several Amazonian Dark Earth sites in the Lavras area (Schaan 2010:212).

Material Culture

Most of the artifacts collected during excavations are ceramic fragments that belong to the Incised and Punctate Horizon. This horizon is characterized by the presence of incision, punctuation, and modelling; it is found in Orinoco, Amazon, British Guianas, and Brazilian Guianas (Meggers and Evans 1961). It presents two ceramic styles found in Belterra plateau, Santarém and Konduri (the latter is found in smaller amount). They are associated to two ethnic groups described in ethnohistorical accounts of the 16th century: Tapajó and Konduri. Furthermore, these accounts described the modern city of Santarém as the “capital” of the Tapajó people. They also stated that these groups did not understand Tupi language; this observation supplied by ceramic analysis conducted some scholars to hypothesize Tapajó and Konduri’s affiliations with Arawakan groups (Linné 1932; Métraux 1930; Nordenskiöld 1930).

Diagnostic artifacts show the presence of typical Santarém phase (AD 1000-1700) material culture, such as caryatid vessels, necked vessels, globular vessels, anthropomorphic figurines, and mat-impressed ceramics. Archaeologists still do not know whether these mat-impressed ceramics were an intentional part of the decorative technique or an unintentional part of the manufacture process from laying the ceramics in woven baskets during the drying process for example. Thus, these ceramics demonstrate the existence of basketry production not directly available in the

archaeological record.

Ceramics from Bom Futuro, Miguel das Freiras, Amapá 1, and Cedro sites have cauxi (*Parmula batesii*) as a tempering agent, either alone or combined with other types of tempers. Most frequent decoration techniques are red slip, incision, and punctuation. The fact that a large amount of burnt clumps of clay were collected at Amapá 1 (178), Miguel das Freiras (185), and Cedro (511) could indicate that ceramic production took place at these sites.

Lithics are quantitatively less numerous than ceramic fragments (Alvaro 2012-2013). While Bom Futuro, Miguel das Freiras, and Amapá 1 have more polished lithics, Cedro has more flaked ones. Moreover, spindle whorls were collected at Amapá 1 and Miguel das Freiras sites and demonstrate the existence of weaving production at these sites.

At first glance the material culture from sites located in the Belterra plateau seem very similar to that found in sites located at the mouth of the Tapajós River, such as the Aldeia and Porto sites. However, more research is needed to elucidate technological differences between both areas and within the sites located upland.

Chronology

Archaeological research conducted in the Santarém area shows that the Tapajó people developed around the 8th or 9th centuries and occupied the mouth of the Tapajós River earlier than the Belterra plateau (Schaan and Alves 2015). Radiocarbon dates obtained from sites with wells within the Belterra plateau show occupation from late pre-colonial and colonial periods that were not simultaneous, While Bom Futuro was occupied from the beginning of the 14th century up to historical times, Amapá 1 was occupied from the beginning of the 16th century up to the early 18th century. Cedro site presents occupations that range from early 14th century to modern times (Stenberg et al. 2014). This chronology permits the formulation of hypotheses concerning the period of transition and changes that constituted European colonization of the region. The occupation of plateau areas could indeed have increased due to the European Conquest (Stenberg et al. 2012:241-242). In 1639 Pedro Teixeira



Fig. 3. View of the Tapajós River from the Belterra plateau near the Centro de Memória of Belterra (photograph by the author 16/07/2013).

wrote that since indigenous slaves were missing in Belém, a great number of Indians from the Tapajós area were being purchased for slavery (Teixeira apud Porro 1996:60). Consequently, indigenous people that survived the first contact progressively left for areas far away from the Tapajós River. Teixeira also mentioned that Portuguese preferred to purchase non-contacted Indians that were more vulnerable to diseases and less aware about the Portuguese slavery enterprise. As it is possible to see the Tapajós River from some of the sites in the plateau, they probably offered strategic defensive areas (figure 3). Moreover, 1639 is precisely the date corresponding to the Tapajó defeat in a war against the Portuguese and the increase in Indian slavery (Schaan 2012:108). Paleoecological data at the Lago Tapajós also corroborates with an abandonment of the riverine region by indigenous inhabitants at the time of the Conquest (Iron et al. 2006). The fact that material culture related to the European presence in the region, for example Portuguese faience or pipes presenting European patterns such as those found during excavations of the Aldeia site (Symanski and Gomes 2012), has yet to be found in these sites may suggest the absence of the Portuguese.

Functions

Data collected during well excavations provide hypotheses about their functions. By their quantity and size, these wells demonstrate the organization of community work in a place that may have been highly populated. Firstly, it is likely that these wells could have served as water provider for human consumption in an area located far away from the main watercourses. Secondly, while populations at the Porto site certainly depended on fishing activities for subsistence, inhabitants of the upland may have relied more on agricultural activities. It is likely that these wells could have served agricultural purposes, as this may have been the main economic activity in plateau areas (Schaan 2013:345). The existence of indigenous roads make exchanges of both types of resources between river and upland sites likely to occur in precolonial times. Ethnohistorical accounts and paleoenvironmental studies give information about landscape transformation by indigenous people at the time of the European conquest. While Carvajal (2011:54–55 [1542]) described the regional landscape as covered in fields with indigenous people burning them, paleoenvironmental data demonstrate that this part of the Amazon basin was forested due to the presence of a wetter climate in the late

Holocene (Behling et al. 2001; Mayle and Power 2008). Moreover, a complete Holocene riverine paleoecological sequence from the Lower basin of the Tapajós River shows stability of a forested environment in contrast to other regions such as the Carajás plateau and the Bolivian savannas (Iron et al. 2006). Thus, unforested areas in this region at the time of the European conquest can be interpreted as having been modified by indigenous people (Roosevelt 2000). Thirdly, as demonstrated by Pino and Osorio (2006) for pre-Columbian wells in Ecuador, these structures represent a good strategy for the management of biodiversity. In this region, researchers noticed that wells that are still in use today attract specific kind of fauna and therefore enhance the biodiversity of the area. They show concentrations of local and migratory birds and animals for hunting (Pino and Osorio 2006:103). Finally, as some wells in Belterra presently have the purpose of storing animals such as turtles, caimans, and fish, this function could also have existed in the past corroborating ethnohistorical descriptions about the presence of water container full of turtles and manatees in indigenous villages.

Contemporary Re-use

Relations between local groups and archaeological remains extend to the long-range use of archaeological structures such as wells, and demonstrate the especially strong relationship between local communities and archaeological sites in this region. As already observed by Nimuendajú in the 1920's (Nimuendajú 2004:123), some of the wells are still used by present-day populations living on archaeological sites located far away from main watercourses. Contemporary use was also observed during the upland surveys; however, some owners explained that they do not use the wells anymore due to agrototoxic contaminations. Mechanized agriculture is indeed one of the biggest treats to archaeological sites in this region as it removes cultural layers of ADE, destroying archaeological contexts and artifacts. As evoked previously, turtles and caimans live in some of the wells, sometimes introduced by the site's owner. For instance, the owner of the Bom Futuro site uses one of the wells of his propriety to raise fish. This could stem from an ancient practice based

on the significant presence of these animals in the iconography of Santarém style ceramics, for example on its necked vessels.

Conclusions

Preliminary research conducted in the Belterra plateau raises many questions concerning the socio-economic and political organization of ancient indigenous societies in the region. The existence of monumental structures and large settlements such as the Cedro site support the existence of populous settlements in the plateau. The presence of roads demonstrate communication between upland and river settlements in precolonial times; however, the nature of this relationship remains to be understood politically and economically. The existence of material culture that seems similar to that found in river sites has to be investigate more closely. While the presence of burnt clumps of clay in some sites could demonstrate local industries, data about raw material sources, style, iconography, and identity through ceramic analysis could help characterize productions of the upland people. Finally, late dates for archaeological sites with well structures questions the conditions of access to water and river resources for people living upland during the European conquest.

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Archaeological Potential in the Flona-Tapajós

Camila Guarim Figueiredo

Introduction

The mouth of the Tapajós River, the location of the present day city of Santarém and its neighboring region, was inhabited by the Tapajó Indians from the 10th until the 18th century. The material culture associated with this group is distributed between the Trombetas and Xingu rivers - west/east - and from Almeirim to the middle Tapajós Rivers – north/south (Gomes 2002). Archaeological and ethnographic data demonstrate that the Tapajó produced the elaborate and intricate Santarém pottery (Prous 1991), which is classified as part of the Incised and Punctate tradition (Gomes 2002; Meggers and Evans 1957; Nimuendajú 1952, 1961; Palmary 1960; Schaan 2012), and can be found around the Tapajós, Trombetas and Nhamundá Rivers. This particular region is distinguished by a rich and varied archaeological landscape consisting of trail networks, inland wells (distant from rivers), and Amazonian Dark Earth (ADE).

Archaeological investigations in the Santarém region started in the early 1870s when Charles Hart associated the ADE with an ancient indigenous settlement (Nimuendajú 1952). Curt Niemuendajú located 65 archaeological sites in the Santarém area in the 1920s while conducting archaeological surveys for the Ethnographic Museum of Gothenburg in Sweden (Nimuendajú 1952). His expedition was important because sites along the Tapajós and Trompetas Rivers were mapped and recorded for the first time. His survey also demonstrated that Santarém style pottery associated with the Tapajó group was distributed over a large geographic area thereby seemingly corroborating the ethno-historic accounts of long distance trade. Furthermore, he noticed the existence of connecting roads from one ADE site

to another within the sites situated on the plateau (Schaan 2012), the construction of wells in areas far from large rivers (Schaan 2012, 2013), and the possible existence of a settlement hierarchy centered in the Santarém region. He also noted the presence of a large indigenous riverine population that had existed prior to the arrival of the Europeans based on differences in the size of the settlements, quantity of archaeological material recovered and ADE soil concentrations (Nimuendajú 1952).

The Lower Amazon Project, directed by Anna Roosevelt, started to conduct archaeological investigations in this area in the 1980s. Although most of the results have yet to be published, Roosevelt describes Santarém city as the center of a great warlike chiefdom, the apogee of which lasted from the 10th to the 16th century AD. Her model suggests the presence of a centralized political or ritual hierarchy where various chiefs controlled and integrated a large area of densely populated settlements. Roosevelt interpreted the settlement data as a reflection of the presence of political elites who extracted tribute and labour from the mass of lower status commoners. She argues that the elite oversaw community construction of housing and defensive works (Roosevelt 1999:23-27). Nevertheless, recent studies conducted by Gomes (2007) in the lower Tapajós, 100km south of Santarém, challenges the centralized chiefdom model. Gomes demonstrated that when the Santarém chiefdom was thought to have reached the height of its power and prestige, around 1000 CE, Santarém style artefacts were rare in this peripheral area (2007). Moreover, stratigraphic sequences in excavations from the lower Tapajós point to a lack of occupation between 1010 CE to 1200 CE. Based on this evidence Gomes suggested



Fig. 1: Flona-Tapajós Location.

that the groups in her study area were resisting Santarém control and influence and were moving along the Tapajós as independent groups. Gomes also argued for the coexistence of “different scales of sociopolitical groups which do not necessarily seek to dominate each other” (2007:67). This line of evidence counters Roosevelt’s interpretation of a powerful and centralized chiefdom.

The study of marginal areas in the Santarém region, such as the Tapajós National Forest (Flona-Tapajós), which is located 50km south of Santarém between the river and the plateau, will

ideally shed light on this key debate. For example, if future archaeological expeditions inside the Flona-Tapajós find low quantities of Santarém style artifacts, as the studies conducted by Gomes had, then it may strengthen Gomes’ theory. In contrast, a high number of Santarém style artifacts recovered in association with significant landscape modifications dating to the 11th century AD would suggest that Roosevelt’s earlier chiefdom model might be relevant for understanding sociopolitical dynamics in the immediate hinterland surrounding Santarém.



Fig. 2: Archaeological Sites and Communities Location in the Flona-Tapajos.

The Flona-Tapajós

The Flona-Tapajós (**Map 1**) was created in 1974 and is one of the largest Brazilian conservation units covering an area of 549,067 km². It is located in the Tapajós River watershed, a white water river. It is an area of great biodiversity, housing several

endemic species, such as the Amazonian manatee (*Trichechus inunguis*), the sagui-de-Santarém (*Callithrix humeralifer*), the tiriba-de-Hellmayr (*Pyrrhura amazomum*) and the papagaio verde-amarelo (*Guarouba guarouba*) (www.ecobrasil.org; www.greatriverspartnership.org consulted on

Table 1: Archaeological sites within the Flona-Tapajós (Rizzo et al. 1997, in IBAMA 2004:209).

| 1 | Approximate Location | ADEs size | Description |
|----------|----------------------------------------------------------------------------------|-----------|-----------------------------------------------------------------------------------------------------------------------|
| PA-ST-37 | Piquiatuba Community | 3.5 he | Ceramic fragments with and without decoration. One decorated fragment with a human face, typical of Santarém ceramics |
| PA-ST-38 | Prainha community (5 km from its center/Sede close to Pau-Rosa waterway/Igarape) | 4 he | Ceramic fragments with and without decoration |
| PA-ST-39 | Itapaiuna community (5 km from its center/Sede close to Jacare waterway/Igarape) | ? | N/A |
| PA-ST-40 | Acaratinga community, 3 km from Sr. Polaco's house, and 800 m from Pojo Lake | 8 he | Ceramic fragments with and without decoration |

3 April 2014). It comprises four towns: Aveiro, Belterra, Placas and Ruropolis; and its limits are defined by the Belterra Town (Km 50 of BR-163) to the north, the highway BR163 to the east, the Tapajós River to the west, and the Gupari River to the south which is situated near kilometer 211 of the Trans-Amazonica highway.

The 2006 national census registered 1,438 families divided into 29 communities living inside the Flona-Tapajós. There are also two indigenous reservations within its boundaries. The town of Aveiro and twenty-one other communities are located along the Tapajós River, five communities are located along the Cupari River, and three in the plateau region, close to BR-163 (**Map 2**) (IBAMA 2004:296). The majority of the populations that have established settlements along waterways are composed of *ribeirinhos* in Portuguese, meaning “riverine people”. With the exception of the urban “center” of Aveiro, subsistence agriculture constitutes the main economic activity of the Flona-Tapajós region. Subsistence logging, hunting and ecotourism are also important to the local economy (Bicalho 2011; IBAMA 2004).

Despite the presence of large ADE areas within the Flona-Tapajós boundaries, which are often associated with archaeological materials, the identification of archaeological sites by Nimuendaju in the 1920s (IBAMA 2004) and oral accounts indicating the presence of ceramic material create associations to the Tapajós and other previous occupants (IBAMA 2004; Gomes 2012), no systematic archaeological survey has ever been conducted here (Schaan 2012). In 1993, government social and economic surveys

reported inhabitants' accounts of the presence of archaeological artefacts in the Maguari community and rock art in the caves along the Cupari River (Couto et al 1993 in IBAMA 2004). In 1996, sixteen ADE sites, some of which were associated with Santarém pottery, were located within the reservation (Imaflora 1996 in IBAMA 2004) (**Map 2**, Table 1). This resulted in a suggestion to create protected areas around some of the sites in order to protect the archaeological heritage (IBAMA 2004:208).

The absence of archaeological research in this reservation may be explained by a few factors. First of all, in order to conduct any research in a forest reservation in Brazil it is necessary to hold a special permit from the Brazilian Institute of Environment (IBAMA). In addition, archaeological projects in the Brazilian Amazon are in most cases only approved in conjunction with massive infrastructure projects. In light of recent development projects (all of which required an environmental/archaeological impact assessment) the number of archaeological studies has steadily increased in the region, especially since the launch of the Growth Acceleration Program in 2007. Regrettably, however, these development projects have still been complicit in the destruction of archaeological and historical sites, cultural heritage, landscape, environment, biodiversity and the livelihoods of native and traditional people. Despite the rise in the number of archaeological projects, the majority of the Amazonian territory has not yet been studied by archaeologists (Heckenberger and Neves 2009; Walker 2012). Accordingly, since the Flona-

Tapajós is a protected area, it will not directly be impacted by development projects. Hence, there is no need for archaeological consulting companies to conduct excavations in the reserve. As mentioned, the majority of the Brazilian academic projects have been undertaken in partnership with the private sector.

The presence of ADE soils and archaeological sites from the Santarém phase combined with the

rich data available from the surrounding area, along with the noted lack of archaeological research in the reservation, makes the Flona-Tapajós an ideal area to collect data for an archaeological survey. The data collected in a survey will not only contribute to our understanding of how peripheral areas integrated with Santarém, but as shown above, it will also, help to investigate the homogeneity of the Tapajó system.

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Analyses and Digital Modeling of Santarém Artifacts

Kjell Denti Gunnarsson and Patrik Castillo

Abstract

This paper presents the methods used by the Cultivated Wilderness project, both in the past and present, while working with the physical archaeological material from the Santarém area which is stored in Gothenburg, Sweden. This paper also presents a resulting bachelor thesis 'Ceramic differences and similarities in the Lower Amazon - A comparative study of ceramic artifacts between two archaeological sites in the Tapajós region' as well as the public efforts made by the project.

Introduction

The Cultivated Wilderness project, which is led by Dr. Per Stenborg of the University of Gothenburg, Sweden, aims to explore the interaction between past human societies and the environment in the pre-Columbian Amazon and determine how they developed their relationship to the natural surroundings. The project, which was funded by the Bank of Sweden Tercentenary Foundation, was launched in 2011 and is a collaboration between Swedish and Brazilian archaeologists and scientists (Cultivated Wilderness 2012). Students in both Sweden and Brazil have participated and helped the project through various channels. The project implements archaeological excavations and soil surveys in and around the Santarém area as well as analytical work in Santarém and Gothenburg. The German born ethnologist and anthropologist Curt Unkel, who later changed his name to Curt Nimuendajú, collaborated with the ethnographical museum in Gothenburg, Sweden, during the early 1920s. Nimuendajú carried out archaeological fieldwork and surveys in the Amazon region of North-eastern Brazil, largely in the Santarém area as thoroughly described

in the book "In pursuit of a past Amazon" compiled by Project director Dr. Per Stenborg (Nimuendajú 2004). Some 8000 artifacts ended up at the facilities of the Ethnographical Museum in Gothenburg, Sweden, as a result of the work carried out by Nimuendajú. Today this material is found at the storage facilities of the Museum Of World Culture in Gothenburg, Sweden. In the following text the Museum of World Culture will be referred to as VKM. The project has studied and conducted numerous analyses on the material from the Santarém area since 2011, mostly focusing on ceramics, but also stone artifacts.

Methods used within the project regarding analysis methods and documentation will be described in the following part of the article.

Analytical work has been completed both in Gothenburg, Sweden, and also at the facilities of Universidade federal do oeste do Para (UFOPA) in Brazil. The channels that are used by the project regarding public efforts include archaeological reports, a blog that students within the Project operate, 3D models available on the project website and lectures held both in Sweden and Brazil.

Analysis methods and documentation within the Cultivated Wilderness Project

The database

Much of the work that has been carried out at VKM has been linked to the Access database that the Cultivated Wilderness project has built up since early 2011. The project started working with the database at VKM from July to October 2011. The project members who worked at the VKM during the summer of 2011 were the Brazilian archaeologist Professor Denise Schaan



Fig. 1. Images from the VKM.

from Universidade Federal do Pará, Márcio Amaral Lima from Universidade federal do oeste do Para (UFOPA), Dr. Per Stenborg and four students (Patrik Castillo, Kjell Denti Gunnarsson, Karolina Müller, and Erik Johnson) from the University of Gothenburg. Imelda Bakunic from the University of Gothenburg, and initially also Liv Westring, also participated. The database was created in Microsoft Access and consists of several fields and variables of interest regarding analyzing ceramic data. At present (October 2014) some 1500 objects have been added to the database at the VKM (the largest proportion being ceramic material). Some 1000 ceramic objects have also been added into the corresponding database in Santarém.

Data fields include the identification number that was given to the object when it was registered at the VKM, weight, color, surface of the object, visible construction techniques, temper, motif and the known geographical provenience of the object. An approach that has suited the project in terms of the work of analyzing the ceramic and stone objects at the VKM and in Santarém can be likened to an assembly line principle. For example, one member analysed the object and determined the temper, weight, motif etc. then another member added the data to the database. Other members scanned literature for objects that resembled the object that was being analyzed and for other useful information. Members then

changed work tasks and continuously discussed the object being studied to obtain the best results possible.

Work on the database is continuously evolving as more plates of ceramic and stone material are analyzed. At the VKM the ceramic and stone material are located in storage facilities in proper conditions in terms of optimum temperature and humidity. Every artifact had a specific number assigned to it as it was registered. In the book “In pursuit of a past Amazon” there are plates in which a large part of the archaeological objects that Nimuendajú collected are drawn. The same plates are available at VKM but in a larger format. The plates are used by the project when selections are made about which ceramic and stone artifacts should be analyzed, and also describes from which location the artifact was collected by Nimuendajú. The plates have each of the artifacts displayed and the accompanying registration number which the object received when it was registered at VKM. As mentioned above, work was also carried out in November 2012 at the Universidade Federal do Oeste do Para (UFOPA). The ceramic material that was analyzed had been excavated by the project in 2011 at Bom Futuro located south of Santarém on the Belterra Plateau. Therése Törnkvist, a student of archaeology at master level at the University of Gothenburg, also helps the project with illustrations of selected ceramic objects for future use in publications and reports.

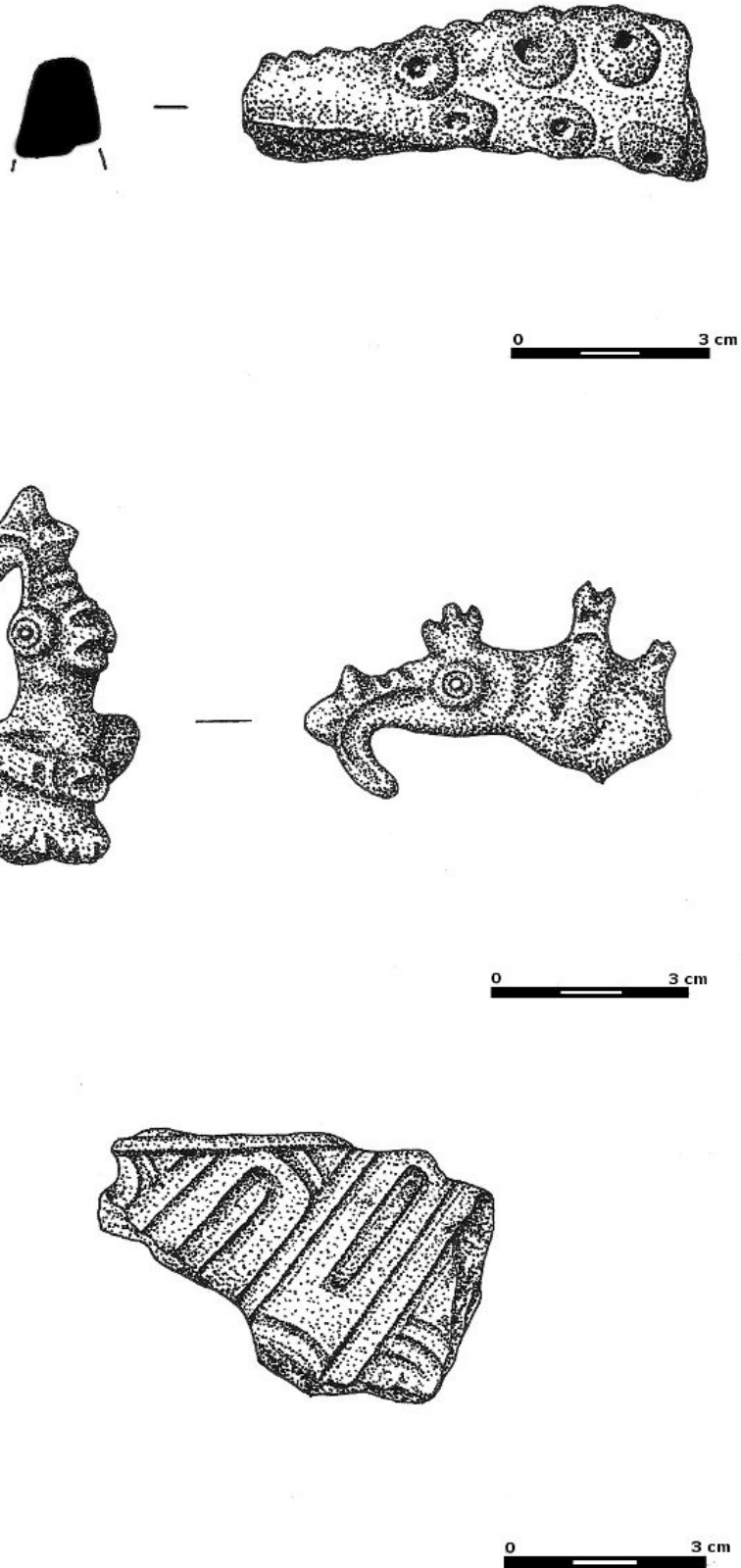


Fig. 2. Illustrations of Santarém material in the VKM collections: Top: 24.16.30.e, from Tauaquera, Rio Arapiuns, centre: 25.14.66, from Santarém Aldea, bottom: 25.14.33, from Santarém Aldea. By Theresé Törnkvist.



Fig. 3. A screenshot of one of the 3D-models (http://cultivated-wilderness.org/3D%20modeller/VKM23_16_280.htm).

Design features on ceramics such as shape, size, form, method of manufacture, and other characteristics are easier to see and study in a drawing than on a photograph (Griffiths et al. 2002).

X-ray fluorescence analysis

Tests and analyses with x-ray fluorescence analysis on ceramic and stone material were carried out at the VKM. The XRF instrument is a fairly small and practical instrument to use. A small x-ray beam is directed into a protective chamber onto the material that is being analyzed. A computer then calculates the constituent elements of the clay or the stone artifact. For example, it is possible to see how much calcium, iron, copper and other substances are present in the clay. The data can then be compared with data collected in the field, for example in the Santarém area. In this way, one can see similarities in the clay used in the ceramics and get an idea of where the ceramics were produced geographically. One idea

might be to look at the relationship between the temper in the ceramics and the presence of various substances in the analysis.

Public efforts

In today's archaeological sector it becomes increasingly important to reach out beyond the research community when it comes to presenting data and finds from, for example, an archaeological excavation. In Sweden, there is a requirement from the authorities that an archaeological survey should result in a report and that any public work will be described (Riksantikvarieämbetet 2012). For example a report released in 2013 by Länsstyrelsen in Stockholm demonstrated how important it had become when several archaeologists came together to write a report of their experiences regarding archaeological fieldwork and data and how they worked to reach the public (Länsstyrelsen Stockholm 2013). It has become more important that excavations, especially their results, become public. It is not

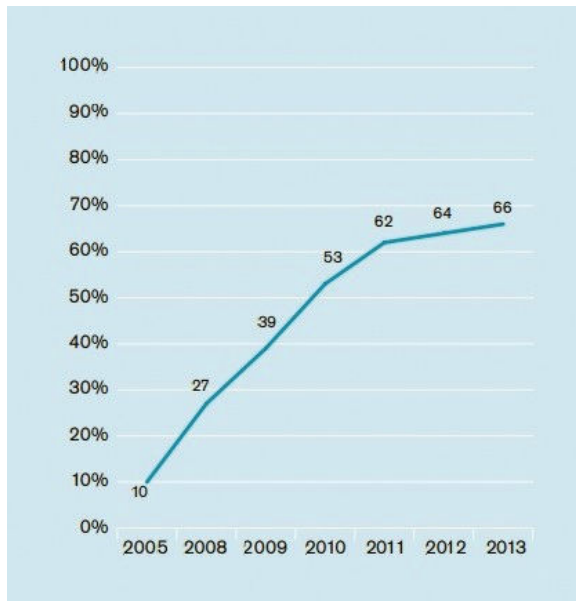


Fig. 4. Percentage of Internet users in Sweden occasionally using social media sites (age 12+). <http://www.soi2013.se/en/communication-and-social-networks/>.

only archaeologically interested individuals who should be able to take part in the work and view the research data. Over the last two years the students within the Cultivated Wilderness Project have held presentations and worked to be able to reach out to both the individuals that are interested in Amazonian archaeology and to the general public. Lectures have been held at both the Department of Historical Studies at the University of Gothenburg, and at other geographical venues both in Sweden and in Brazil such as Universidade Federal do Oeste do Pará (UFOPA), and Gotland, Sweden. As the project is working at the VKM analyzing and cataloguing archaeological material from the Santarém area, lectures and presentation materials have been developed in which the audience is given an opportunity to get acquainted with the archaeological material. They are not only given a visual and audio presentation by the project members, but they are also able to have direct contact with the archaeological material, for example looking at the material through a microscope and also by touching it and comparing it to material from different archaeological sites. Gloves are obviously used by the participants when they are given the opportunity to feel and observe the material and one of the project members remains close by to answer questions and make sure that the material is safe. Interest in a presentation about

the Cultivated Wilderness Project in this form has been raised by a large association in Gothenburg which has a deep interest and knowledge in local pre-history, but which also shows an interest in archaeology from other geographical venues. A powerpoint has been developed by the students in the project and a great deal of work has gone into developing as highly educational presentation as possible, which not only conveys the facts but also raises and maintains the interest of the listeners.

Website management

3D-models

“According to constructivist and constructionist theories, the best way of creating understanding for people of different learning abilities and interests is to allow them to interact with the object in question.” (Champion 2008:210)

The Cultivated Wilderness Project has made several efforts to create 3D-models for display on the website. The models were created with public participation in mind, as well as the opportunity for researchers outside of Gothenburg examine the material. They were created in a program called 3Dsom Pro using images from a dSLR camera that were shot and subsequently merged together. The use of 3D-models seems to be on the rise within the field of archaeology and history as methods of creating 3D-models becomes easier and can be done with relatively simple equipment and software. Museums like the Smithsonian Institution are in the process of digitalizing their collection which includes objects like the Wright Flyer plane, fossils and archaeological objects (Smithsonian X 3D). The Swedish Museum of Mediterranean and Near Eastern Antiquities is also in the process of digitizing their collection of Egyptian mummies with the help of a CT-scanner for the purpose of research and public participation (Museum of Mediterranean and Near Eastern Antiquities n.d.).

Currently there are only a few 3D-models available on the Cultivated Wilderness Project website (Cultivated Wilderness Website) with more being planned.

Social media

With 'web 2.0' the opportunity and importance for organizations to present themselves online are greater. Recent studies in Sweden show that around 66% of internet users visit social networks occasionally, and that ~33% of time spent on the internet by those between the ages 12–25 is used visiting social networks. For the ages 26–55 around 22% of time spent on the internet is used for social networks (The Swedes and the Internet 2013).

Students assisting the Cultivated Wilderness Project are also involved in managing the associated internet blog (<http://cultivated-wilderness.org/blog>). The blog operates using Wordpress which is free of charge and easy to use when it comes to managing and updating it (www.wordpress.org). The project uses an app that could be downloaded to smartphones which enables easy and fast uploads.

Through an interactive internet platform we hope to present the project and geographical area. The website is public, and the main content published is photographs and updates regarding the field and lab work as well as personal reflections.

The blog was created in 2011 and has since been visited a number of times. Since the website traffic trackers were installed in October 2013 the monthly average of visitors has been around 1,000. A website plug-in enables the opportunity for administrators to view the search terms that led internet users to the website. Some examples of search terms are "vessel fragment with bird", "cultivated wilderness" and "artifacts drawings". The website also provides the opportunity for visitors to leave comments which enables a visitor-researcher interaction.

One museum site constantly being recognized for its social media presence is the Smithsonian Institution's website. They continuously update their website media channels and offer several ways to connect and interact, for example Twitter, Facebook, Flickr, several blogs, Pinterest, Google+, Podcasts and Instagram (Smithsonian Institution 2014).

Conclusion

In today's connected society it is becoming increasingly important to interact and have a presence on the internet and several social media channels, such as Facebook, Instagram, twitter, flickr or whatever social media is popular in one's region.

It is both important and exciting for the project to work with 3D modeling, blogging and other social media in order to find ways to reach out with information and results. Individuals outside of Gothenburg who are interested in studying the Santarém ceramics housed in Gothenburg can interact and examine the ceramics through 3D modeling.

It is positive to see large and important archaeological and historical institutions and projects, for example the Smithsonian, take advantage and use the Internet and social media to interact with their audience and public. This is also inspiring to the Cultivated Wilderness project.

Ceramic differences and similarities in the Lower Amazon - A comparative study of ceramic artifacts between two archaeological sites in the Tapajós region

This section will present the findings of the bachelor's thesis Ceramic differences and similarities in the Lower Amazon - A comparative study of ceramic artifacts between two archaeological sites in the Tapajós region by Kjell Denti Gunnarsson. The data for the thesis was analyzed for the Cultivated Wilderness Project during 2011–2012.

A total of 191 ceramic artifacts collected by the ethnographer Curt Nimuendajú were studied at the Ethnographic Museum in Gothenburg. The ceramic pieces were collected from two sites: Santarém/Santarém Aldêa and Lavras, both of which are situated in the Lower Amazon region in Brazil. Santarém/Santarém Aldêa is located next to the River Tapajós while Lavras is located further inland. The artifacts' temper were analyzed and organized into five categories: Sand, cauxi, rock, grogg and cariapé. Cauxi is a fresh-water sponge (Lima da Costa et al. 2004:167) and grogg is the name used for crushed ceramics which can be found re-used in some ceramic material.

The purpose of the survey was to ascertain if

Table 1: A statistical table of the temper.

| Temper | Santarém | Lavras |
|---------|----------------------------------------|----------------------------------------|
| | (% of artifacts containing the temper) | (% of artifacts containing the temper) |
| Sand | 44.8% | 19.8% |
| Cauixi | 89% | 58.1% |
| Rock | 10.5% | 11.4% |
| Grogg | 72.4% | 87.2% |
| Cariapé | 5.7% | 10.5% |

there were any regional differences between the areas in ceramic temper, to discuss what such differences may be related to, and if any regional differences did exist, why did they occur?

Santarém

Santarém is a city located in Pará, Brazil, and has a long history of human habitation. Curt Nimuendajú described Santarém Aldêa as “The most profitable and most interesting of all finding-places known to me hitherto in the lower Amazon region” (Nimuendajú 2004:127). The pottery suggests a standardized production (McEwan et al. 2001:153) and the ceramic hosts a variety of figurines which are anthropomorphic, zoomorphic and a combination of both.

Lavras

Lavras is an upland locale situated south of Santarém. Nimuendajú made trips to Lavras to obtain artifacts from the farmers in the area. In the book “In pursuit of a past amazon” Nimuendajú mentions interesting specimens he managed to gather from Lavras, but “not very characteristic ones” (Nimuendajú 2004:131). The Cultivated

Wilderness Project mapped the sites Lavras 1-3. Lavras 1 contained “large quantities of pottery, predominantly of Santarém type are visible on the surface of the ground.” (Stenborg et al. 2012:248).

Method

The VKM items were analyzed with microscopes by members of the Cultivated Wilderness Project and student assistants. The statistics were compiled with SPSS Statistics. Of the 191 artifacts studied, 105 were from Santarém/Santarém Aldêa and 86 came from Lavras.

Conclusion

From the statistical compilation of the areas’ temper it is clear that they differ in some variables. Santarém ceramics, for example, are tempered with considerably more sand and cauixi. This perhaps comes as little surprise given that Santarém is located near a river (Rio Tapajós) which provides the materials. The finds do indicate the local production of ceramics and the usage of local material, but more material, especially from a greater number of sites, would be needed to make any larger conclusion.

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Plant Food Consumption and the Origin of Amazonian Dark Earth in the Lower Tapajós Region

Daiana Travassos Alves

Introduction

The Amazon region has traditionally been seen as a pristine tropical rainforest where pre-Columbian inhabitants had passively adapted to the natural environment (Meggers and Evans 1957; Steward 1948). Recently, however, several scholars (e.g. Balée 2006, 2008; Erickson 2003; McKey et al 2010; Neves and Petersen 2006; Oliver 2001) have argued that the environment was in fact a constructed environment produced by both ecological and anthropogenic factors. The assumption of their argument is that humans domesticated the landscape by transforming it to further their needs; the consequences of this process included an increase in the abundance of plant species, with a wider distribution, and the formation of Amazonian Dark Earths (ADE).

ADE is an extremely fertile soil widespread in Amazonia that has been studied by scholars from several fields who are still engaged in the process of understanding its origins (e.g. Glaser and Woods 2004; Lehmann et al 2004; Teixeira et al 2010; Woods et al 2009). This multidisciplinary effort has significantly advanced knowledge about ADE such as the differentiation between *Terras Pretas* (TP) and *Terras Mulatas* (TM). *Terras Pretas* are considered to be a product of the daily activities of settlements (e.g. food production, manufacture, fuel, house construction), while *Terras Mulatas* are associated with pre-European agriculture practices (Arroyo-Kalin 2010; Denevan and Woods 2004; Woods and Denevan 2009; Woods and Glaser 2004). The main characteristics of *Terras Mulatas* when compared to *Terras Pretas* are their lighter coloration (dark brown), the absence or low quantity of artefacts, their high level of organic matter, and their direct spatial association with TP areas (Sombroek et al 2010; Woods and McCann 1999).

The identification of distinct activity areas and their respective functions at the sites is a fundamental advancement for understanding ancient land use, mobility behaviours, subsistence systems, food production, and social and spatial organization at Amazonian Dark Earth sites. Aside the comprehension of the processes of formation and persistence of ADE, this differentiation is important because of its conceptual implication. Namely, the reconnaissance of ancient population as agents in a dialectical relationship with the surrounding environment which is related to the aforementioned debate in Amazonian archaeology regarding the influence of human habits and practices on tropical forest.

A number of Amazonian Dark Earth studies were carried out in the Lower Tapajós region, especially in the great extensions of ADE between Santarem and Belterra Plateau which were defined as the first differentiation between TP and TM (Smith 1980; Sombroek 1966; Woods and McCann 1999). A significant number of archaeological sites and their position in the landscape are now known on the Santarem-Belterra region. Five types of site were identified in different ecozones in the region: large sites with a deep ADE layer near the main watercourses; smaller sites near riverine areas that are not the main ones and feature a thinner ADE; and small sites placed on bluffs, plateau and summit areas with a varying ADE depth and limited access to water resulting in some sites having artificial wells ranging from 15 to 20 m in diameter and horseshoe-shaped mounds (Schaan 2012, 2013; Stenborg et al. 2012).

The studies of *Terras Mulatas* in the region had classified them as a product of cultivation (Sombroek 1966; Woods and McCann 1999).

However, none of the studies identified the cultivars or even the plants managed in the region. This is a very important gap to be filled in order to improve our knowledge about the origins of Amazonian Dark Earth in the Lower Tapajós region. This paper discusses archaeological contexts in the Lower Tapajós region and presents a hypothesis on plant food consumption and the formation of the ADE in the area.

The Lower Tapajós Region

The archaeological sites of the lower Tapajós River region have been described elsewhere for more than a century, especially in the Santarem area (Barbosa Rodrigues 1885; Hartt 1875; Nimuendajú 1949, 2004). Nevertheless, archaeological research only started at the end of the 1980s when the Taperinha, Caverna da Pedra Pintada, and Porto de Santarem sites were excavated under the Lower Amazon Project (Roosevelt 1991, 1993, 1999, 2000a, 2000b; Roosevelt et al. 1991, 1996). Investigations at these sites provided data from which the first chronological sequence for the Lower Amazon region could be established. This begins around 11,200 years ago with a Paleo-Indian occupation at the Caverna da Pedra Pintada site, which includes early pottery production from 7,000 years ago at the Taperinha site, and finished with the agricultural based, densely populated, and regionally organized societies at the mouth of the Tapajós River A.D. 1600 (Roosevelt 1991, 1999, 2000a; Roosevelt et al. 1991, 1996). Archaeological research focused on those sites for about 20 years.

Recently, this situation has changed. Considerable data on the regional distribution of sites and intrasite spatial organization had been produced by academic and commercial archaeology (Alves 2012; Gomes 2006; Nimuendajú 2004; Schaan 2010, 2012; Stenborg et al. 2012). It is now accepted that the archaeological sites (Santarem-Aldeia and Porto de Santarem) placed under the modern city of Santarem were the “centre” of a large polity that included more than a hundred sites (Roosevelt 1987, 1993, 1999a, 1999b; Schaan 2012; Stenborg et al. 2012). This regional complex social organization included sites of varied sizes placed in different environments such as large sites located in riverine areas of

main watercourses, smaller sites in secondary watercourses, and small sites in upland areas e.g. bluffs, plateaus and summits (Nimuendajú 2004; Schaan 2012; Stenborg et al. 2012). However, the nature of the relations between people living in these different areas is not yet clear. The centre-periphery relations are discussed in this volume (Schaan *this volume*).

The majority of sites in the Santarem-Belterra area present Amazonian Dark Earths and share the Santarem ceramic style classified as part of the Incised and Punctuate Horizon that was chronologically determined to date from the period A.D. 1000–1600 (Gomes 2002; Quinn 2004; Schaan 2012). However, ceramics from another style were collected at some of the sites in the area (Schaan 2013); potsherds were classified as Globular and Konduri styles during laboratory analyses. Konduri belongs to the Incised and Punctuate Horizon, as does the Santarem style (Guapindaia 2008; Hilbert and Hilbert 1980). Globular is part of the Incised Rim Tradition chronologically determined to date from the period A.D. 100–800 (Meggers and Evans 1961).

During the last quarter of the nineteenth century, scholars have suggested that the ceramics found in areas of black soils were produced by the Tapajós, an indigenous group contacted by the Portuguese in the sixteenth and seventeenth centuries (Hartt 1875; Barbosa Rodrigues 1885; Nimuendajú 2004). Departing from those studies, ethno historical accounts, and her own research in the area, Roosevelt (1987, 1992, 1993, 1999a, 1999b) proposed that around 1000 years ago a large complex society whose economy was based on seed crop cultivation, aquatic faunal resources, and the collection of edible tree fruits developed at the mouth of the Tapajós river (Roosevelt 1992:26).

The Tapajós chiefdom would have had a centre located at the current city of Santarem, including the Porto Site. Chemical analyses of the soil at the Porto site indicated an increase of the animal and vegetal food consumption starting around A.D. 1020 (Tapajó period) at the base of the ADE layer. Such a society was supposedly highly hierarchical with power in the hands of chiefs legitimated by religious specialists and by the possession of prestige goods (e.g. elaborated pottery and stone

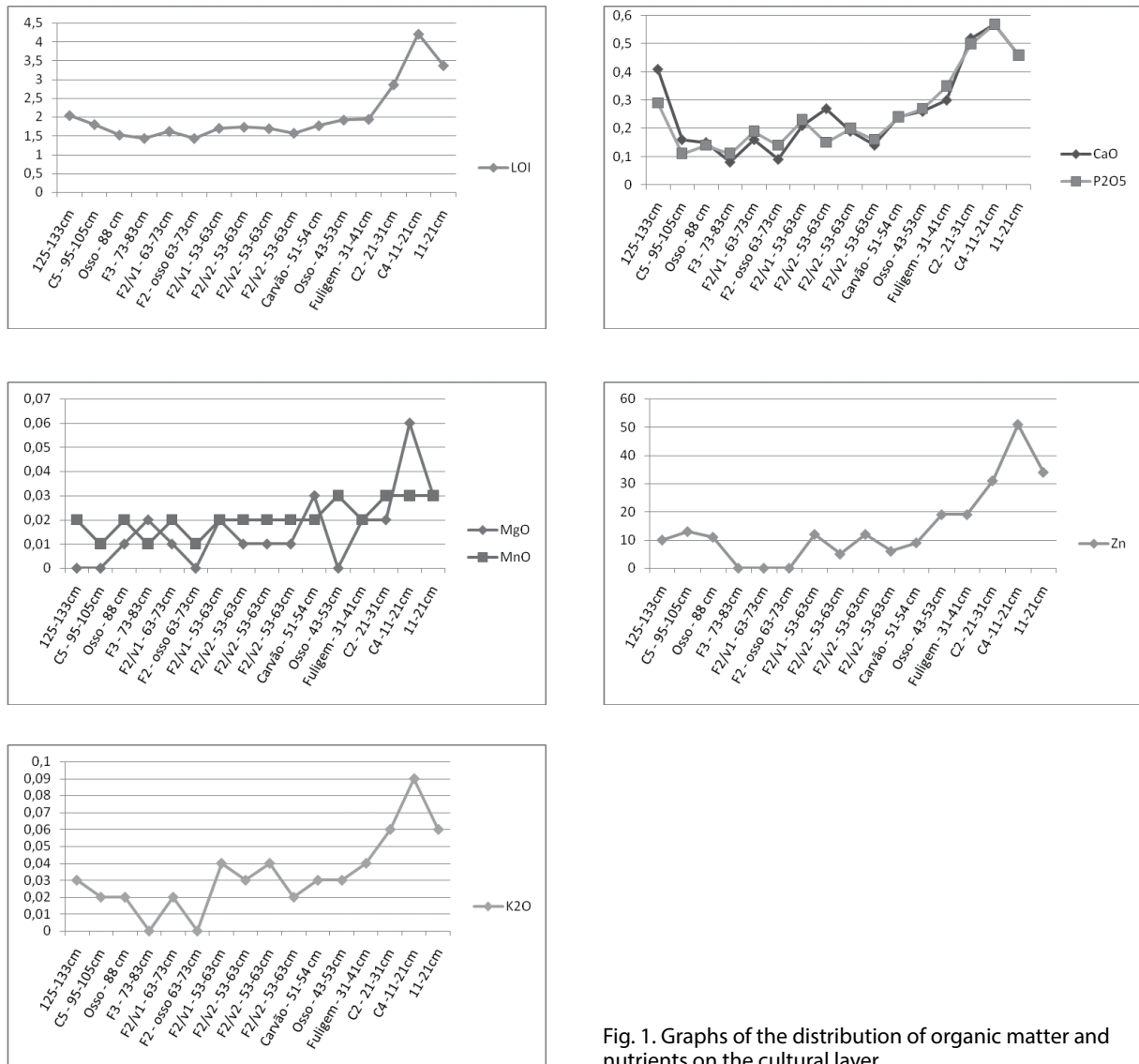


Fig. 1. Graphs of the distribution of organic matter and nutrients on the cultural layer.

sculptures — *muiraquitãs*) (Roosevelt 1987, 1992, 1993, 1999a, 1999b).

The Porto de Santarem site is located on the right bank of the Tapajos River in its confluence with the Amazon River. In the port area the site is managed by the *Companhia Docas do Pará* – CDP, whose activities have partially disturbed it. However, deep deposits of *Amazonian Dark Earths* are found in some parts of the site that cover an area of about 350.000 m², and have a north-south flat topography and gentle east-west slope. It is covered by *Paspalum* grass and by a mosaic of plant species characteristic of anthropogenic forests (Balée 1989) such as *Hog plum* (*Spondias mombin*), *Guava* (*Psidium L.*), *Macaúba Palm* (*Acrocomia aculeata*), *Juçara palm* (*Euterpe edulis Mart.*), *Muruçi* (*Byrsonima basiloba*), *Tucum* (*Astrocaryum*

tucuma), *Cutite* (*Pouteria macrophylla*) (Schaan 2012) and fruit trees such as *cashew* (*Anacardium microcarpum*) and *mango* (*Mangifera indica L.*).

Two different chronological periods were determined from 30 radiocarbon dates on wood charcoal collected from stratified deposits: a Pre-Tapajó period (Cal B.C. 1610–1000), and a pre-conquest Tapajó period (A.D. 1020). Furthermore, different activity areas were mapped and investigated, some of them related to household contexts such as middens and house floors, and others related with ritual contexts such as “ritual” pits (*bolsões*) and a burial area (Alves 2012, 2014; Schaan 2010, 2012b; Schaan and Roosevelt 2008).

The stratigraphy of the Porto site was disturbed by the contemporaneous port activities.

Nevertheless, a well-preserved stratigraphy was identified in area 10A across different field seasons from 2001 to 2013. The cultural layer was 133 cm deep and featured two substrata that present differences in the soil composition and in their material components (Alves 2012, 2014).

The deeper substratum (133 to 63 cm) has a brown soil with low quantities of artefacts (e.g. ceramics and lithics), which increases through it. Chemical analyses of the soil indicated low rates of organic matter, Calcium, Potassium, Magnesium, Manganese, Phosphorus and Zinc, but above that of the surrounding Oxisol. The first 33 cm of this substratum contained plenty of large blocks of charcoal with small flakes and potsherds among it. Two samples of charcoal from this context were radiocarbon dated to Cal B.C. 1610 (117cm) and Cal BC 1410 (101cm). In the rest of the substratum there was a regular deposition of ceramic and lithic artefacts (e.g. small flakes, grater teeth, calibrators and potsherds) as well as small pieces of charcoal. A charcoal sample collected from a semi-fragmented ceramic bowl was dated to Cal B.C. 1210 (83 cm). The appearance of animal bones in the last 10 cm, just before the beginning of the *Terra Preta* substratum, was an important find from this substratum (Alves 2012, 2014).

The second substratum was a *Terra Preta* soil, with large amounts of diverse pottery artefacts (e.g. fragmented figurines, fragmented decorated pottery vessels) and lithics (e.g. spindle whorls, a probable arrow shaft, a green stone/*muiraquitã*, and grater teeth) as well as small animal bones and pulverized charcoal (Alves 2012, 2014). A sample of charcoal collected among a concentration of three fragmented pots was dated to Cal A.D. 1020. The quantity of bones significantly increases in the base of this substratum compared to the top of the deeper layer and then decreases through the *Terra Preta* layer. The rates of the nutrients and organic matter on the soil are consistent with this variation in the distribution of the bones (Alves 2012, 2014).

The substrata compositions and components indicate different forms of occupation at the site. Beyond that, significant changes occurred before the formation of ADE. The pattern of distribution of bones is consistent with the increase of material

culture that clearly belongs to the Santarem occupation which is associated with a regionally distributed and ranked organized society that intensively managed multiple natural resources (e.g. aquatic fauna, small mammals, and collected and cultivated plants) (Roosevelt 1987, 1992, 1993, 1999a, 1999b; Schaan 2012). Therefore, is likely that the subsistence system has changed. According to the approaches of the “Santarem society”, it had a subsistence based on aquatic resources complemented with harvesting, hunting and intensive cultivation of seed crops (Roosevelt 1987, 1992, 1993, 1999a, 1999b; Schaan 2012). Some bones collected during the excavations indicate the consumption of fish and turtles (Alves 2012). Even so, the plant component of the diet remains unknown.

The study of micro and macro botanical remains extracted from grater teeth, pottery fragments, and soil samples is particularly important to address this issue. Small lithic flakes identified as grater teeth were collected during the excavations at the Porto site (Alves 2012; Araújo de Lima and Schaan 2012). It is common to assume that these small objects were fixed on wooden slabs which were used to grate manioc tubers; however, archaeobotanical studies have shown that a diversity of plants were processed with these tools, especially maize (Berman et al 1999; DeBoer 1975, Iriarte and Dickau 2012; Berman and Pearsall 2008; Perry 2002). Therefore, phytolith and starch analysis have provided both the identification of the types of plants consumed and the function of some archaeological artefacts (Berman and Pearsall 2008; Iriarte and Dickau 2012).

The food consumption of a variety of botanical species was identified in Llanos de Mojos in Bolivia from macro and micro botanical remains (extracted from pottery and lithic artefacts used in food preparation), which have shown the presence of tuber plants (*yam* - *Dioscorea* sp. - and manioc), seeds (peanuts and maize), legume plants (squash) and peach palm (Dickau et al 2012). The integrated phytolith, pollen and charcoal analysis results have also provided the comprehension of changes in land use at the savannahs of Guiana, where the controlled use of fire was identified as a strategy used by the farmers on raised fields (Iriarte

et al 2012). There, the integrated approaches of archaeology, paleoecology, aerial imagery and archaeobotany provided a map of agricultural landscapes (raised fields) and the identification of the types of cultivated plants (McKey et al 2010). Maize phytoliths were identified in samples collected from all sites, but phytoliths of squash and starch from maize and manioc were also identified.

The results of integrated studies of micro and macro-botanical remains had indicated that pre-Columbian populations relied on the consumption of a variety of vegetal species (Perry 2002). Even though, maize has appeared as one of the main cultivars in Central America sites (Berman and Pearsall 2008; Perry 2002) and in the savannahs of Guiana (Iriarte et al 2012; McKey et al 2010), it has been always associated with other plants.

Based on ethno historical accounts and archaeological data, Roosevelt (1980) suggested that the Tapajó consumed maize as a fermented beverage in ceremonial settings. The study of tools used for food preparation (e.g. griddles, grater teeth), soil samples, and macro botanical remains collected at sites in Santarem-Belterra region help to provide information about plant food consumption at the Tapajó main site. This research might be able to indicate whether the consumption of maize was as widespread in the area as claimed by Heriarte (1874), or was only consumed as a drink in ceremonial settings as Roosevelt suggests.

Implications for understanding ADE formation

Amazonian dark earths are anthropic soils formed by the consistent discard of organic material (e.g. ashes, charcoal, animal bones, urine, faeces, leaves, ceramic and lithic artefacts) related to land use practices and domestic activities performed in each living area (Schmidt et al 2014). The decomposition of organic matter enriches the soil by increasing the soil pH, the organic carbon, and the rates of some nutrients such as Nitrogenous, Calcium, Phosphorus, Potassium, Zinc, Magnesium, and Manganese among others (Schmidt & Heckenberger 2009). Wood ashes, dry plants, animal viscera, and human faeces are responsible for the addition of elements such as

Magnesium, Manganese, Zinc, and Potassium (Wilson et al. 2008; Woods 2004). Bones, urine, and food preparation activities contribute Phosphorus and Calcium to this soil composition (Canuto et al 2010; Woods 2004). The controlled use of fire would also produce the enormous amounts of small charcoal bits present in these soils that are responsible for its dark colour and its resilience.

The intentionality of ADE production is the subject of debate between specialists. Some Scholars argue that the intentional management of the soil and its resources around the villages were aimed at enriching the soil (Arroyo-Kalin 2010, 2010a, 2012, 2014; Denevan 2010; Woods and McCann 1999). Others suggest that the formation of ADE is related to long-term occupation of the settlements, which produced a great volume of discarded organic materials resulting in the alteration of the soil chemical composition (Kampf et al 2003; Kern et al 2010; Schaan 2012).

The Amazonian Dark Earths have been found in a variety of environments such as floodplains, bluffs of main and minor rivers, interfluvial areas and uplands (*Terra Firme*) (Woods and McCann 1999; Denevan 1992, 1996, 2003, 2010; Sombroek et al 2010). In the face of this diversity of contexts, the specialists have tried to understand the origin of ADEs both as a broad Amazonian phenomenon as well as on a local scale (Arroyo-Kalin 2010, 2010a, 2012 and 2014; Denevan 2010; Heckenberger and Neves 2009; Kampf et al. 2010; McMichael et al. 2014; Schmidt et al 2014; Neves and Petersen 2006; Rebellato et al. 2009; Sombroek et al 2010; Woods and Denevan 2009).

With regard to *Terras Pretas*, a pattern of spatial organization of the settlements was identified in different areas of Amazonia e.g. Upper Xingu region, Central Amazonia, Lower Trombetas River and Lower Tapajós River (Neves and Petersen 2006; Rebellato et al. 2009; Schaan 2013; Schmidt 2013; Schmidt and Heckenberger 2009; Schmidt et al. 2014). Even though this is a point of convergence where the formation of ADEs has a diversity of processes, it is related with both environmental and social/cultural factors. It can therefore be different according to the

function of the spaces within the archaeological site (Schmidt 2013; Schmidt and Heckenberguer 2009; Schmidt et al. 2014).

The pattern proposed is the distribution of terraces and horseshoe-shaped mounds on *TP* sites. The mounds were interpreted as midden and the terraces as house areas (Schmidt et al 2014: 153). Such assumptions are based on contextual information from excavations and soil chemical analyses from the two types of structures at sites investigated on the areas referred to above. The results of chemical analyses have indicated differences in soil characteristics in the form of pH, organic matter and nutrient rates. The samples from middens presented the highest mean for each characteristic observed. In the face of this fact, the midden areas were considered most suitable for ADE formation (Schmidt et al. 2014: 161).

For *Terras Mulatas* formation, a crucial role of intensive or semi-intensive semi-permanent cultivation practices can be suggested. Implying human management of the environment with a combination of different techniques for the enrichment of the soil e.g. in-field burning with incomplete combustion resulting in charcoal, composting, mulching and fallow periods for regeneration (Arroyo-Kalin 2010, 2010a, 2012, 2014; Denevan 2010; Sombroek 2010). However, there is a lack of consensus as to whether the ADE producers had a diet based on multi-cropping cultivation complemented with faunal resources and harvesting (Denevan 2001, 2003, 2010) or a main crop e.g. maize (*Zea mays*) and manioc (*Manihot sculenta*) (Arroyo-Kalin 2010, 2010a, 2012, 2014; Oliver 2001; Piperno and Pearsall 1998; Roosevelt).

From this background I raised the following questions which guide my research on plant food consumption in the Lower Amazon/Santarem-Belterra region: I) what is the vegetal component of the diet of ancient inhabitants of the Lower Tapajós region? II) How is plant food production related to the formation of Amazonian Dark Earth in the study area? III) Had this vegetal component changed through time? In terms of which species are represented in the samples and its proportional frequencies both horizontally and vertically on the stratigraphy of the sites.

Hypothesis

The diet of Santarem-Belterra region inhabitants and their subsistence activities are topics that remain unsolved, similar to the relationship between subsistence strategies and its impacts on the landscape. The hypothesis of the paper is that the production of ADE at the beginning of the Santarem phase occupation signals important changes in subsistence strategies that include an increase in plant food consumption, which is equilibrated by animal resources. Previous research in the region has not conducted archaeobotanical analysis, so there is no available data on diet and crop cultivation. Therefore, the region has an immense potential for the investigation of the transformation of subsistence strategies and social organization some centuries before European contact.

Methodology

The methods of archaeobotany seem to fit the questions raised above. Phytolith, starch-grain, and macro botanical analyses will be carried out including:

I - analysis on the soil samples from previous excavations in a midden and from other areas of the Porto site

II - column samples from soil-depth profiles from future archaeological excavations

III - residues from the plant-processing tools and containers recovered in excavations (e.g. plant grinding stones, stone grater teeth, ceramic containers)

IV - crossing the results of phytoliths and chemical analysis of the soil

V – compare the results with the other sites under investigation

Conclusion

The more detailed the archaeological investigations in Santarém-Belterra region get; the clearer it becomes how important it is to comprehend the subsistence strategies employed by ancient people in this area. Their activities are likely to

have significantly changed the environment as indicated by the formation of dark soils. In the Porto de Santarém site the appearance of Terra Preta and the Tapajó occupation are correlated. Changes in subsistence strategies simultaneous to their appearance are pointed to by preliminary chemical studies of the soil and contextual information from the Porto site.

The dark earths are spread all over the Santarem-Belterra region and are always related to archaeological sites where the material culture attributed to the Tapajó group is found. The deep knowledge of the Tapajó people about the Santarem-Belterra environment is perceived in

the placement of their sites in different ecozones and the structures built at those sites (e.g. artificial wells and mounds). Thus, the hypothetical Tapajó regional organization is no longer only based on the regionally widespread ceramics from the Santarem phase, but instead on their broad exploitation of both upland and riverine resources. However, this hypothesis lacks further information on food production and consumption. The investigation of plant food production is crucial for the comprehension of the Tapajó subsistence system and the nature and extension of its relation to the ADE formation.

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Investigating Amazonian Dark Earths as Agro-Ecosystems and their Impact on the Regional Landscapes of the Lower Amazon

José Iriarte

Introduction

The nature and scale of the pre-Columbian impact on Amazonia, the largest tropical forest on Earth, is one of the most debated topics in archaeology and paleoecology today (e.g. Balée and Erickson 2006; Denevan 1992; Heckenberger et al. 2008; McKey et al. 2010; Iriarte et al. 2012; McMichael et al. 2012; Meggers 2003; Mayle et al. 2007; Schaan 2012). The highly modified soils generally located along the bluffs of the Amazon River and its major tributaries, known traditionally as *Terras Pretas do Índio* and more recently as Amazonian Dark Earths (ADEs), are arguably one of the most compelling pieces of evidence of human transformation of tropical environments in the Americas (Glaser and Woods 2004; Heckenberger and Neves 2009; Petersen et al. 2001; Schaan 2012; Woods et al. 2009).

In Amazonia, where typical *terra firme* soils are heavily leached and infertile, ADEs are notorious for their high content of charcoal, organic matter, higher pH values and greater concentrations of P, Ca, and Mg which lends their ability to maintain nutrient levels over hundreds of years (see chapters in Glaser and Woods 2004; Lehmann et al. 2004; Teixeira et al. 2010; Woods et al. 2009). The charcoal content of ADEs is generally four times greater than neighbouring soils but can be as much as 70 times higher (Glaser et al. 2001). As a result of the high concentration of inert charcoal, ADEs are more recalcitrant (Glaser et al. 2003), which makes them some of the most fertile soils in the world (e.g., Lehmann et al. 2003). ADEs can occur in patches ranging in size from less than a hectare to several hundred hectares (Wood and McCann 1999), though the majority of the sites recorded are less than 2 hectares (Kern et al. 2003). They are estimated

to cover about 0.1-0.3% (6,000-18,000 km²) of the forested lowland Amazon basin (Woods and Denevan 2009), though recent predictive modelling by McMichael et al. (2013) estimates that ADEs may have covered as much as 3.2% (ca. 154,063 km²) of the Amazon basin. ADEs are generally located along the major rivers, though in our study region they are located on plateau areas (Schaan 2012; Stenborg et al. 2012) and in consistent numbers in other interfluvial areas such as in the Middle Purus-Middle Madeira interfluves (Levis et al. 2012). In the Central and Lower Amazon the vast majority of occupations associated with their formation began around or after 1 AD.

Recent botanical studies show that vegetation growing on ADEs is quite distinct. Research by Junqueira et al. (2011) and Levis et al. (2012) in the Middle Madeira region show that ADEs exhibit higher density and greater species richness than non-ADE soils. In general, ADEs are characterised by lower canopy vegetation, a more closed understory and the presence of some indicator species. Woods and McCann (1999) have repeatedly observed Brazil nut (*Bertholletia excelsa*), cacao (*Theobroma cacao*), cupuaçu (*Theobroma grandiflorum*) and saumauma (*Ceiba pentandra*) growing on ADE sites in the Lower Amazon. Botanical inventories carried out in riverine caboclo communities of the Middle Madeira by Junqueira et al. (2011) have identified 11 indicator species, including three palms that feature prominently, *caiaué* (*Elaeis oleifera*), *urucuri* (*Attalea cf. phalerata*) and *murumuru* (*Astrocaryum murumuru*). Collectively, the apparently distinct composition, structure and phenology of some plants (in particular palms) that are characteristic of ADEs show promise for the use of remote sensing to identify them (Thayn et al. 2010).

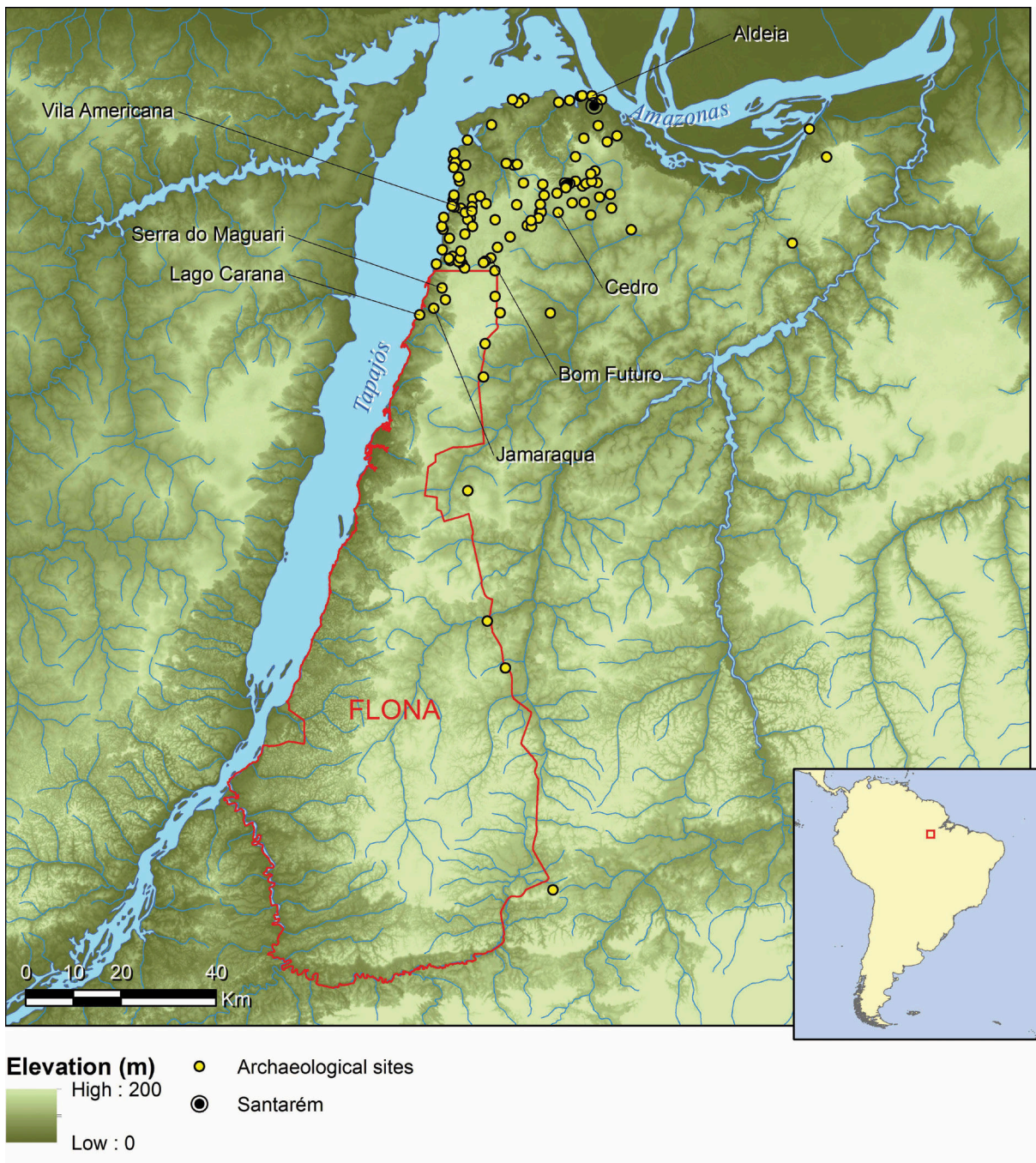


Fig. 1. Regional map of Santarém showing archaeological sites mentioned in the text.

There is a general consensus among archaeologists and geographers that ADEs are cultural deposits created through the decomposition of waste around habitation areas, including plant and animal food wastes, fish bones, human excrement, plant materials used for constructions, among others (Arroyo-Kalin 2012; Woods et al. 2009). Regardless of their initial origin, ADEs have usually been associated with sustained intensive agriculture (Heckenberger and Neves 2009; Neves and Petersen 2006; Rebellato et al. 2009;

Sombroek 1966). However, there is controversy about a) the exact nature of agricultural practices and the inventory of crops that were planted on them; b) the genesis and use of *Terra Preta* vs. *Terra Mulata*; and c) the spatial extent of forest perturbation resulting from ADE formation and agricultural practices. I address these topics in more depth in the next sections.

This chapter is very different to the rest of the book which presents novel data based on several years of field and laboratory work in the region

of Santarem (Figure 1). This chapter will briefly highlight the larger issues in ADE research that can benefit from fossil and modern plant multi-proxy studies while outlining the methodological approach that the PAST (Pre-Columbian Amazon-Scale Transformations) project has just begun to employ to answer the questions raised in more detail below. This chapter is not intended to be an exhaustive review of all the literature on ADEs, but it is focused on bringing to the fore some of the major research questions that remained unresolved. It can be tackled with an interdisciplinary approach combining archaeology, archaeobotany, palaeoecology, soil science, botany and remote sensing.

Agricultural use and environmental impact of ADEs

Agricultural potential of ADEs

There is still a long-standing debate about what the staple crops of the Late Holocene complex Amazonian societies were. Some scholars have proposed that Amazonian farmers became increasingly dependent upon intensive food-production systems as human populations increased through the Late Holocene (De Paula Moraes and Neves 2012; Rebellato et al. 2009), they began to either rely on manioc (*Manihot esculenta*) (Arroyo-Kalin 2010; Lathrap 1970; Heckenberger 1998; Oliver 2001; Piperno and Pearsall 1998) or maize (*Zea mays*) as the principal staple crops (Roosevelt 1993).

Archaeobotanical, ethnohistorical data, and modern studies about the potential agricultural use of ADEs by Caboclos (Amazon peasantry with mixed ancestry) and indigenous groups, which can shed light on these issues, are diverse. Archaeobotanical data is at a very early stage in the Amazon. For example, in the Araracuara region of the Colombian Amazon, pollen data from several ADE sites, beginning around A. D. 790, have documented the presence of a diversity of plant resources including tuber crops such as sweet potato (*Ipomoea batatas*) and manioc, maize, fruit trees such as cashew-nut (*Anacardium occidentale*) and maraca (*Theobroma bicolor*), palms, including *Astrocaryum*, *Euterpe*, *Geonoma* and *Iriartea*, along with spices like chilli peppers (*Capsicum chinensis*) (Herrera et al., 1992). In

the Central Amazon, phytolith analysis from an artificial mound context built with surrounding ADE soils documented the presence of maize, squash (*Cucurbita* sp.), gourd (*Lagenaria* sp.) and *Calathea*, in addition to *Heliconia* and *Bactris*-type palm phytoliths around 1000 AD (Bozarth et al., 2009).

Early European accounts in the region of Santarem usually describe the cultivation of both maize and manioc by early historic indigenous societies along the Amazon (Woods and McCann, 1999); however, a particular reference to the Santarém area by Heriarte (1874 [1662]) indicates that the main cultivar of the Tapajós people was maize. Nowadays, local populations use ADEs in different ways across the various regions of Amazonia. Studies in caboclo and indigenous communities tend to show that ADEs are used to plant nutrient-demanding crops. In the Lower Tapajós and the Central Amazon, they generally use ADEs to plant maize, beans (*Phaseolus* spp.) and squash (*Cucurbita* spp.), among others (German 2004; Hiraoka et al. 2004; Woods and McCann 1999). In other less commercially oriented areas, like the Middle Madeira, the Caboclos use ADEs to farm many varieties of manioc that grow productively in them (Fraser 2010; Fraser and Clement 2008; Fraser et al. 2012). The Kiukuro indigenous group of the Upper Xingu plant their staple crop manioc in the upland *terra firme* soils, while the other more nutrient-demanding crops such as maize, papaya (*Carica papaya*) and tobacco (*Nicotiana tabacum*) are farmed in ADEs created around modern and abandoned villages (Schmidt and Heckenberger 2009). The Araweté group inhabiting the liana forest of the Xingu River preferred the nutrient-rich ADEs to plant maize, which they claim ‘makes the corn grow’ and/or ‘makes the corn happy’ Balée (2013:44).

In terms of productivity, ADEs can produce high yields for both maize and manioc farming. Available data for maize production in ADEs from the Central Amazon, which are similar to maize production in modern experiments of raised-field agricultural systems in different Neotropical savannas (Iriarte et al. 2010). Data from multiple measurements on two ADE sites in Central Amazonia show an average yield of 3.925 t ha⁻¹ at Apui and a range between 3.6 and 6 t

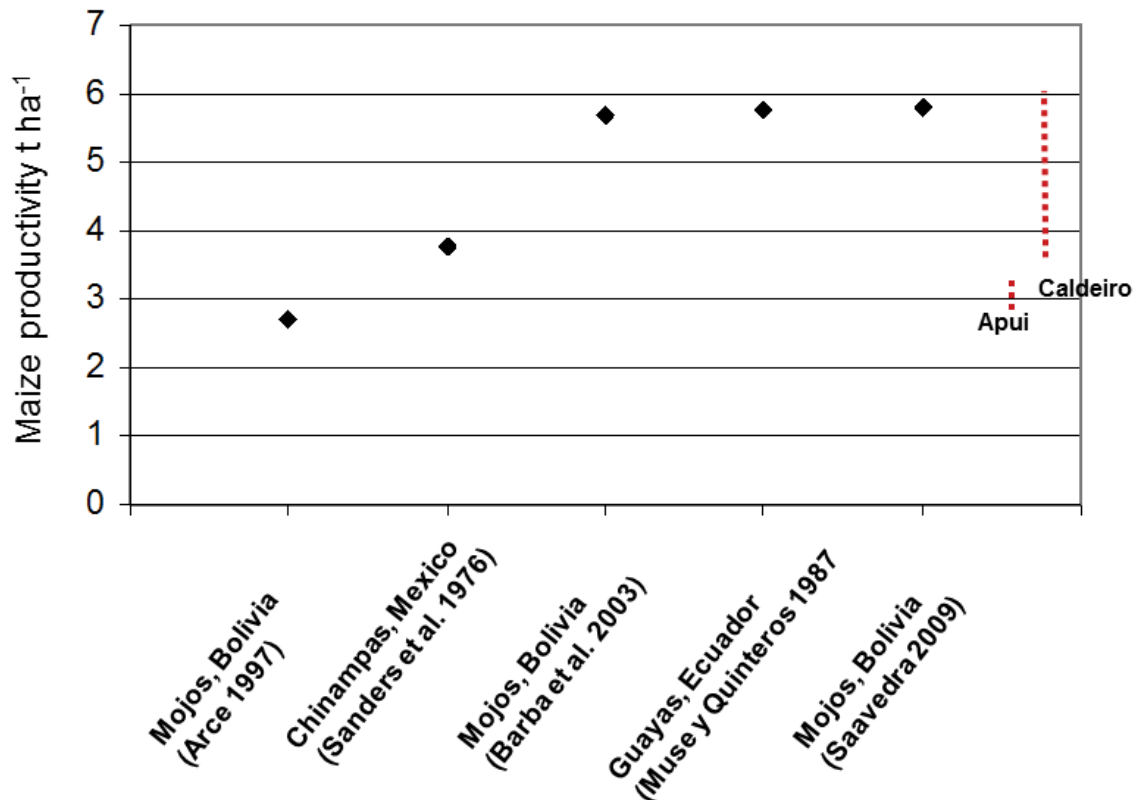


Fig. 2. Comparison of maize productivity in raised-field experiments (diamonds) and ADE sites (dashed lines).

ha⁻¹ at the Caldeiro research station (Wenceslau Teixeira, Pers. Comm. 2010) (Figure 2). Major et al. (2005) reported that in comparison with the typical nutrient-poor Amazonian Oxisols, maize yields can be up to 65 times greater on ADEs. When comparing with raised-field agriculture, it is interesting to note that while raised-field soils which supported maize in the past are currently depleted of nutrients (McKey et al. 2010), ADEs continue to be extremely fertile.

German (2003) argued that a high yielding maize staple is one of the main advantages of ADE farming. Since maize only takes a few months to mature, only one weeding may be necessary for such a fast growing crop. On the contrary, given the growing period of manioc, which can take from 8-24 months, it would require weeding several times. However, Fraser (2009) reported that farmers in the Middle Madeira region grow many varieties of manioc productively in both ADE and non-ADE soils. The average productivity of manioc cultivation from 12 ADEs in Central Amazon averaged about 6.5 t ha⁻¹, which is well above typical yields from the Ultisols (3.5 t ha⁻¹) and Oxisols (4 t ha⁻¹) that dominate the region

(Fraser et al. 2009). Largely based on these figures, Denevan (2014:212) recently suggested that of eight to ten million people could have lived in pre-1492 Greater Amazonia based on maize and manioc cultivation on ADEs.

Despite these advances and after decades of research on ADEs by archaeologists, geographers, soil scientists and ecologists (Glaser and Woods 2004; Lehmann et al. 2004; Woods et al. 2009), key questions remain unresolved due to the lack of any systematic investigation of the plant component of these agricultural systems. For example, we know very little about the context in which ADEs emerge in our region of study. What was the origin of ADE sites in the Lower Amazon during the Late Holocene? In particular, what type of land-use management was practiced before the formation of ADEs and what were the environment and plant associations in which the first ADEs in the Lower Amazon arose? Did an “Agroforestry Stage” precede ADE formation as suggested by Roosevelt (2007)? In a similar vein, we still do not know which crops were planted in ADEs in pre-Columbian times, and, in particular, the major dietary staples that sustained the pre-

Columbian cultures that created these soils. For instance, were ADEs used to plant nutrient-demanding and nutritious crops like maize, less demanding crops like manioc, fruit-tree crops, or a combination of these in multi-cropping systems?

Terra Pretas and Terra Mulatas

Another controversy relates to the origin and use of *Terra Preta* (hereafter TP) versus *Terra Mulata* (hereafter TM). Although scholars now agree on the anthropogenic nature of ADEs, there is no clear consensus on the respective origin and use of these two commonly distinguished types of ADEs. While “proper” TP is black and deep, filled with ceramics and other cultural artefacts/ecofacts and generally seen as the result of midden refuse accumulation from permanent habitation sites (e.g. Erickson 2004; Kern and Kampf 1989; Woods and McCann 1999), TM is lighter in colour (dark brown to brown), shallower, more extensive and often surrounds patches of TP. TM also contains very few artefacts and has been linked to semi-intensive cultivation over long periods involving organic amendments and low-temperature near-surface fires; the so-called “slash and char” method (e.g., Arroyo-Kalin 2012; Denevan 2004; Schmidt and Heckenberger 2009; Sombroek 1966; Steiner et al. 2004; Woods et al. 2000). Micromorphology studies in TM carried out by Arroyo-Kalin shows evidence of a clear truncation between the lower part of a well-preserved buried A horizon and its underlying B horizon indicating some form of scraping, raking and churning along with magnetic susceptibility data showing the alteration of soil iron likely caused by near surface burning. Collectively, this evidence gives support to Sombroek’s (1966) proposal that TM is the result of burning associated with agricultural practices. Despite major advances which have recently been made, archaeobotanical studies are required to further test these hypotheses in different regions of the Amazon. Archaeobotanical research is needed to better understand the difference in origin and use of TP and TM sites, as well as to investigate how the cultivation of TP soils differed from that of TM.

Environmental impact of ADEs

Last but not least, there is a debate about the spatial extent and long lasting effect of ADE formation and use. While McMichael et al.’s (2012) paleoecological evidence suggests that even in some ADE sites of the Central Amazon (e.g. Tefe, Barcelo) the impact on the local vegetation is small, floristic inventories by Junqueira et al. (2010) suggest that ADEs in the Middle Madeira have a long-lasting effect increasing biodiversity. Unfortunately, none of these studies have incorporated archaeology and archaeobotany and they are either solely based on paleoecology or floristic inventories. This prevents contrasting past human disturbance with modern vegetation to test different scenarios of past human impact and their modern legacy. As a result, important questions remain unresolved. What was the past human impact and the modern legacy of this type of land-use management on the fluvial and *terra firme* tropical forests? More specifically, did the Tapajós culture restrict its environmental impacts to the areas around TP and TM sites as commonly assumed, or did they extend their influence to *terra firme* rainforests well beyond the rivers? What are the changes in forest composition associated with the development of ADEs?

In the remainder of this chapter, I will succinctly describe the methodological approach that the PAST (Pre-Columbian Amazon-Scale Transformations) project is developing in the Lower Amazon to investigate ADEs in collaboration with the ‘Cultivated Wilderness Project’. Results from the PAST project are expected in the coming years.

A multi-proxy approach

The region around Santarém city at the confluence of the Tapajós and the Amazon Rivers, the alleged site of the capital of the Tapajós chiefdom, represents a unique setting to address the questions raised in the previous section since it exhibits some of the highest densities of ADE sites in Amazonia (Nimuendajú 2004; Schaan 2012; Sombroek 1966; Stenborg et al. 2012; Woods and McCann 1999) (Figure 1). The Tapajós culture, whose apogee lasted from AD 1000 to 1600, is known for its elaborate pottery vessels which belong to the Incised Punctuate Tradition. They



Fig. 3. Top. View of the Tapajos River from the Vila Americana ADE site. Bottom. View of the Jamaragua ADE site on the western edge of the escarpment from the Tapajos River.

are typically decorated with representational and geometric plastic and painted designs, in particular anthropomorphic and zoomorphic adorns displayed in caryatid and neck vessels. They also exhibit polished-stone figurines representing various animals and humans locally called “muiraquitás” (Gomes 2007; Nimuendajú 2004; Palmatary 1960; Roosevelt 1993; Schaan 2012). Roosevelt (1992) envisages a chiefdom-level society, which may have control over a territory

of 23 km² with densely populated settlements encompassing a population of several thousand.

Santarém and its surroundings provide a unique setting to understand the origin, development and agricultural use of ADEs since it exhibits a diversity of ADE sites, including TP and TM, along both major waterways (Tapajós and Amazon rivers) and in *terra firme* settings along the Belterra plateau (130–180 m.a.s.l) (Figure 1 and 3) (Stenberg et al. 2012). Stenberg et al. (2012) carried out a survey

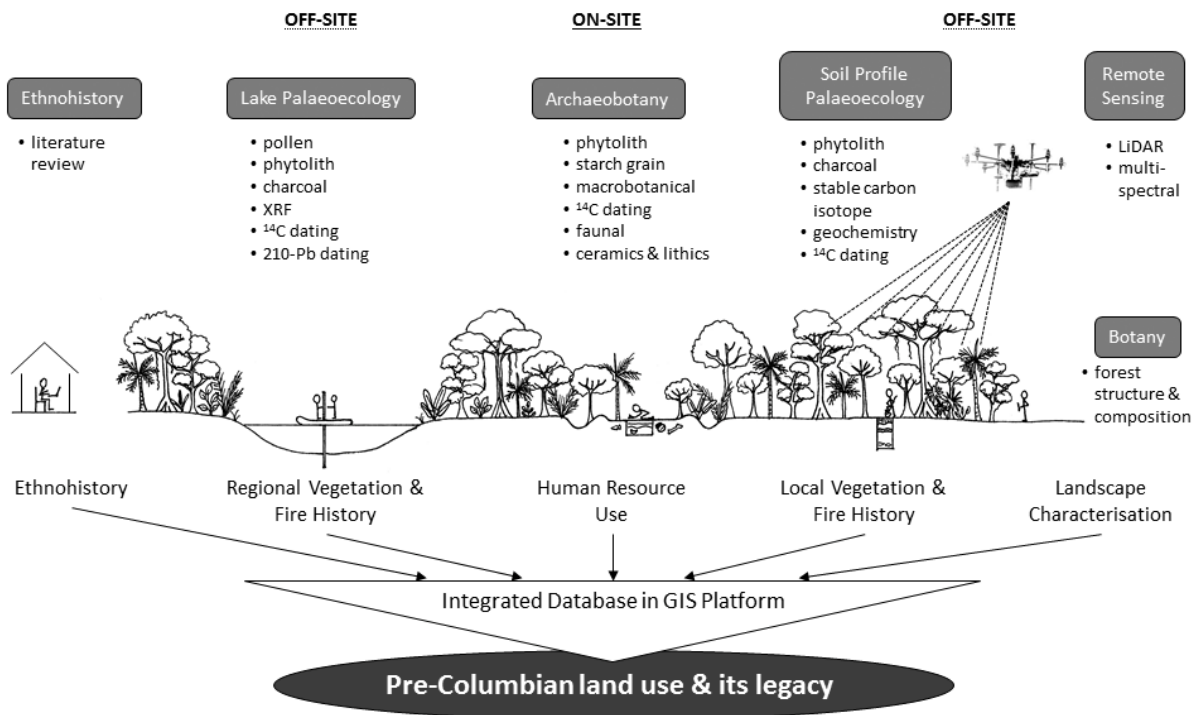


Fig. 4. Schematic diagram showing the integration of multiple techniques used by the PAST project.

which located 104 sites along the Tapajo River and the Belterra plateau, the majority of which are ADE sites. Site size ranges from small sites merely covering 1 ha (Guari) to large sites, such as Santarem Aldeia, that can be spread over 16 ha. Based on this survey, the authors have classified the sites in three main categories: (i) large sites, located close to main water course which contain high concentrations of artefacts, deep ADE deposits occurring in few numbers (e.g., Santarem Aldeia); (ii) large sites, which may or may not be located close to main watercourses and contain lower concentrations of artefacts, thinner ADE deposits (in many cases of lighter colour corresponding to TM) occurring in few numbers (e.g. Labras sites) and (iii) small sites, often located on hills with limited access to water, which contain high concentrations of artefacts and ADE deposits of varying depth (e.g., Bom Futuro). The detailed chronology of these sites is presented in the remaining chapters of this book.

Importantly, this survey has identified a clear gradient between TP>TM>*terra firme* Oxisols at several sites in the Belterra plateau including Cedro, Bom Futuro and recently surveyed sites like Serra do Maguari in FLONA. These sites represent an ideal opportunity to understand the differences in the origin and use of these different

anthropic and natural soils which are of particular interest for the application of the methodology described below.

To understand the agricultural use of ADEs we are employing a multi-pronged methodological approach that combines complementary fossil plant proxies from different contexts to study the plant component of past diets, land-use management techniques, as well as changes in vegetation and fire regimes at the local and regional level. The methodology employed in this project is an outgrowth of previous approaches that have been successfully applied by our team in other parts of the Neotropics including coastal French Guiana (Iriarte et al. 2012; McKey et al. 2010), Llanos de Moxos, Bolivia (Brownen et al. 2013, 2014; Dickau et al. 2012) and Acre, Brazil (Watling 2014; Mayle and Iriarte 2014).

Figure 4 illustrates our methodology. The approach combines data from archaeological sites. ‘On-site’ refers to regional data, ‘off-site’ includes lake and terrestrial palaeoecology, botanical inventories and remote sensing. This approach integrates different fossil and modern plant proxies recovered from different contexts that generally complement themselves in terms of preservation, taxonomic resolution and spatial scale.

Archaeobotanical studies at the 'on-site' level

We will employ the state-of-the-art battery archaeobotanical techniques at the archaeological site level to acquire general data about human resource use and diets including macrobotanical remains, phytoliths and starch grains. For example, in ADE sites we plan to carry phytolith, starch-grain, charcoal and macro-botanical analyses from: (i) a diversity of selected archaeological features, such as habitation floors, midden refuse areas, "ritual" pits (bolsões) and funerary urns, (ii) column samples from soil-depth profiles taken during archaeological excavations, and (iii) residues from the plant-processing tools and containers recovered in excavations (e.g. plant grinding stones, potential stone grater teeth, ceramic containers).

Phytolith are particularly advantageous in these contexts. They decay in place and are well-preserved in tropical soils. Importantly, phytolith can be used to identify important cultigens such as maize, squash, bottle gourd and the root crops manioc, arrowroot (*Maranta arundinacea*), and leren (*Calathea alluioia*), among others (e.g. Ezell et al. 2006; Piperno 2006). Moreover, diagnostic phytoliths are produced in more than one structure of some crops plants (e.g., maize). Fires also leave diagnostic records in the form of charred, but still morphologically identifiable, phytoliths that document ignition of both woody and non-woody taxa. These characteristics make phytolith analysis unrivalled as a tool for studying past agricultural landscapes. Since traditional tropical agricultural systems usually grew a diversity of crops in one plot, it is good practice to sample a series of closely spaced locations on each exposed horizontal layer of ADE. By creating a composite sample from each layer we increase the probability of recovering phytoliths from the full range of crops grown in them. We will also collect control samples from *terra firme* forest where ADEs are absent for comparative purposes. This will allow us to distinguish between background noise, phytoliths and starch grain patterns that reflect human selection of plant species. For example, if TM is the result of slash and char technique (e.g. Steiner et al. 2004), then phytolith assemblages should be dominated by burnt grass (Poaceae), herbs (e.g. Cyperaceae, *Heliconia*, among others)

and crop residues –with little evidence of arboreal taxa.

Starch-grain analysis is crucial for documenting the presence of certain economically important tubers such as sweet potato, achira (*Canna edulis*), yam (*Dioscorea* sp.) and legume grains (e.g. *Phaseolus*), which are unidentifiable from their phytoliths (e.g. Iriarte et al. 2004; Perry 2004; Piperno et al. 2000). Flotation of selected archaeological features to recover potential charred plant macro-remains should be carried out in tandem from these different contexts. Previous work from our lab combining all these plant proxies have provided evidence, for the first time, of the diversity of plants consumed in the Bolivian Amazonian in pre-Columbian times (Dickau et al. 2012).

Palaeoecological studies

Lake palaeoecology

In tandem with 'on-site' archaeobotanical analysis, palaeoecological studies can provide information about the regional and local vegetation and fire histories. Lake sediment cores were taken around Alter de Chao city and in Lake Carana in Flona (Figure 5). Pollen, phytoliths and charcoal analyses of radiocarbon dates will be undertaken from these lake sediments to provide a detailed history of changes in forest cover, floristic composition and fire regimes over at least the last four thousand years, spanning the duration of the pre-ADEs Formative period (1100 B.C.) to the Santarém culture period (c. A.D. 1000–1600). As Mayle and Iriarte (2014) argue, 'Palaeoecological studies, based on analysis of micro/macroscopic plant remains within lake sediments (e.g., pollen, charcoal, phytoliths), typically comprise continuous, uninterrupted time series spanning sub-centennial to multi-millennial and sometimes even glacial e interglacial time-scales. If cultural indicators are found within these lake sediments (e.g. evidence of agriculture, arboriculture, deforestation, burning), then the culture identified via artefactual remains at a nearby archaeological site may be placed within a potentially high-resolution temporal framework via its cultural legacy recorded in the neighbouring palaeoenvironmental record of radiocarbon-dated lake sediments.' Prior research

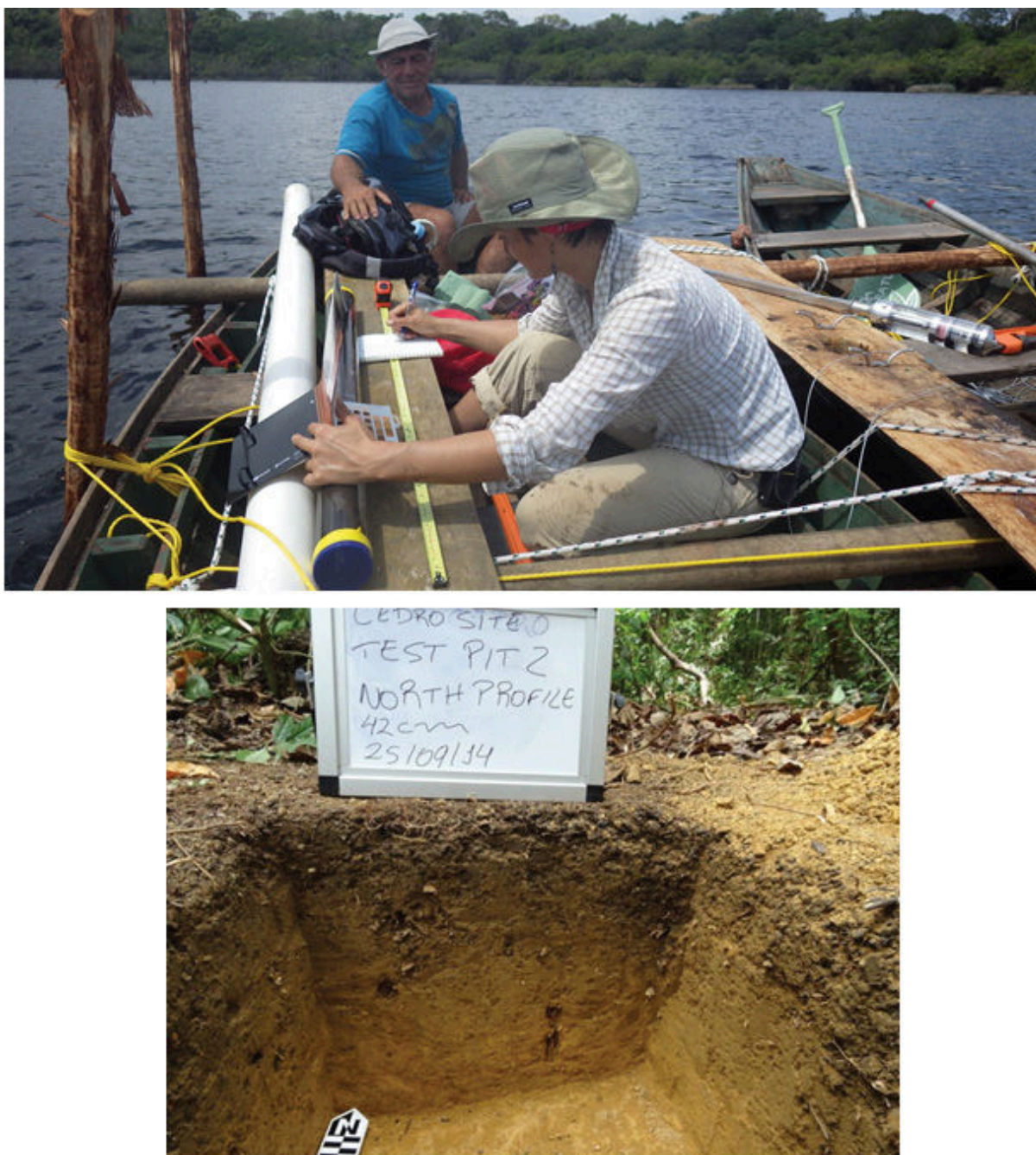


Fig. 5. Top. Palaeoecologist Shira Yoshimi Maezumi coring at Lake Carana (FLONA). Bottom. Profile of Terra Mulata at the Cedro site under excavation by Daiana Alves.

in Iriarte's and Mayle's labs has shown that the different ecosystems of lowland Amazonia can be reliably differentiated through phytolith and pollen analysis (e.g. Burn et al. 2010; Dickau et al. 2013; Watling et al. n.d.), demonstrating that past changes in forest cover and floristic composition can be detected from lake sediment pollen records. For example, past spatio-temporal changes in open herbaceous vegetation, old-growth forest, and early-successional forest, can reliably be distinguished by both pollen and

phytolith analyses (e.g. Gosling et al. 2009; McMichael et al. 2012). These palaeo-vegetation proxies also have the potential to identify more subtle compositional changes in past vegetation communities, especially in light of recent methodological advances. For instance, pollen of the important neotropical tree family Moraceae, which dominates most Amazonian forest pollen records, can now not only be differentiated from Urticaceae pollen, but also be identified to genus level; e.g., *Brosimum*, *Pseudolmedia*, *Pourouma*,



Fig. 6. Left. Archaeologist Per Stenborg mapping the Irundaba site with Differential GPS. Bottom. Botanists Edmar Almeida and Izaias Brasil da Silva carrying out botanical inventories at Serra do Maguari (FLONA).

Maquira, *Sorocea*, *Maclura*, *Helicostylis* (Burn and Mayle, 2008). More importantly for our study, several crops (e.g., maize, *Manihot*, *Ipomaea*) and tree taxa of potential economic importance (e.g. *Mauritia*, *Sorocea*, *Brosimum*) are identifiable by their pollen (e.g. Burn and Mayle 2008; Herrera and Urrego 1996; Iriarte et al. 2012). Furthermore, improvements to the technique for concentrating large, rare pollen grains from lake/bog sediment samples (Whitney et al. 2012) now means that palynologists' ability to detect the pollen of important cultigens, such as maize, manioc, and sweet potato, is greatly enhanced.

Soil profile transects

In addition, transects of soil profiles can provide a local, fine scale resolution of vegetation, fire history and human modification of soils. This methodology is particularly appropriate to create a transect of soil profiles that transverse the gradient TP > TM > Oxisols in selected sites like Cedro, Bom Futuro or Maguari (Figure 5). The

local scale of test units will be complemented with the more regional signature and higher temporal resolution of lake sediments. Soil phytolith analysis is an unrivalled tool to study agricultural landscapes in soils, especially in the absence of pollen which is poorly preserved within soils. They are deposited in place, well-preserved in tropical soils, and diagnostic records left by fires in the form of charred phytoliths. Importantly, the conflagration of herbs and grasses usually results in ash which cannot be detected by charcoal analysis, but this can be documented in the form of burnt phytoliths from these plant types. Building upon previous work (Dickau et al. 2013; Watling 2014), our laboratory has laid the groundwork to distinguish different types of Neotropical forests, early successional growth typical of human disturbance, and crop plants that will provide direct evidence of agriculture through the phytolith signature they leave in soils. Charcoal analysis is another major component of this study. Natural fires in Amazonia are rare today,

but fire was a mainstay of pre-Columbian land use in the tropics, therefore macroscopic charcoal recovered in terrestrial test pits and lake sediments will provide evidence of past human disturbance. In addition, soil geochemistry including total organic carbon (TOC), pyrogenic carbon (black carbon, BC), phosphorus and calcium levels can detect human presence such as settlement sites or agriculture. Both TOC and BC can be indicative of the anthropogenic enrichment of soils and agricultural burning, respectively. Total phosphorus (P) has been used to detect man-made soils, particularly settlement sites and exchangeable Ca, Mg, K, among other elements that are often associated with ADE soils (McMichael et al. 2012). Soil organic matter stable carbon isotopes also represent a good proxy for detecting coarse changes in forest (C3) vs. human-cleared forest openings (C4) that, alongside charcoal and soil geochemistry, can detect changes in land use.

Collectively, the multi-proxy analysis from different contexts (archaeological site, lake and terrestrial soil profiles) will allow us to reconstruct pre-Columbian land use and the degree of forest perturbation. For example, synchronous increases in *Cecropia* (a pioneer weed-tree), charcoal, economically important plants both wild and domesticated (e.g. *Mauritia* and *Sorocea* palms, maize, manioc and arrowroot domesticated plants), grasses and herbs, are coincident with a decrease in forest cover. Together they would provide a very strong suite of evidence for the onset of enhanced anthropogenic impact, especially if they correlate with the onset of earthwork construction and/or ADE sites. Conversely, the inverse of these trends would signify the reduction of human impact and the onset of forest recovery.

It is anticipated that pollen, phytolith, and charcoal analyses from lake cores will provide a regional-scale vegetation and fire history spanning most of the Holocene that will spatially complement the local-scale phytolith- and charcoal-based vegetation and burning histories from the soil-depth profiles. In turn, this data will be compared with eastern Amazonian pollen records which show that human populations were likely altering the landscape with fire from the start of the Holocene (Behling 1996), producing significant forest disturbances around 5600 yr B.P.

and demonstrating the introduction of maize by 3350 yr B.P. (Bush et al. 2000). Closer to our study region, it will be interesting to test the changes in the landscape recorded during the Holocene by the multi-proxy record obtained by Irion et al. (2006) from the Lower Tapajos River. Although this record has very poor chronological resolution, the study suggests important changes in the landscape that predate the formation of ADEs in the region. A more significant change in this record took place between ca. 5500 and 4200 cal. yr B.P. and shows an increase in grasses (Poaceae) at the expense of the pioneer tree *Cecropia* coinciding with a transition from coarser to finer sediments. As a tentative explanation, Irion et al. (2006) suggested that this was likely spurred by climatic change which resulted in the formation of local grasslands. A close comparison of this record with the ones we are processing and the archaeology of the region will help us disentangle natural vs anthropic factors that resulted in these landscape changes which curiously predate the known dates of ADE formation in the region.

Botany and remote sensing: The modern legacy of past land management of ADE sites

To assess the modern legacy of pre-Columbian human disturbance, the reconstructions of the vegetation and fire histories will be compared with modern forest inventories and remote sensing data allowing us to determine whether the modern forest structure and composition are correlated with palaeoecological evidence of historical disturbance. If so, remote sensing information will be used to quantify what the extent of these transformations are.

Floristic inventory

In our study region we will set up permanent vegetation plots in ADE sites and control areas to create inventories of all plant species >10 cm in diameter at breast height (DBH), paying particular attention to species of economic importance based on ethnobotanical works and previous inventories of anthropogenic forests (Figure 6) (Junqueira et al. 2011). Metrics of species richness, species evenness, similarity/dissimilarity, tree density, DBH distribution, biomass and alpha- and beta-diversity

will be calculated so that floristic comparisons can be made between ADE and non-ADE sites.

Remote sensing

To characterize and quantify the extent of pre-Columbian human-modified forests, we will also use a combination of multi-scale remote sensing information including: (1) a novel concept of very high resolution multi-spectral and Light Detection and Ranging (LIDAR) data from sensors mounted onboard an Unmanned Aerial Vehicle (UAV); (2) high spatial resolution Landsat data (30m spatial resolution); (3) high temporal resolution Moderate Resolution Imaging Spectroradiometer (MODIS) data (250–500 m spatial resolution). The proof of concept is currently being developed with the support of INPE (National Institute for Space Research of Brazil). We envision collecting spectral and structural forest data with the UAV in conjunction with Landsat spectral signatures allowing for the extrapolation of plot features at landscape level. Due to its high temporal resolution (daily images) MODIS data will support the spectral analysis by providing phenological (temporal) signatures of the forest sites surveyed. Recent studies showed that distinct spectral patterns from orbital sensors, such as Landsat and MODIS, can be used to estimate the extent of different types of *terra firme* forests, such as bamboo (de Carvalho et al. 2013), and palm-dominated forest (Nelson 2006), which may be the result of anthropogenic disturbances. They also show promise for detecting anthropogenic forests in ADEs (Thayn et al. 2011). The design of the field plots encompassing areas with a known history of pre-Columbian anthropogenic disturbances and areas without human interference will provide a

basis for evaluating changes in the spectral and structural variables between forested ADE and non-ADE sites. The successful application of this powerful, cost-efficient and portable airborne LIDAR technology certainly has the capacity to revolutionise Amazonian archaeology.

Concluding remarks

In summary, a close integration between these different approaches can help us answer critical questions in the current debate about the nature and scale of the past human impact in the Amazon. Collectively, the results from these innovative palaeoecological, botanical, soil science and remote sensing techniques in combination with other lines of archaeological evidence such as site distribution maps, features, and artefact density will provide much more detailed and conclusive evidence about past human diets, land use, and ecosystem impacts than would otherwise be possible. These are interesting times for Amazonian archaeology.

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Properties of Amazonian Dark Earths at Belterra Plateau, Pará, Brazil

Jan Eriksson, Mats Söderström and Christian Isendahl

Introduction

The value of anthropogenic soils known as Amazonian Dark Earths (ADE; broadly subdivided into black colored *terra preta* and more brownish *terra mulata*) for understanding the prehistory of the Amazonian cultural landscape and as a resource for sustainable agriculture has been recognized for some time (Smith 1980; Sombroek 1966). Pioneering work on this phenomenon was undertaken by Hartt in the 1870s, Katzer in the 1890s, and Nimuendajú in the 1920s (Hartt 1874; Katzer 1903; Nimuendajú 2004). Multidisciplinary investigations of ADE began during the 2000s (e.g. Glaser and Birk 2012; Glaser and Woods 2004; Lehmann et al. 2003; Woods et al. 2009). Data collected indicate that ADE formed as a result of anthropogenic redistribution and the concentration of soil nutrients through domestic and agricultural activities during the prehistoric period, including accretion of soil organic matter from long-term concentrated settlement and “slash and char” agriculture resulting in a high content of pyrogenic carbon (biochar) through pyrolysis (Steiner et al. 2004). While organic matter normally decomposes rapidly under tropical climate conditions, pyrogenic carbon is resistant and increases the long-term nutrient and water holding capacity of the soil. In contrast to the strongly weathered Ferralsols that dominate the region, ADEs have a higher pH, soil organic carbon (SOC) content, cation exchange capacity (CEC), concentration of elements such as phosphorus (P), calcium (Ca), and magnesium (Mg), and are more resistant to leaching. ADEs were recently recognized as a soil unit within the Anthrosol reference soil group of the WRB classification system (WRB, 2014)

through the introduction of a new diagnostic surface horizon, the pretic horizon.

An ADE can be classified as Pretic Anthrosol if it has a pretic horizon, the layers of which have a combined thickness of ≥ 50 cm, within ≤ 100 cm of the mineral soil surface. A pretic horizon has a dark color, a SOC content of ≥ 10 g kg⁻¹, a base saturation (BS) of $\geq 50\%$, an exchangeable Ca plus Mg concentration of ≥ 2 cmol_c kg⁻¹ and the Mehlich 1 extractable P is ≥ 30 mg kg⁻¹. In addition it contains $\geq 1\%$ of artefacts (by volume) and/or the charcoal content is $\geq 1\%$ (by volume) and/or it has evidence of past human occupation in the surrounding landscape. As an anthropogenic soil resulting from pre-Columbian human activities, ADE forms one of the most important and complex archaeological data sources for understanding Amazonian prehistory. The presently known distribution of ADE sites is concentrated to relatively accessible areas on the floodplain bluffs along the main waterways of the Amazon watershed and in and around current population centers such as the city of Santarém, where ADE was originally described (Hartt 1874; WinklerPrins and Aldrich 2010). Notwithstanding the increasing intensity in ADE research over the last decade, however, the current site record poorly represents the full range of ADE distributions (WinklerPrins and Aldrich 2010). ADEs are also present in areas away from the main waterways.

An important task for the soils section of the “Cultivated Wilderness” project was to investigate if hand-carried field proximal soil sensing (PSS) could be used to map the extent of patches of ADE. The results from the PSS measurements are presented by Mats Söderström in another chapter in this book. In this chapter the focus is

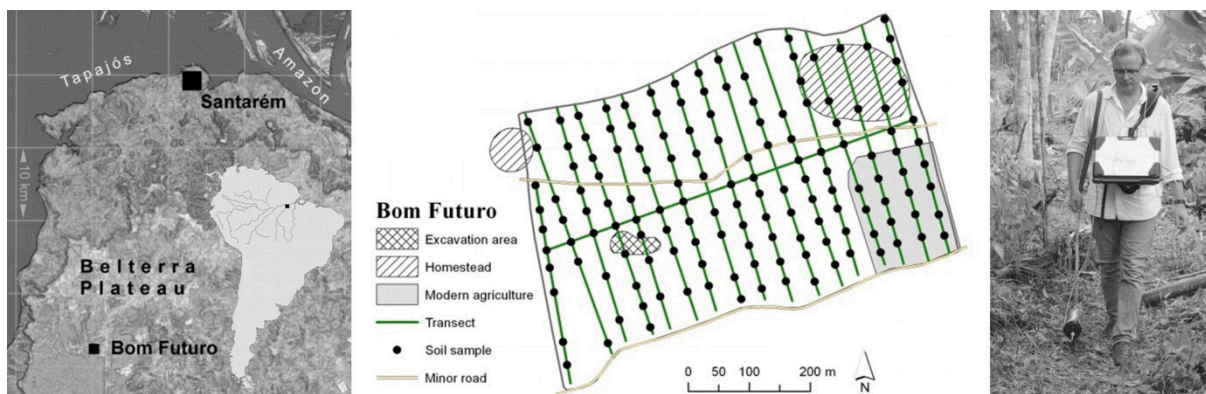


Fig.1. Location and of the Belterra plateau south of Santarém, in Pará, Brazil, and a map showing the study area at Bom Futuro and the transects from which soil samples were taken (Illustration: Mats Söderström).

on properties of soils in the investigated areas with a focus on ADEs. Data from our studies in one of the investigated areas, Bom Futuro, have also been published in Araújo et al. (2015) and Söderström et al. (2013).

Study areas

The soil studies were carried out on the Belterra Plateau, 20 - 40 km south of the city of Santarém in the state of Pará, Brazil (Figure 1). The Belterra Plateau is an upland environment elevated ca. 150 m above the Amazon and Tapajós River floodplains. Geologically it is part of the Cretaceous Alter do Chão Formation. One 28-ha study area was located at the Bom Futuro farm ca. 40 km south of Santarém. Archaeological excavations in the southwest sector of the study area (Figure 1) demonstrate that farmers had settled at this location by at least the late prehistoric period and occupied the area into the early contact period (c. 14th–17th centuries A.D.; unpublished data). Soil samples down to 20 cm were taken in transects covering the study area. Soil profiles were sampled and described in the excavation area in the south west and in the arable field in the south east.

The São Francisco research area is located ca. 20 km south-southwest of Santarém city. The area covered by ADE soil extends over slightly more than 10 hectares. In the last 8 years most of this area had been under soybean and maize cropping using modern agricultural methods. The ADEs at this location were very characteristic in colour, but also demonstrated an interesting pattern of soil colour variation that is hypothetically linked to differences in intra-site settlement patterns. The areas that had the darkest soils had a high density of ceramics on

the surface. Soil was also at the São Francisco site sampled in transects laid out over the soil with clear ADE character (Figure 2). Reference soils (non-anthropogenic natural soils) were also sampled (the northernmost and southernmost sampling points). Soil profiles were sampled and described at the locations indicated in Figure 2.

Analyses

Soil pH was measured in a soil:solution ratio of 1:2.5; Soil organic carbon (SOC) content was determined by wet oxidation with K-dichromate using a modified Walkley & Black method

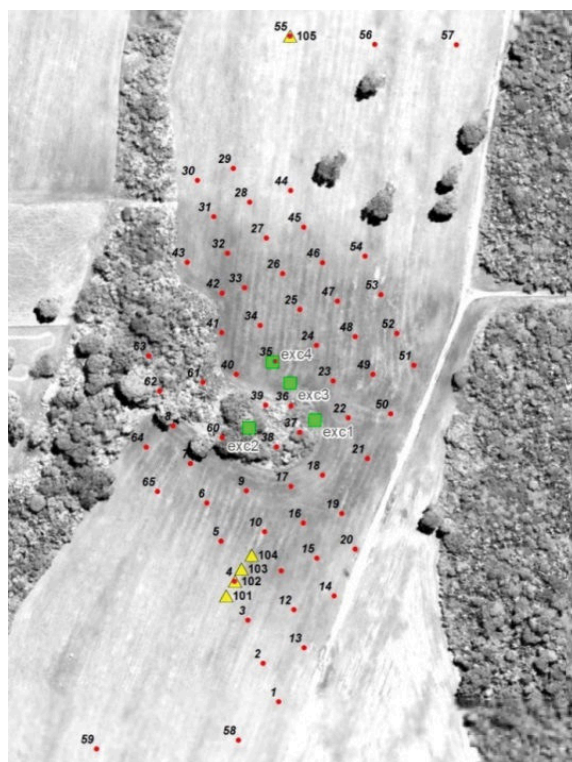


Fig. 2. Sampling points (red dots) and soil profiles (yellow triangles) at São Francisco (Illustration Mats Söderström).

(Embrapa, 2009); extractable P by Mehlich 1; exchangeable calcium (Ca^{2+}), potassium (K^+), magnesium (Mg^{2+}), and acidity were extracted with 1 M calcium acetate at pH 7; and exchangeable aluminum (Al^{3+}) with 1 M KCl. Exchangeable acidity ($\text{H}^+ + \text{Al}^{3+}$) was determined volumetrically by a back-titration of the acetate extract with NaOH in the presence of phenolphthalein as an indicator. All exchangeable cations were analysed with atomic absorption spectrophotometry (AAS). Contents of sand (2–0.05 mm), silt (0.05–0.002 mm), and clay (< 0.002 mm) were determined by the densimeter-sedimentation method, using calcium hexametaphosphate 0.1 M and sodium hydroxide 0.1 M as dispersing agents (Gee et al. 1986). Cation exchange capacity at pH 7 (CEC) and corresponding base saturation (BS) were calculated from analyses results of base cations and exchangeable acidity.

The soils at Bom Futuro

The average soil organic carbon concentration of the upper 20 cm of the soil in the Bom Futuro research area is 23 g kg⁻¹ (Table 1). Eighty per cent of the values are in the range of 18–30 g kg⁻¹. Concentrations in the lower end of or below this range were found in the eastern part of the area (Figure 3), which was affected by

homestead domestic activities and modern cash crop production. Organic litter is continuously swept from the ground by residents of the present homestead. The soil surface is also hardened by trampling which further promotes the removal of loose organic litter by wind action. The lower C content in the arable field is probably a result of tillage, which promotes decomposition. Harvest of biomass also promotes lower soil C content unless compensated for by an increased production of roots and crop residues due to fertilization. The highest organic C concentrations were found in the sector where prehistoric and early historic settlement remains were excavated and in the kitchen garden plots of the homestead in the north western part of the area.

The depth of the A-horizon enriched in organic matter is larger than the average at the excavated site in the arable field and in the area north of the homestead. In these places the A-horizon frequently reaches below the 20 cm sampling depth (Figure 3). The thicker A-horizon in the arable field correlates with the depth of soil tillage, but fails to meet any other requirement for an ADE other than high Mehlich 1 P content. Whether the relatively thick A-horizons north of the homestead are owing to prehistoric or present land use, or any other factor, is unclear.

Table 1. Summary statistics of soil properties (0 – 20 cm depth) at Bom Futuro (n = 148).

| Soil property | Mean | Min | 25%-per-centile | Median | 75%-per-centile | Max |
|--------------------------------------------------------|------|-----|-----------------|--------|-----------------|-----|
| A-horizon depth (cm)* | 9 | 0 | 5 | 8 | 12 | 20 |
| SOC (g kg ⁻¹) | 23 | 10 | 20 | 23 | 26 | 38 |
| pH-H ₂ O | 5.0 | 4.0 | 4.6 | 4.9 | 5.3 | 6.1 |
| pH-KCl | 4.3 | 3.6 | 3.9 | 4.2 | 4.6 | 5.5 |
| P-Mehlich1 (mg kg ⁻¹) | 10.2 | 2.0 | 4.0 | 5.0 | 9.3 | 117 |
| Ca ²⁺ (mmol _c kg ⁻¹) | 32 | 2 | 12 | 26 | 42 | 128 |
| K ⁺ (mmol _c kg ⁻¹) | 1.2 | 0.5 | 0.8 | 1.0 | 1.2 | 3.1 |
| Mg ²⁺ (mmol _c kg ⁻¹) | 10 | 1 | 5 | 9 | 12 | 36 |
| Al ³⁺ (mmol _c kg ⁻¹) | 9 | 2 | 2 | 5 | 14 | 29 |
| Exchangeable acidity (%) | 59 | 26 | 49 | 59 | 70 | 102 |
| CEC (mmol _c kg ⁻¹) | 102 | 48 | 86 | 96 | 113 | 197 |
| Base saturation (%) | 39 | 4 | 24 | 39 | 53 | 87 |

* The real A-horizon depth is deeper than 20 cm in some sampling points, but only the upper 20 cm were sampled so the exact depth is unknown.

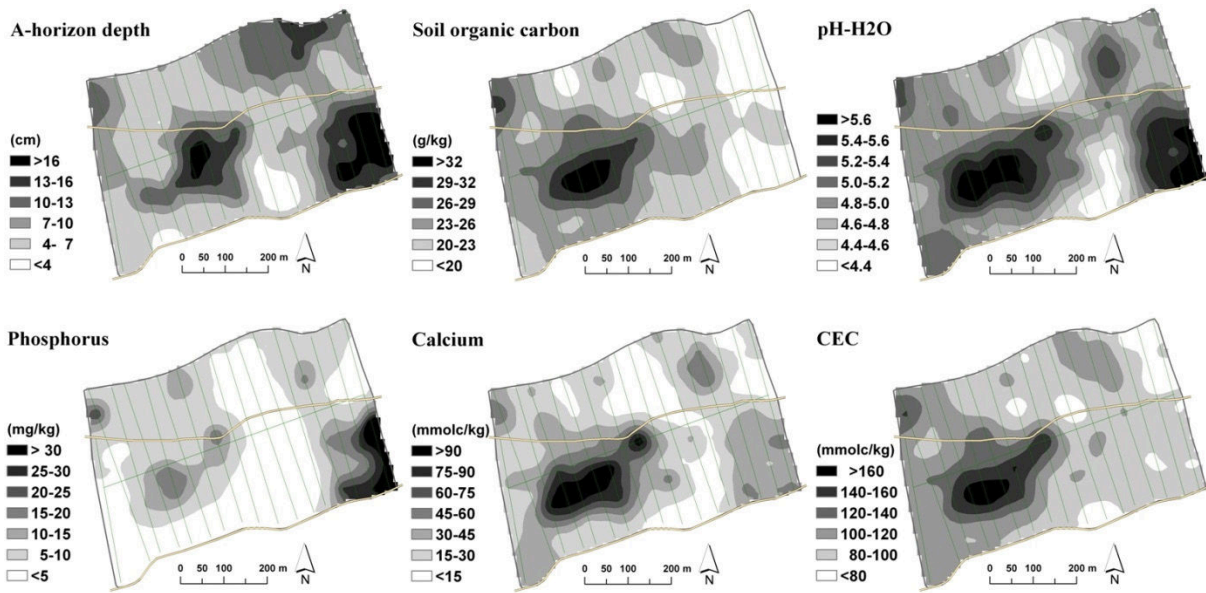


Fig. 3. Interpolated maps of soil properties normally used as indicators of ADE soils. (Illustration Mats Söderström).

In the research area, pH-H₂O ranges from 4.0 to 6.1 with an average of 5.0. Eighty percent of the values are in the range of 3.6 to 5.5. For pH-KCl the average is 4.3 (Table 1). The lower pH in the KCl solution indicates that the soil material has a negative net charge. Elevated pH values were recorded in the arable field and the excavated ancient settlement area. This is presumably due to liming in the arable field. The pH values in other areas vary from low to moderate in a rather irregular pattern. This variation is probably related to the mosaic spatial pattern of shifting cultivation intensity, i.e. the ash produced when trees are felled and burned increases the pH of the soil in newly opened clearings.

The average Mehlich soluble P concentration is 10 mg kg⁻¹. Values are highest around homesteads, present and past, indicating influence from P-rich kitchen waste, particularly bones. However, only seven samples had P concentrations above the 30 mg kg⁻¹ required for a pretic surface horizon according to WRB (2014). The anthropogenic soil profile in the excavated settlement area has P concentrations up to 350 mg kg⁻¹ in the 53 cm deep pretic A-horizon. The high phosphorus level in the arable field is probably mainly due to P fertilization. P levels are very low in areas not clearly influenced by human activities. This is characteristic for the strongly weathered Ferralsols that dominate the area. These are poor in P and have a great capacity to adsorb P in a form not readily available to plants. Phosphorus adsorption capacity increases with decreasing soil pH.

The spatial variation in CEC largely reflects the variation in C content (Figure 3) indicating that most of the CEC can be ascribed to negative charges on organic matter and charcoal. Data from the sample sites with the lowest organic matter content and from deep horizons in soil profiles presented in Araújo (2012) indicates a CEC of less than 50 mmolc kg⁻¹ of soil not influenced by human activities. Calcium is the dominating cation in soils with pH-H₂O of 5.0 and higher. In more acid and usually less C-rich soils Al³⁺ is the dominating cation. Al³⁺ takes over the exchange complex when its solubility increases at a low pH. Thus, the spatial variation in Al³⁺ is largely a mirror image of the variation in pH. There is also a very close correlation between pH and base saturation. The base cations Ca²⁺, Mg²⁺ and K⁺ tend to be highest where C content is highest, a reflection of higher CEC and less competition from Al³⁺ due to a higher pH at those locations. In the arable field the concentration of K is high despite a fairly low CEC, indicating inputs from fertilization. The Ca in the anthropogenic soils may have been supplied from bones. The calcium carbonates in bones have probably also had a lime effect on anthropogenic soil layers.

A soil profile (Figure 4 and Table 2) on a minor platform in the excavation area (Figure 1), interpreted as the remains of a dwelling, was classified as Pretic Anthrosol (Clayic, Orthodystric, Ferralic) (WRB, 2014).

Table 2. Properties of the ADE soil profile in the excavation area at Bom Futuro.

| Depth, cm | SOC, g kg ⁻¹ | pH-H ₂ O | pH-KCl | P, mg kg ⁻¹ | Clay, % | Silt, % | Sand, % |
|-----------|-------------------------|---------------------|--------|------------------------|---------|---------|---------|
| 0-8 | 57 | 6.4 | 5.9 | 348 | 68 | 17 | 16 |
| 8-30 | 27 | 6.0 | 5.3 | 209 | 80 | 10 | 10 |
| 30-53 | 27 | 5.7 | 4.8 | 354 | 75 | 15 | 10 |
| 53-88+ | 3 | 5.4 | 4.6 | 149 | 86 | 7 | 7 |

| Depth cm | K ⁺ | Ca ²⁺ | Mg ²⁺ | Al ³⁺ mmol _c kg ⁻¹ | Acidity | CEC | BS % |
|-------------|----------------|------------------|------------------|--------------------------------------------------------|---------|-----|---------|
| 0-8 | 1.7 | 144 | 11 | 2 | 52 | 209 | 75 |
| 8-30 | 1.0 | 91 | 15 | 2 | 66 | 172 | 62 |
| 30-53 | 0.6 | 85 | 13 | 3 | 103 | 201 | 49 |
| 53-88+ | 0.3 | 26 | 5 | 2 | 37 | 68 | 46 |



Ah1 0-8 cm, abrupt wavy boundary; black (10YR 2/1) dry, clay; moderate to strong very fine to medium angular blocky; < 1 mm channels in peds; common very fine to fine roots, ashes in between aggregates.

Ah2 8-53 cm, clear wavy boundary; yellowish gray (2.5Y 4/1) dry, few to common very fine distinct mottles, clay; very small orange (bricklike) mottles (1%); moderate fine angular blocky; few very fine to fine roots, few earth worm channels; charcoal (1-3%), layers of B-horizon character (ca 5%), pottery sherds (1-2% of surface area).

Bo 53-88+ cm; dull yellow orange (10YR 6/4 in upper part, 10YR 6/5 lower part) moist, clay; weak to moderate very fine to fine subangular blocky; very few fine and very few medium roots.

Fig 4. (Above) Soil profile description of an ADE at Bom Futuro of the Terra preta type at Bom Futuro. Photo: Jan Eriksson.



Fig. 5. (Left) Classification of sampling points in transects based on the grey scale in Fig 2. Dark red background, dark blue points = strong ADE character; orange background and light blue points = medium ADE character; yellow background: pink = weak ADE character (transitional) and yellow points = non ADE (reference). (Illustration Mats Söderström).

Table 3. Soil properties at São Francisco. Averages for the 0–20 cm layer for all soil groups except those where another depth is given.

| | n | pH- H ₂ O | pH- KCl | P mg kg ⁻¹ | K ⁺ | Ca ²⁺ | Mg ²⁺ mmol _c kg ⁻¹ | Al ³⁺ | Acidity | CEC | BS % | SOC g kg ⁻¹ |
|----------------------|----|-------------------------|------------|--------------------------|----------------|------------------|--------------------------------------------------------|------------------|---------|-----|---------|---------------------------|
| All soils | 65 | 6.3 | 5.5 | 117 | 3.5 | 99 | 19 | <1 | 33 | 155 | 76 | 37 |
| Arable soils: | | | | | | | | | | | | |
| Reference | 5 | 5.3 | 4.6 | 23 | 1.7 | 38 | 7 | 3 | 56 | 102 | 45 | 23 |
| ADE min | 9 | 6.2 | 5.4 | 36 | 3.4 | 61 | 13 | <1 | 35 | 113 | 66 | 27 |
| ADE medium | 17 | 6.4 | 5.6 | 88 | 4.0 | 97 | 20 | <1 | 30 | 151 | 79 | 37 |
| ADE max | 26 | 6.6 | 5.7 | 180 | 4.0 | 125 | 23 | <1 | 27 | 179 | 85 | 42 |
| Forest soils: | | | | | | | | | | | | |
| Reference | 2 | 5.9 | 5.2 | 14 | 1.6 | 93 | 22 | <1 | 57 | 173 | 68 | 36 |
| ADE | 6 | 6.1 | 5.3 | 158 | 2.8 | 103 | 21 | <1 | 39 | 166 | 76 | 41 |
| Deep ADEs: | | | | | | | | | | | | |
| 0-20 cm | 28 | 6.4 | 5.7 | 170 | 4.3 | 127 | 24 | 1 | 29 | 184 | 84 | 45 |
| 20-40 cm | 28 | 6.2 | 5.4 | 113 | 2.1 | 75 | 15 | 1 | 30 | 122 | 75 | 24 |

Table 4. Correlation coefficient (r) matrix* for properties of top soils (0 – 20 cm) collected at São Francisco (n = 65).

| | SOC | pH-H ₂ O | pH-KCl | ln(P) | Ca ²⁺ | K ⁺ | Mg ²⁺ | Acidity | CEC |
|---------------------|-------|---------------------|--------|-------|------------------|----------------|------------------|---------|-------|
| pH-H ₂ O | 0.39 | | | | | | | | |
| pH-KCl | 0.47 | 0.79 | | | | | | | |
| ln(P) | 0.60 | 0.52 | 0.60 | | | | | | |
| Ca ²⁺ | 0.78 | 0.63 | 0.78 | 0.80 | | | | | |
| K ⁺ | 0.49 | 0.51 | 0.50 | 0.50 | 0.55 | | | | |
| Mg ²⁺ | 0.78 | 0.55 | 0.59 | 0.56 | 0.82 | 0.53 | | | |
| Acidity | -0.21 | -0.72 | -0.76 | -0.51 | -0.63 | -0.35 | -0.48 | | |
| CEC | 0.87 | 0.47 | 0.61 | 0.73 | 0.94 | 0.56 | 0.86 | -0.34 | |
| BS | 0.56 | 0.76 | 0.88 | 0.68 | 0.88 | 0.501 | 0.75 | -0.87 | 0.708 |

* Prob.-values: Dark grey box = p < 0.001, light grey box = p < 0.01; grey italic = not significant.

The soils at São Francisco

The presence of pyrogenic carbon gives ADEs a darker colour. We therefore tried to classify soils at São Francisco based on colours in the panchromatic, high-resolution satellite image shown in Figure 2. The resulting map shows that the most strongly developed ADEs surround the narrow strip of forested land that stretches eastwards into the field (Figure 5). The elongated orange strips outside the ADE area are remnants of present day burning of vegetation residues when the field was cleared for mechanized cropping. There is a depression at the tip of the forest strip and two more are situated further north.

Data from soil analysis (Table 3) show that there is a clear gradient in soil properties from

the non-anthropogenic (reference) to the soils with increasingly pronounced ADE character according to Figure 5. The analyses, together with field observations, show that the soils in the forested strip in the middle also have a strong ADE character. The average SOC content is 42 mg kg⁻¹ in the most developed ADEs on arable land compared to 23 mg kg⁻¹ in the non-anthropogenic soils. This causes a corresponding increase in CEC. The pH-H₂O also increases from 5.3 in reference soils to 6.6 in the ADEs and thus acidity decreases and BS increases accordingly. Higher CEC and higher BS in the ADE also mean that concentrations of exchangeable cations are considerably higher in the ADEs than in the reference soils. These relationships between soil

Table 5. Properties of the soil profiles studied at São Francisco.

| Depth cm | pH H ₂ O | pH KCl | P mg kg ⁻¹ | Na ⁺ | K ⁺ | Ca ²⁺ | Mg ²⁺ mmol _c kg ⁻¹ | Al ³⁺ | Acidity | CEC | BS % | SOC g kg ⁻¹ |
|-------------------------|------------------------|-----------|--------------------------|-----------------|----------------|------------------|--------------------------------------------------------|------------------|---------|-----|---------|---------------------------|
| Profile 101 | | | | | | | | | | | | |
| 0-20 | 5.8 | 4.8 | 27 | <0.2 | 2.5 | 42 | 9 | 2 | 54 | 109 | 50 | 25 |
| 20-29 | 4.5 | 4.1 | 4 | <0.2 | 0.7 | 7 | 2 | 18 | 55 | 64 | 14 | 16 |
| 39-50+ | 4.7 | 4.1 | 1 | <0.2 | 0.5 | 4 | 1 | 13 | 33 | 39 | 14 | 8 |
| Profile 102 | | | | | | | | | | | | |
| 0-19 | 4.8 | 4.2 | 10 | <0.2 | 2 | 28 | 6 | 6 | 66 | 101 | 35 | 24 |
| 19-29 | 4.7 | 4.1 | 1 | <0.2 | 0.7 | 8 | 2 | 12 | 39 | 49 | 21 | 10 |
| 34-50 | 4.7 | 4.1 | <1 | <0.2 | 0.4 | 6 | 1 | 10 | 30 | 37 | 19 | 7 |
| Profile 103 | | | | | | | | | | | | |
| 0-18 | 5.8 | 5.0 | 43 | <0.2 | 3.3 | 92 | 22 | <1 | 34 | 152 | 77 | 31 |
| 18-33 | 5.1 | 4.6 | 2 | <0.2 | 0.8 | 36 | 8 | 1 | 26 | 71 | 63 | 13 |
| 33-50 | 5.7 | 4.7 | 2 | <0.2 | 0.3 | 26 | 5 | 1 | 18 | 49 | 64 | 9 |
| Profile 103 | | | | | | | | | | | | |
| 0-24 | 5.7 | 5.6 | 36 | <0.2 | 4.5 | 149 | 14 | <1 | 29 | 197 | 85 | 49 |
| 24-35 | 5.9 | 5.1 | 6 | <0.2 | 0.9 | 73 | 13 | <1 | 14 | 102 | 86 | 17 |
| 35-50 | 6.1 | 5.6 | 4 | <0.2 | 0.4 | 44 | 8 | <1 | 9 | 61 | 86 | 11 |
| Profile 105 (reference) | | | | | | | | | | | | |
| 0-20 | 5.5 | 4.6 | 13 | <0.2 | 1.3 | 37 | 7 | 4 | 46 | 91 | 50 | 20 |
| 20-40 | 4.5 | 3.9 | 2 | <0.2 | 0.5 | 7 | 1 | 18 | 53 | 61 | 14 | 12 |
| 40-50 | 4.4 | 4.0 | 1 | <0.2 | 0.4 | 3 | 1 | 20 | 39 | 43 | 11 | 9 |
| Excavation pit 1 | | | | | | | | | | | | |
| 0-33 | 5.4 | 4.9 | 136 | <0.2 | 6.3 | 118 | 20 | 1 | 35 | 179 | 80 | 50 |
| 38-59 | 5.4 | 4.5 | 5 | <0.2 | 2.9 | 19 | 3 | 1 | 22 | 47 | 53 | 9 |
| Excavation pit 2 | | | | | | | | | | | | |
| 0-22 | 6.2 | 5.4 | 393 | <0.2 | 1.9 | 139 | 22 | <1 | 39 | 202 | 80 | 47 |
| 22-32 | 6.0 | 5.4 | 209 | <0.2 | 0.4 | 79 | 8 | <1 | 23 | 110 | 79 | 18 |
| 32-77 | 6.2 | 5.4 | 106 | <0.2 | <0,2 | 37 | 3 | <1 | 11 | 52 | 78 | 8 |
| Excavation pit 4 | | | | | | | | | | | | |
| 0-32 | 6.2 | 5.7 | 614 | <0.2 | 2.8 | 177 | 21 | <1 | 41 | 243 | 83 | 54 |
| 32-54 | 6.3 | 5.5 | 812 | <0.2 | 0.3 | 122 | 5 | <1 | 25 | 152 | 83 | 25 |
| 54-100 | 6.4 | 5.7 | 165 | <0.2 | <0,2 | 42 | 2 | <1 | 10 | 54 | 82 | 7 |



Bo 53-88+ cm; dull yellow orange (10YR 6/4 in upper part, 10YR 6/5 lower part) moist, clay; weak to moderate very fine to fine subangular blocky; very few fine and very few medium roots.

Bo 40-50+ cm; brown (10 YR 4/6) moist, clay; moderate very fine to medium granular and subangular blocky very few fine roots

Fig. 6. Soil profile description of a reference soil at São Francisco (profile 105). Photo: Jan Eriksson.



Ah1 0-32 cm; clear wavy boundary; black (10 YR 2/1) moist, brownish black (10 YR 3/2) dry, clay; fine orange mottles (burnt soil); moderate to strong granular, friable moist; sticky, plastic; common pottery sherds, common 2-4 mm charcoal pieces

Ah2 32-54 cm; clear wavy boundary; grayish yellow brown (10 YR 4/2) moist, clay; fine orange mottles (burnt soil); pottery sherds in part of the horizon, few charcoal pieces

Bo 54-100+ cm; yellowish brown (10 YR 5.5/6) moist, clay; contains spots with A-horizon character a few cm in thickness

Fig. 7. Soil profile description of an ADE at São Francisco of the Terra preta type. Photo: Jan Eriksson.

properties are confirmed by the high correlation coefficients in Table 4. Phosphorus concentrations are much higher in the ADEs than in the reference soils. Disregarding the five reference soils, over 80 % of the sampled soils had a P concentration at or higher than the 30 mg kg⁻¹ required for a pretic surface horizon according to WRB (2014). A pretic horizon shall also have a depth of 20 cm or more. The medium developed ADEs in Figure 5 had an average A-horizon depth of 22 cm according to measurements of the cores from the auger. Half had an A-horizon depth of 20 cm or more. Three fourths of the strongly developed

ADEs had an A-horizon of 20 cm or thicker; at two sites it was 40 cm and the average depth was 25 cm. The deepest A-horizon, 54 cm, was recorded in excavation pit 3.

A non-anthropogenic reference soil (nr 105 in the northern part of the area in Figure 2) was classified as Xantic Ferralsol (Clayic, Hyperdystric, Vetic) (WRB, 2014). Data and a soil profile description are presented in Table 5 and Figure 6 respectively. A proposed classification of the soils in the excavation pits (nr 1, 3 and 4 in Figure 2) would be, Pretic Anthrosol (Clayic, Eutric, Ferralic). For the soil in excavation 4 (Table 5 and



A 0-22 (19-25) cm; clear wavy boundary; dark brown (10 YR 3/3 - 3/4) moist, clay; moderate very fine to fine granular, friable moist; sticky, plastic; some charcoal pieces in lower part

AB 22-32 (29-34) cm; gradual wavy boundary; dark brown (10 YR 3/4) moist, clay; moderate fine to medium granular, friable moist; sticky, plastic

BA 32-50+ cm; yellowish brown (10 YR 5/4 - 5/5) moist, clay; weak to moderate very fine to medium granular, friable moist; sticky, plastic

Fig. 8. Soil profile description of an ADE at São Francisco of the Terra mulata type. Photo: Jan Eriksson.

Figure 7) Eutric can be detailed to Hypereutric, while the soils in excavation 1 and 3 (no soil profile descriptions presented here) presumably are Epieutric and Orthoeutric respectively (no data for depths below 77 and 59 cm respectively, see Table 5). The sequence of soils (nr 101-104 in Figure 2) in the southern part of the area has A-horizon depths of around 20 cm (Table 5). A depth of 20 cm in combination with fulfilment of criteria like a colour value ≤ 4 and a chroma ≤ 3 , a Mehlich P content of $>30 \text{ mg kg}^{-1}$ etc. shows that they have a diagnostic pretic horizon, but it is not thick enough for classification as Anthrosols. In an Anthrosol the antropogenic horizon should be at least 50 cm thick. The classification would be Pretic Xantic Ferralsol (Clayic, Hyperdystric, Vetic). A soil profile description of soil nr 103 is shown in Fig 8.

Discussion

The soils from both locations, geographically separated by 20 km, were generally very similar in properties; they are all very clayey (70-90 %). According to Irion (1984), the soils in the Central and Lower Amazon have a homogenous composition and frequently consist of more than 80 % kaolinite. The strongly weathered more or less natural soils were classified as an Xantic Acric Ferralsol (Clayic, Hyperdystric, Vetic) in Bom Futuro and Xantic Ferralsol (Clayic, Hyperdystric, Vetic) in São Francisco according to the World Reference Base for Soil Resources (WRB 2014).

These very similar classifications also indicate the homogeneity in the composition of the non-anthropogenic soils in the area.

The introduction of the pretic horizon solves the problem that the two best alternatives until now available in the WRB classification system, the hortic and plaggic horizon, only partly cover the typical character of the ADE surface horizons. The new concept introduces lower limits for the content of artefacts and charcoal and explicitly relates it to a landscape with evidence of past human occupation (WRB, 2014). The definition of the pretic horizon is similar to that suggested by Kämpf et al. (2003), but the limit for Mehlich 1 P is lower: 30 mg kg^{-1} . Kämpf et al. (2003) suggested 65 mg kg^{-1} .

Archaeologists tend to see soils subjected to modern agriculture as destroyed from an archaeological point of view. The studies at São Francisco show that this is only partly true. The stratigraphy of the superficial layer is of course broken up by tillage and the archaeological artefacts may have been broken into smaller pieces. However, in both São Francisco and Bom Futuro the studies of the soil profiles indicated a depth of tillage that was less than 20 cm meaning that a large part of the anthropogenic layers remain more or less undisturbed in the more developed ADEs. Since considerable land areas in the vicinity of these places have traditionally been used for shifting cultivation, there has also already been some disturbances to the topsoil due to the

planting of, for example, cassava and banana plants. A striking and more advantageous effect of the exposition of the soil on arable land was that the degree of development of the ADEs and the spatial distribution of the different types of ADEs was directly visible. As shown above it was also possible to make a classification of the soils based on light emittance from the surface of the soil.

Some of the chemical properties distinguishing ADEs from surrounding natural soils may be affected by modern farming methods. We have little information on the management of the studied soils, but at Bom Futuro the rather high Mehlich 1 P concentrations in the arable land compared to the soils with little or no ADE character in the forest must be due to phosphorus fertilization (Figure 3). At São Francisco the phosphorus concentration in the reference soils on the field (Table 3) was at the same level as in Bom Futuro. This soil should also have been fertilized with P since tropical strongly weathered soils are often very poor in this element. ADEs are still clearly discernible based on the P concentrations, however, since they often have a much higher P concentration than that achieved by fertilization. Ca may also be added if the arable soil is limed or if nitrate of lime is used as N fertilizer. The exchangeable Ca determined in our investigation is largely a function of the CEC of the soil. In Bom Futuro the elevated Ca concentration and pH in the arable field, despite a fairly low CEC, may be due to liming or fertilization (Figure 3). At São Francisco (Table 3) the Ca concentration and pH in the reference soil is in level with that at Bom Futuro, but the concentration is markedly higher in the ADEs also for this element.

At Bom Futuro only a few sites in our grid had a Mehlich 1 P concentration at 0–20 cm above the 30 mg kg⁻¹ which is the limit for a pretic horizon (WRB, 2014). In most cases the A horizons were also less than 20 cm thick (Table 1). However, data from the excavated profiles and the PSS

measurements indicate that there are soil patches of ca. 100 m² clearly affected by ancient domestic activities (e.g. carbon and ash from hearths, deposition of food remains and excrement) that have pretic horizons more than 50 cm thick. To be classified as Pretic Anthrosol a soil must have a pretic horizon thicker than 50 cm (WRB, 2014). These soils could definitely be referred to as Terra preta. Some of the other anthropogenic soils in the area are probably better termed Terra mulata. Anthropogenic surface horizons at São Francisco tend to be thicker and higher in P concentration than at Bom Futuro, but also at this site ADEs with a pretic horizon thick enough to classify the soil as Anthrosol cover very limited areas. In our present understanding of prehistoric settlements in the Amazon, less intense signatures, including less distinct ADE soil profiles, are to be expected since long-term settlement appears to have been concentrated along the main waterways whereas the uplands were occupied relatively late, a few centuries before European contact. Radiocarbon and OSL dating at Bom Futuro indicate that the occupation of settlements was most extensive during the centuries that preceded European contact (from AD 1300) and into the European contact period (up to AD 1800) (Stenborg et al, 2014). Thus the strong human impact on soil formation may be of shorter duration than in areas nearer to the main waterways. The impact on soils should also depend on population density in general and on village size at specific sites. On the Belterra plateau with its very thick regolith there are few permanent water courses and lakes which means that water shortages during the dry period makes permanent settlement difficult. Results from the Cultivated Wilderness project indicate the settlers overcame these difficulties by using natural or artificial ponds that are commonly found on the Belterra plateau (Stenborg et al, 2014).

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Sensors for Efficient Field Mapping of Amazonian Dark Earths

Mats Söderström, Jan Eriksson, Christian Isendahl, Suzana R. Araújo

Brazilian and Swedish archaeologists and soil scientists collaborated in the multidisciplinary research project Cultivated Wilderness (CW) to investigate Amazonian Dark Earth (ADE) locations in the Santarém-Belterra region of the Brazilian Amazon. One of the goals in the CW project was to investigate the potential of rapid geophysical data collection to assess the properties and spatial distribution of ADE. About 300 reference soil samples were collected at different ADE locations. A range of soil sensors (based on various principles: electromagnetic induction, gamma-ray spectrometry, x-ray fluorescence, and reflectance spectroscopy) were used both in the field and in the laboratory. This paper synthesizes the potential of these sensors in ADE surveys.

Background and aim

Amazonian dark earths (ADE; terra preta) have long since been recognized as a valuable resource for agriculture and as a key source for understanding the prehistory of the Amazonian cultural landscape (Smith 1980; Sombroek 1966), but the focused scientific multidisciplinary investigation of this phenomenon did not take off until the late 1990s (e.g. Glaser and Woods 2004). These studies show that ADE soils formed both by the intentional deposition of organic matter to increase plant productivity and as a side-effect of the concentration of nutrients at and around prehistoric settlements. Soil and social scientists have investigated a number of different aspects of ADE formation and management that are not only regionally relevant, but sometimes have universal applications. For instance, the principles of ADE formation and the benefits of high amounts of pyrogenic carbon (or biochar)

(Burns and Ritz 2012)—which is higher in carbon concentration than ordinary soil organic matter (SOM) and resists decay for centuries (Lehmann 2007)—have become key issues for research on carbon sequestration and long-term soil fertility (Lehmann and Joseph 2009; Verheijen et al 2010). Organic matter content is normally low in soils in hot tropical climates due to conditions that favor rapid decomposition. Pyrogenic carbon has similar properties to other SOM but is much more resistant to decomposition. ADE remains the most important resource for smallholder agriculture in the region and is a demonstrably sustainable resource under low-intensity management regimes. The presently known distribution of ADE sites is concentrated to relatively accessible areas on the floodplain bluffs along the main waterways of the Amazon watershed and in and around current population centers such as the city of Santarém in the state of Pará, where ADE was originally described (Hartt 1874; WinklerPrins and Aldrich 2010). However, notwithstanding increasing intensity in ADE research over the last decade, the current site record poorly represents the full range of ADE distributions (McMichael et al. 2014; WinklerPrins and Aldrich 2010) and there is a need to develop efficient approaches to soil mapping and analysis for documenting ADEs. In recent years, digital soil mapping (DSM) has evolved as a cost-efficient approach to predict spatial patterns of soil properties across geographical scales by integrating quantitative methods with proximal and remote sensing, soil observations and other covariates such as digital elevation data (Grunwald 2010). This type of technique is of particular interest in areas such as the Amazon, where the available information on



Fig. 1. Locations of ADE sites near the city of Santarém (Pará, Brazil) where soil sensors were used in this project: BF = Bom Futuro (two sites BF2 and BF6), SF = São Francisco, and C = Cedro. The 3D landscape model is displayed in perspective from the northwest. A 10 km net shows the scale (illustration: Mats Söderström).

the quality of land and soil resources that guides land-use planning decisions is scarce, fragmentary and coarse in resolution (Fearnside and Filho 2001; Teixeira et al. 2008). Airborne or satellite remote sensing has been used to study soil properties (e.g. SOM and clay concentrations) for many years and has proven to be a cost-effective method in DSM (Boettinger 2010). In DSM remote sensing data can be combined with other data to construct prediction models using multivariate data analysis techniques (Minasny et al. 2008; Wetterlind et al. 2008). Proximal soil sensing (PSS; when sensors are used in close contact with or within a distance of a few meters) is a way to rapidly and often non-destructively collect detailed information on the soil surface or of a given soil volume (Viscarra Rossel and McBratney 1998) using various geophysical instruments. PSS instruments use the soil's ability to emit energy in different parts of the electromagnetic spectrum, and can for example be based on electromagnetic induction (EMI), natural gamma-ray emission or X-ray fluorescence (Adamchuck and Viscarra Rossel 2013). Such instruments may be used directly in the field, while other instrumentation such as hyperspectral reflectance spectroscopy (visible to near infrared / mid-infrared [visNIR/MIR] spectroscopy), has so far mostly been used on soil samples in the laboratory, although such equipment designed for field use is available. The aim of this work was to amalgamate results reported within the Cultivated

Wilderness (CW) project between 2011–2014 with the potential to use different soil sensing techniques such as those mentioned above for assessment of ADE soil properties and their spatial distribution. Techniques suitable for studies in different scales were used – from alternatives to laboratory analyses of soil samples, to regional assessment of ADE occurrence. Extensive soil surveys including sensor measurements and soil sampling and analyses were carried out on different ADE sites on the Belterra Plateau, an upland area near the city of Santarém, Pará in the Brazilian Amazon.

Experiences from three studies focusing on the use of soil sensors in ADE surveys carried out within the CW project are reported in this chapter:

- Proximal soil sensing for mapping ADE in a forested area;
- Determining soil properties in ADE by reflectance spectroscopy; and
- Sensors for mapping ADE properties in land under modern agricultural production.

Study areas and soil sensors used

Soil surveys (including soil sampling, soil profile descriptions and measurements with different types of sensors) were carried out at four ADE sites on the Belterra Plateau south of the city of Santarém in the state of Pará, Brazil (Figure 1),

during 2011 and 2012. The Belterra Plateau is an upland environment elevated about 150 m above the Amazon and Tapajós river floodplains that geologically is part of the Cretaceous Alter do Chão Formation. These sites consist of patches of ADE surrounded by the Ferralsols that dominate the region in general. The results from work at Bom Futuro and São Francisco, the main field work locations, are reported in this text. Bom Futuro is a 28-ha study area mostly covered by forested terrain located some 40 km south of Santarém. Two study areas were sampled at Bom Futuro: the main study area (BF2) and a validation site (BF6), located about 2 km from BF2 (Figure 1). Local smallholders practice low intensity, long-fallow slash-and-burn shifting cultivation that results in a local mosaic of vegetation where shrub and medium-high forests dominate. Moreover, there are two homesteads and a part of an open agricultural field for soybean production in the BF2 area. The São Francisco research area is located

about 20 km south-southwest of Santarém. The area covered by ADE soil extends over slightly more than 10 hectares, most of which is an open arable field under soybean and maize cropping using modern agricultural methods.

Results from the soil analyses (elements analyzed and methods used) and profile descriptions at Bom Futuro and São Francisco are reported in detail in the chapter by Eriksson et al. (this volume).

Three types of non-invasive geophysical instruments were used for scanning in the field:

A) A sensor based on electromagnetic induction (EM38-MK2; Geonics Ltd., Mississauga, ON, Canada) which registers the apparent soil electrical conductivity (ECa in mS m⁻¹) at two depths simultaneously (mainly 0–0.75 m and 0–1.5 m depth, here denominated ECa05 and ECa10 respectively), as well as values proportional to

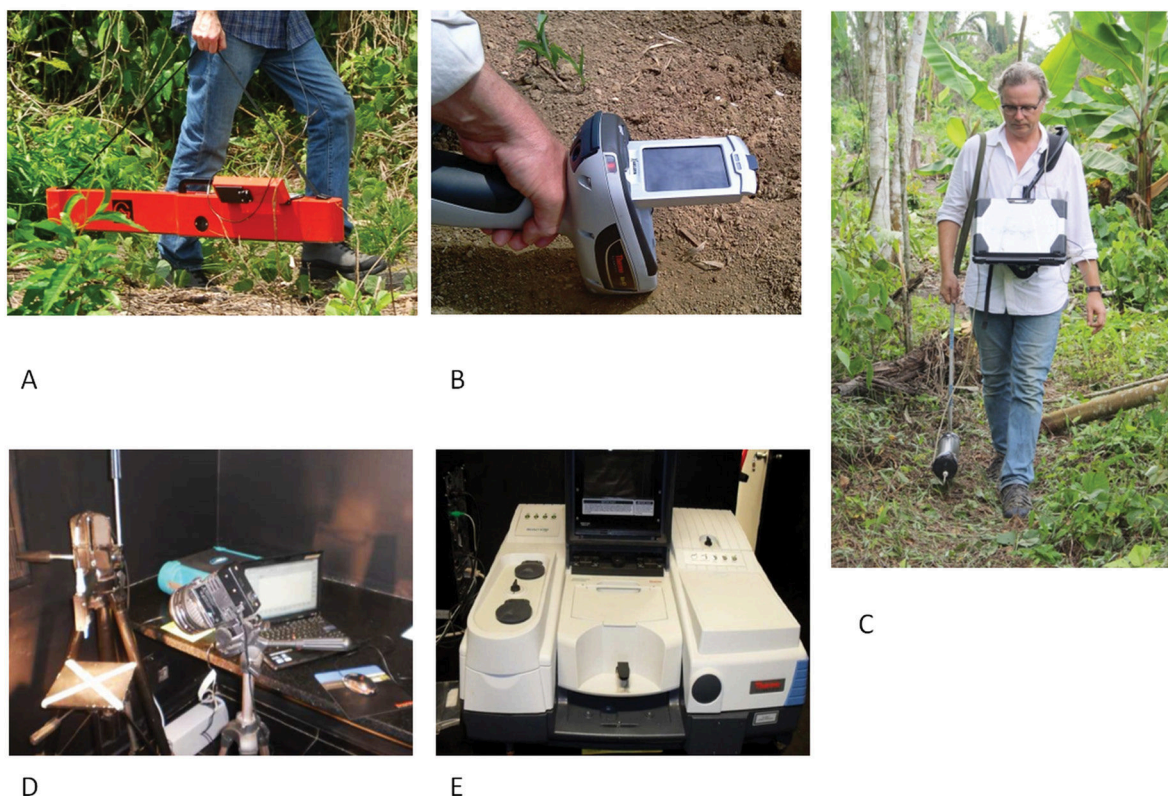


Fig. 2. Proximal soil sensors used: A) EM38-MK2 (Geonics Ltd., Mississauga, ON, Canada) for measuring soil electrical conductivity and magnetic susceptibility (photo Christian Isendahl); B) Niton XL3t GOLDD+ (Thermo Scientific, Billerica, MA, USA), a portable X-ray fluorescence (PXRF) analyzer for detection of the total concentrations of many elements (photo Mats Söderström); C) The Mole (The Soil Company, Groningen, the Netherlands) – a gamma ray spectrometer (photo Mats Söderström); D) FieldSpec Pro FR Spectroradiometer (Analytical Spectral Devices, Boulder, CO, USA) measuring reflectance in the range of 350-2500 nm (visNIR) (photo Suzana R. Araújo); E) Nicolet 6700 Fourier Transform Infrared (Thermo Fisher Scientific, Waltham, MA, USA) measuring reflectance in the range of 2500-25000 nm (MIR) (photo Suzana R. Araújo).

the apparent magnetic susceptibility (MSa05 and MSa10; with an effective depth of about half that of ECa) (Figure 2A);

B) A portable X-ray fluorescence (PXRF) analyzer (Niton XL3t GOLDD+; Thermo Scientific, Billerica, MA, USA) for detection of the total concentrations of range of elements – but only in about half a cubic cm of soil (Figure 2B);

C) A gamma ray sensor (the Mole, Soil Company, Groningen, the Netherlands) that records the natural occurrence of the radioactive isotopes ^{238}U (uranium), ^{232}Th (thorium), ^{40}K (potassium), ^{137}Cs (cesium) and TC (total counts in the decay per second) in the topsoil (from the surface to about 0.3 m soil depth) (Figure 2C).

The instruments A and C were carried by hand about 15 cm above ($z = 15$ cm) ground along soil sampling transects with measurements

continuously being taken every second. The position of each measurement was logged simultaneously (at 1 Hz); the position of the EM38 was registered by a TDS Nomad GPS (Tripod Data Systems, Corvallis, OR, USA) and the gamma sensor by a Bu-353 GPS (GlobalSat, New Taipei City, Taiwan). In addition, at São Francisco (only the EM38 was used at that site), measurements were made with a duration of 15 seconds at each of the soil sampling points with the instrument at $z = 15$, and also placed on the ground ($z = 0$). This was done in order to collect detailed sensor data and to test whether the measuring height had an impact on the correlation between soil properties and sensor values. Instrument height above the ground modifies the proportion of signal contribution from different soil depths. The PXRF was only used in the field at São Francisco. Measurements were made on the soil surface at the soil sampling locations. Each measurement lasted 4 minutes per sample point. The PXRF was also

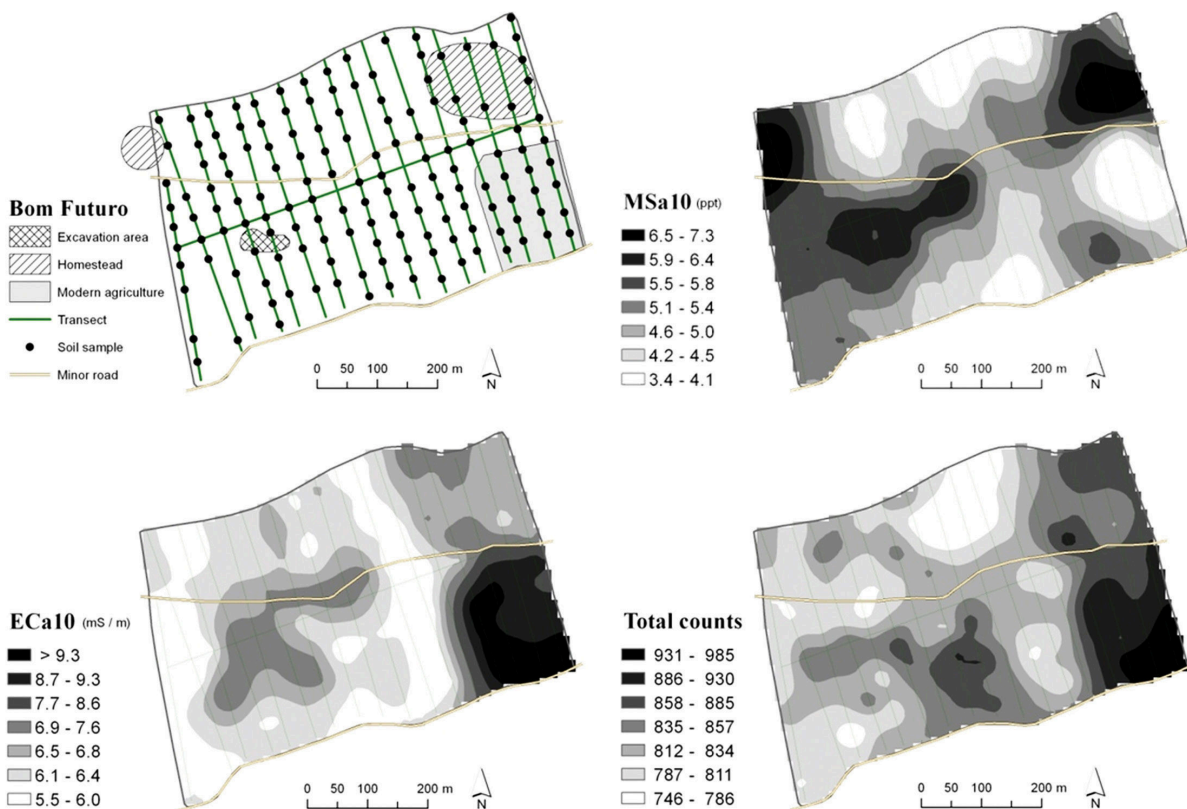


Fig. 3. Upper left: general outline and land use of the Bom Futuro survey area (BF2 in Figure 1). Interpolated sensor maps from EM38 and the Mole: upper right: magnetic susceptibility (MSa); lower left: electrical conductivity (ECa); and lower right: total gamma counts (TC). Modified from Söderström et al. (2013).

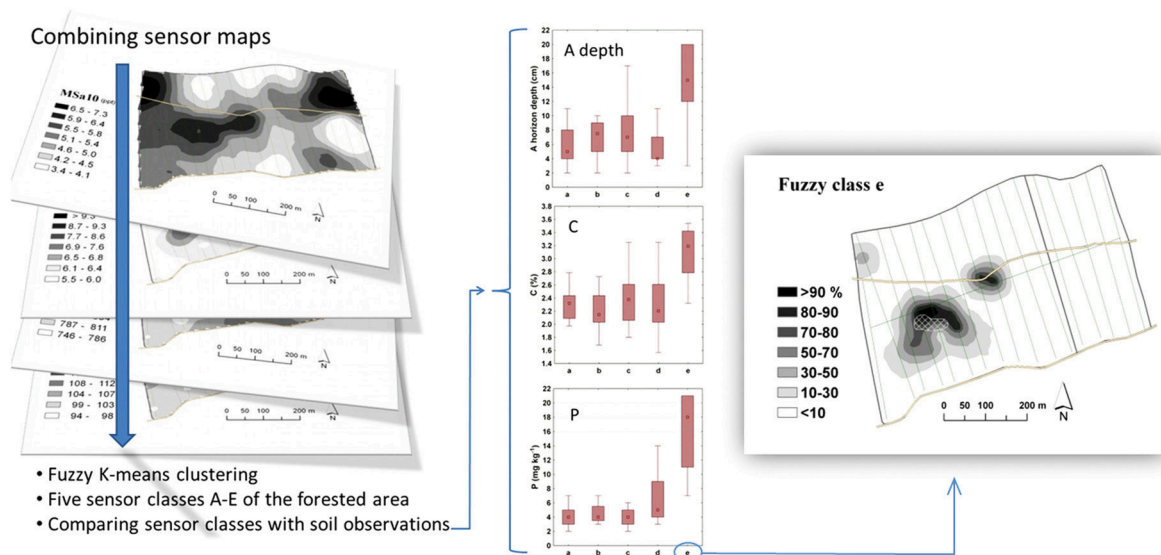


Fig. 4. Sensor maps combined in five classes (a-e) using fuzzy k-means clustering. Box plots display depth of the A horizon (A depth), soil organic carbon (C) and phosphorus (P) in the different classes. The box = 25–75 percentiles, the mark = median and the whiskers indicate non-outlier range (as defined by Hill & Lewicki 2007). The number of soil analyses in the different classes was: a = 18; b = 16; c = 28; d = 19; e = 9. The final map exposes likelihood of belonging to fuzzy soil class e. The current archaeological excavation area is crosshatched. Modified from Söderström et al. (2013).

tested in the laboratory on some soil samples (dried and sieved) from Bom Futuro. For laboratory analyses and modelling of properties in ADE soil samples by visNIR/MIR reflectance spectroscopy a FieldSpec Pro FR Spectroradiometer (Analytical Spectral Devices, Boulder, CO, USA) in the range 350–2500 nm (visNIR) (Figure 2D) and a Nicolet 6700 Fourier Transform Infrared (Thermo Fisher Scientific, Waltham, MA, USA) in the range 2500 to 25000 nm (MIR) (Figure 2E). Details on the management and analysis of the soil spectra are reported by Araújo et al. (2015). Partial least squares regression (PLSR) was used to create calibration models (chosen by leave-one-out cross-validation) for different soil properties on a subset of the soil samples at Bom Futuro BF2 (45 soil samples). These calibration models were then tested on the remaining 103 soil samples in a validation dataset at Bom Futuro, but also on a number of soil samples from the neighboring ADE site BF6 (Figure 1).

In addition to the proximal soil sensors, we obtained a high-resolution satellite image (Spot 6, Astrium / Airbus Defence and Space, Toulouse, France) acquired at the time of field work in 2012 (from 27 November 2012) in order to compare such data with data derived from the soil surveys (soil sample analyses and sensor measurements) on open land under modern mechanized

agricultural practices. Spot 6 images have a spatial resolution of 1.5 m in the panchromatic band and 6 m multispectrally. The spectral bands are: panchromatic (450–745 nm), blue (450–525 nm), green (530–590 nm), red (625–695 nm), and near-infrared (760–890 nm).

Proximal soil sensing for mapping ADE in a forested area

The goal of this part of the CW project was to investigate if hand-carried field soil sensors could be used to detect and map the extent of patches of ADE in at the Bom Futuro BF2 site, a mostly forested area. Results of the work are reported in detail in Söderström et al. (2013). Soil samples were taken and soil sensing with the EM38 and the Mole were carried out along transects mostly through secondary forest (Figure 3). Sensor maps of MSa10, ECa10 and TC are shown in Figure 3. It is possible to distinguish various features in the sensor maps, for example the part of the area consisting of open arable land in the SE corner, which yielded relatively high ECa values, low MSa and high TC. MSa was particularly high in the homestead areas. The more central areas had high MSa and relatively high ECa.

We used fuzzy *k*-means clustering (e.g. Burrough and McDonnell 1998 describes the method) to combine the sensor maps into five classes. The

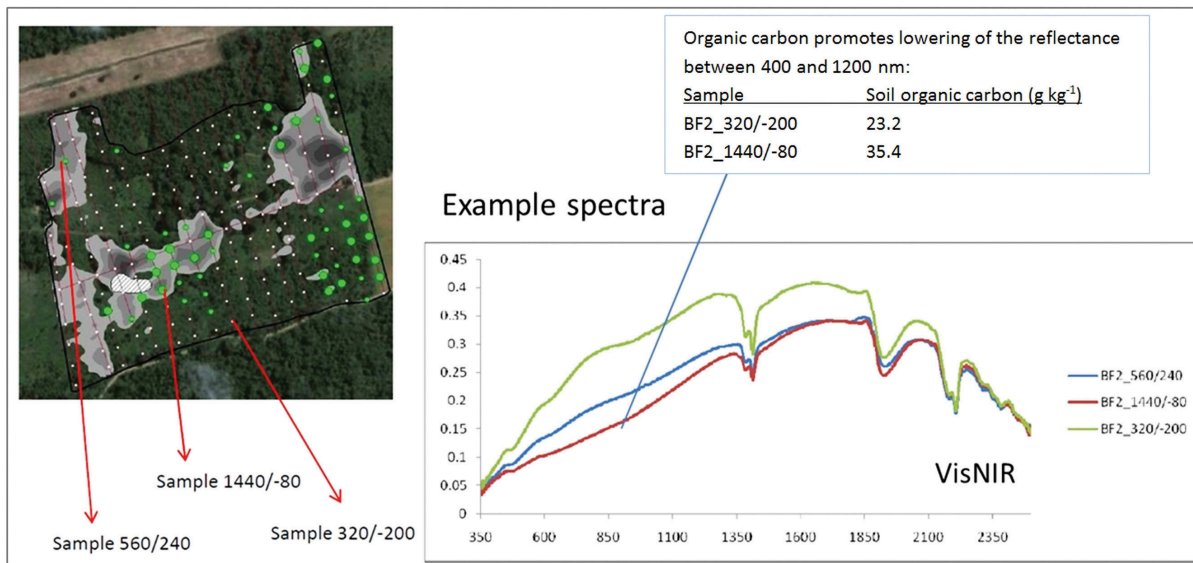


Fig. 5. The map shows the Bom Futuro survey area (BF2 in Figure 1). Areas with elevated MSA values (Figure 3) are marked in grey. Soil sampling locations with A horizon depth > 15 cm are green. Spectra in the visNIR range of three soil samples with different organic carbon content are shown in the diagram (abscissa = wavelength in nm; ordinate = reflectance) (illustration: Suzana R. Araújo and Mats Söderström).

Table 1. Validation results (n = 103 independent soil analyses) of PLSR models at Bom Futuro (BF2 in Figure 1). The calibration models were based on randomly selected soil samples at BF2 (n = 45). Modified from Araújo (2013).

| | Sensor | R ² | RMSEP* | RPD* |
|-------------------------------|--------|----------------|--------|------|
| SOC (g kg ⁻¹) | visNIR | 0.52 | 3.00 | 1.57 |
| | MIR | 0.50 | 2.90 | 1.62 |
| CEC (mmolc kg ⁻¹) | visNIR | 0.53 | 17.2 | 1.40 |
| | MIR | 0.55 | 16.9 | 1.42 |
| Ca (mmolc kg ⁻¹) | visNIR | 0.53 | 18.3 | 1.47 |
| | MIR | 0.64 | 15.25 | 1.76 |
| P (mg kg ⁻¹) | visNIR | <0.10 | 16.3 | 1.02 |
| | MIR | 0.10 | 15.6 | 1.06 |

disturbed easternmost part (homestead and open arable land) was avoided. Using the combined map we compared how a number of pertinent ADE indicators such as A horizon depth and how carbon (C), and phosphorus (P) concentrations varied between the different fuzzy classes (Figure 4). Class e contained by far the highest values of all of these soil variables, suggesting that this class is a sign of the occurrence of ADE soil. For the other classes, a-d, these soil variables only generally had small differences between classes, although the range of values in some classes was quite large, the latter indicating that the derived classes were not entirely homogenous.

To map the class e areas, membership values for class e were interpolated using kriging (Isaaks and Srivastava 1989), producing an estimate of

the likelihood that a location belonged to this class (Figure 4). According to this map only a small area was likely to belong to class e. Those soils were found in a crescent-shaped area – partly congruent with the area where the archaeological excavations took place; a good indicator of the occurrence of ADE. Another, circular area in the center is also portrayed as belonging to class e. In the northwest, close to a homestead, soils would likely also belong to class e. MSA has been used as an indicator of frequent burning in archaeological contexts (e.g. Jordanova et al. 2001; Tite and Mullins 1971). The heating of soil transforms some iron oxides (haematite) to the easily magnetized minerals magnetite or maghaemite. High soil magnetic susceptibility is a good indicator of various burning activities

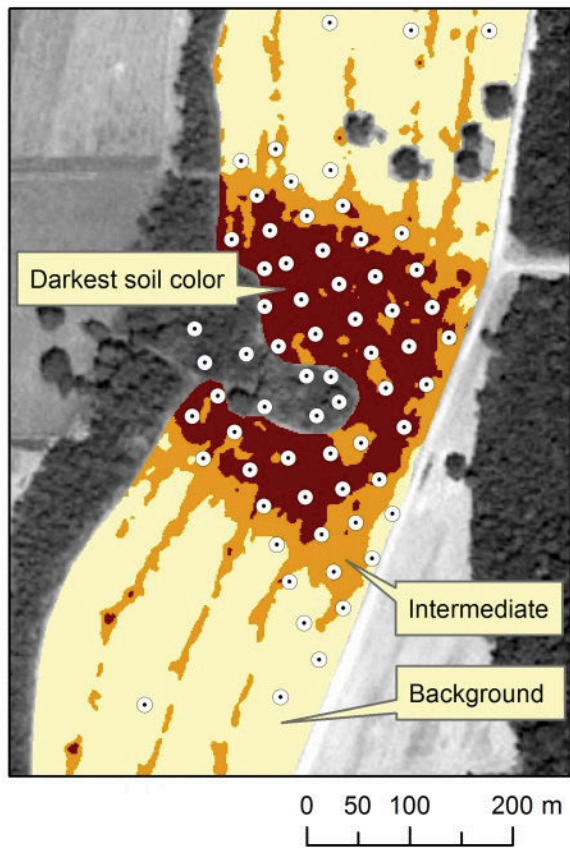


Fig. 6. The São Francisco ADE site located in a soybean and maize field cultivated using modern agricultural methods (SF in Figure 1). The map was generated by grey-scale classification into three classes of a bare ground SPOT 6 panchromatic satellite image from Nov 27, 2012; the darkest soils = red-brown map color (strong ADE character), intermediate = orange (medium ADE character), light grey regarded as background = yellow. The orange striped pattern is a rest from burning vegetation at the time of clearing the field from vegetation, a typical feature of agricultural land in the area.

associated with intense occupation over a long period of time. As shown in Figure 3, both current homesteads in the study area, as well as the area of the excavated settlement have high MSa values, but MSa is also elevated in some other sectors. Since slash-and-burn cultivation is likely to result in high soil MSa, recent forest clearing and burning could be one reason for the short-range variability of MSa. More or less the entire research area is subjected to this type of management, or has been in the recent past. To date these readings requires archaeological excavation.

Determining soil properties in ADE by reflectance spectroscopy

Example reflectance spectra of three soil samples in different parts of the Bom Futuro BF2 area (with different depths of the A horizon and different MSa values) are shown in Figure 5 (detailed results of this research were reported in Araújo et al. 2015). These spectra show differences that are typical for variations in soil organic matter content. VisNIR and MIR calibration models for SOC and CEC were particularly good (high R^2 , low RMSE and high RPD in the cross-validation). It was not possible to produce good models for P and K. The MIR models for Mg, Ca, BS, pH and acidity were fair. In general, MIR models had better cross-validation results than the corresponding visNIR models. When the calibration models at BF2 were applied on an independent dataset from the

Table 2. Correlation coefficients (R)* between satellite data bands (Spot 6; Nov 27, 2012) and soil properties (0–20 cm depth) at São Francisco (SF in Figure 1). Sample locations are shown in Figure 6, only samples in the arable field are included (n=53).

| Soil property | PAN | B | G | R | NIR |
|-------------------------------|-------|-------|-------|-------|-------|
| SOC (g kg ⁻¹) | -0.74 | -0.70 | -0.70 | -0.68 | -0.72 |
| pHH ₂ O | -0.60 | -0.58 | -0.58 | -0.51 | -0.62 |
| pHKCl | -0.66 | -0.62 | -0.61 | -0.53 | -0.69 |
| ln(P) (mg kg ⁻¹) | -0.72 | -0.70 | -0.70 | -0.67 | -0.74 |
| Ca (mmolc kg ⁻¹) | -0.82 | -0.79 | -0.78 | -0.74 | -0.83 |
| K (mmolc kg ⁻¹) | -0.36 | -0.32 | -0.33 | -0.26 | -0.43 |
| Mg (mmolc kg ⁻¹) | -0.83 | -0.79 | -0.79 | -0.73 | -0.85 |
| Acidity (%) | 0.52 | 0.51 | 0.49 | 0.45 | 0.55 |
| CEC (mmolc kg ⁻¹) | -0.82 | -0.79 | -0.79 | -0.75 | -0.83 |
| BS (%) | -0.75 | -0.73 | -0.71 | -0.65 | -0.78 |

* Prob.-values: Dark grey box = $p < 0.001$; light grey box = $p < 0.01$; white box = $p < 0.05$; grey italic = not significant

a PAN = panchromatic; B = blue; G = green; R = red; NIR = near infrared

Table 3. Correlation coefficients (R)* between EMI sensor data (apparent electrical conductivity (ECa) and magnetic susceptibility (MSa) measured with the sensor placed on the ground (Z0) or held 15 cm above the ground (Z15)) and soil properties (0–20 cm depth) at São Francisco (SF in Figure 1). Sample locations are shown in Figure 6 (n = 60).

| Soil property | ECa10 _{Z15} | ECa05 _{Z15} | MSa10 _{Z15} | MSa05 _{Z15} | ECa10 _{Z0} | ECa05 _{Z0} | MSa10 _{Z0} | MSa05 _{Z0} |
|-------------------------------|----------------------|----------------------|----------------------|----------------------|---------------------|---------------------|---------------------|---------------------|
| SOC (g kg ⁻¹) | 0.45 | 0.43 | 0.69 | 0.36 | 0.42 | 0.22 | 0.70 | 0.56 |
| pHH2O | 0.58 | 0.07 | 0.48 | 0.44 | 0.56 | -0.04 | 0.48 | 0.59 |
| pHKCl | 0.68 | 0.16 | 0.62 | 0.54 | 0.66 | 0.03 | 0.60 | 0.67 |
| ln(P) (mg kg ⁻¹) | 0.73 | 0.44 | 0.64 | 0.44 | 0.71 | 0.27 | 0.64 | 0.64 |
| Ca (mmolc kg ⁻¹) | 0.68 | 0.43 | 0.79 | 0.59 | 0.65 | 0.21 | 0.82 | 0.78 |
| K (mmolc kg ⁻¹) | 0.42 | 0.13 | 0.44 | 0.35 | 0.41 | 0.08 | 0.45 | 0.40 |
| Mg (mmolc kg ⁻¹) | 0.43 | 0.36 | 0.75 | 0.48 | 0.39 | 0.15 | 0.74 | 0.65 |
| Acidity (%) | -0.63 | -0.13 | -0.44 | -0.51 | -0.61 | -0.07 | -0.41 | -0.54 |
| CEC (mmolc kg ⁻¹) | 0.53 | 0.45 | 0.81 | 0.49 | 0.50 | 0.21 | 0.82 | 0.71 |
| BS (%) | 0.68 | 0.27 | 0.72 | 0.62 | 0.65 | 0.12 | 0.71 | 0.74 |

* Prob.-values: Dark grey box = $p < 0.001$, light grey box = $p < 0.01$; white box = $p < 0.05$; grey italic = not significant

Table 4. Correlation coefficients (R)* between some elements measured with PXRF in the field and soil properties (0–20 cm depth) at São Francisco (SF in Figure 1). Sample locations are shown in Figure 6 (n = 60).

| Soil property | XRF_Al | XRF_Ca | XRF_Fe | XRF_Si | XRF_Nb | XRF_Sr | XRF_Th | XRF_Zr |
|-------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| SOC (g kg ⁻¹) | -0.37 | 0.60 | -0.51 | -0.34 | -0.35 | 0.65 | -0.32 | -0.18 |
| pHH2O | 0.00 | 0.32 | 0.01 | 0.08 | 0.04 | 0.39 | 0.04 | 0.04 |
| pHKCl | -0.06 | 0.46 | -0.08 | 0.03 | 0.05 | 0.50 | 0.05 | 0.05 |
| ln(P) (mg kg ⁻¹) | -0.20 | 0.57 | -0.17 | -0.15 | -0.27 | 0.57 | -0.20 | -0.31 |
| Ca (mmolc kg ⁻¹) | -0.30 | 0.75 | -0.33 | -0.24 | -0.24 | 0.76 | -0.23 | -0.15 |
| K (mmolc kg ⁻¹) | -0.06 | 0.29 | -0.11 | -0.02 | -0.14 | 0.30 | -0.21 | -0.12 |
| Mg (mmolc kg ⁻¹) | -0.38 | 0.69 | -0.44 | -0.32 | -0.24 | 0.73 | -0.26 | -0.06 |
| Acidity (%) | -0.09 | -0.32 | -0.17 | -0.16 | -0.15 | -0.29 | -0.12 | -0.08 |
| CEC (mmolc kg ⁻¹) | -0.41 | 0.77 | -0.49 | -0.37 | -0.35 | 0.79 | -0.34 | -0.20 |
| BS (%) | -0.19 | 0.59 | -0.17 | -0.10 | -0.04 | 0.61 | -0.07 | 0.01 |

* Prob.-values: Dark grey box = $p < 0.001$, light grey box = $p < 0.01$; white box = $p < 0.05$; grey italic = not significant

same location the statistical test values were not as good, although the models for e.g. SOC, CEC and Ca performed rather well (Table 1). Such a dataset is more realistic than cross-validation, and exemplifies how reflectance spectroscopy would perform if used instead of laboratory analyses on soil samples from an ADE location. In this case, laboratory analyses were done on 30% of the samples, and reflectance spectroscopy was used on the remaining soil samples. In general, MIR performed better than visNIR, but the differences were small.

We also tried to deploy the calibration models from BF2 at the nearby BF6 ADE site. Chemical analyses of the soil samples from BF6 were used to

test the models. Results of SOC and CEC showed that both MIR and vis-NIR models had the ability to predict unknown samples at BF6 very well. Models with MIR data performed better than those with vis-NIR (see Araújo et al. 2015 for further details).

Sensors for mapping ADE properties in land under modern agricultural production

Intensive mechanized farming has expanded significantly in the Brazilian Amazon in the last decades. For example, the soybean production area increased by >3.6 million hectares from 2001 to 2004 (Morton et al. 2006). In the Santarém-Belterra region the landscape has changed rapidly

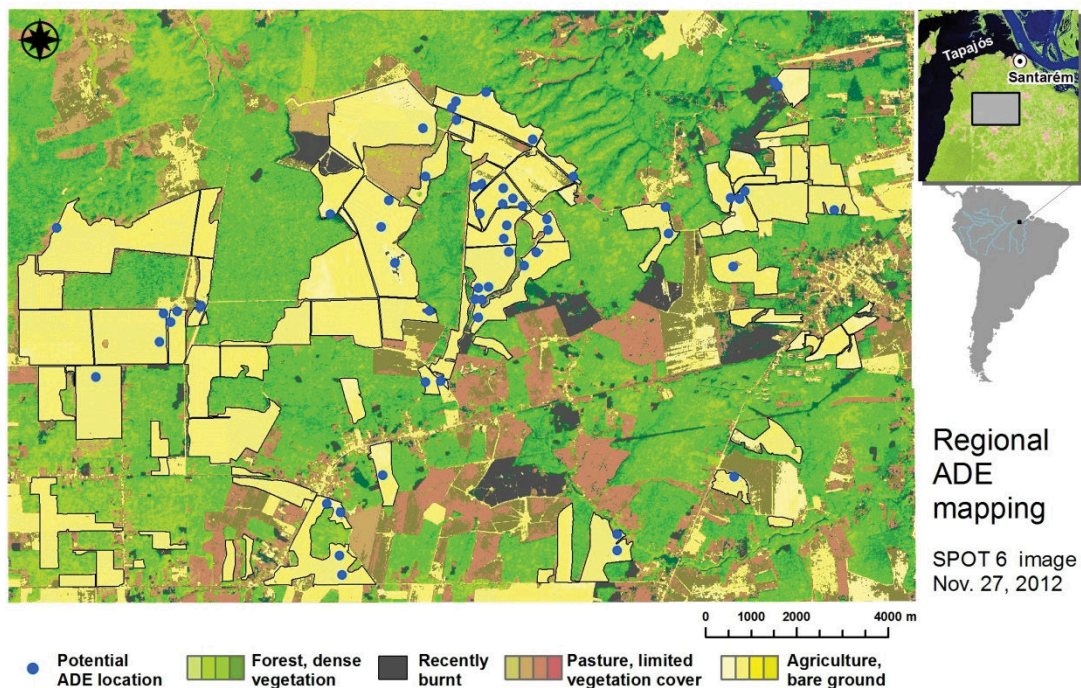


Fig. 7. Regional map of land use and potential ADE sites in open agricultural land (the yellow areas) in an area south of Santarém produced by classification of a Spot 6 satellite image. The map should be regarded as an example in the use of satellite imagery to locate and delineate soils with ADE characteristics in non-vegetated bare ground. Field control is still required in order to validate the map. The arrow indicates the field shown in Figure 8. (Illustration: Mats Söderström).

with expanding forest clearance to prepare mainly for soybean and maize production for national and global fodder markets (Corrêa et al. 2011). It is to be expected that parts of the cleared areas also include ADE soils, intentionally or unintentionally. From an archaeological point of view it is of course valuable to assess how large-scale cultivation using modern methods affects the possibilities to interpret the historic record at such a site. In this project we measured with the sensors EM38 and PXRF at São Francisco, about 8 km WNW from Belterra, at 60 of 65 locations where samples of topsoil were obtained for laboratory analyses as a reference (seven of which were in the forested part of the site, the rest in the agricultural field). These locations are shown in Figure 6, with a classified satellite image (the panchromatic band according to the darkness of the soil) in the background.

Correlations between the different bands in the satellite image and soil analyses of the topsoil in the non-vegetated arable field are shown in Table 2. Many of these soil properties co-vary (see Eriksson et al., this volume), which is also the case with the reflectance in the different bands registered by the satellite sensor. When the

satellite image covers both background soils and ADE soils, this means that there is a correlation between most soil properties and the satellite data.

Similar correlations between laboratory soil analyses and field sensors are shown in Tables 3 and 4, although in this case the data covers both forested and non-forested sampling sites. Correlations between soil properties and the EM38 sensor (two tested scanning methods) are displayed in Table 3). ECa10, MSa10 and MSa05 were significantly correlated with the soil properties. The ECa05 sensor values were more unstable and did not correlate well with the soil data. Holding the instrument 15 cm above ground and putting the instrument on the ground did not produce major differences in the correlations. The measurements for PXRF (Table 4), in particular of Ca and Sr (the latter being geochemically closely related to Ca), were significantly correlated with several of the soil properties analyzed. Except for Ca, the soil properties CEC, Mg and to some extent SOC in the topsoil had the highest correlation coefficients ($R = 0.6 - 0.8$) with Ca or Sr as measured by the PXRF. So even if the PXRF instrument only responds to a soil thickness of a few mm and a surface area of about 1 cm^2 , the

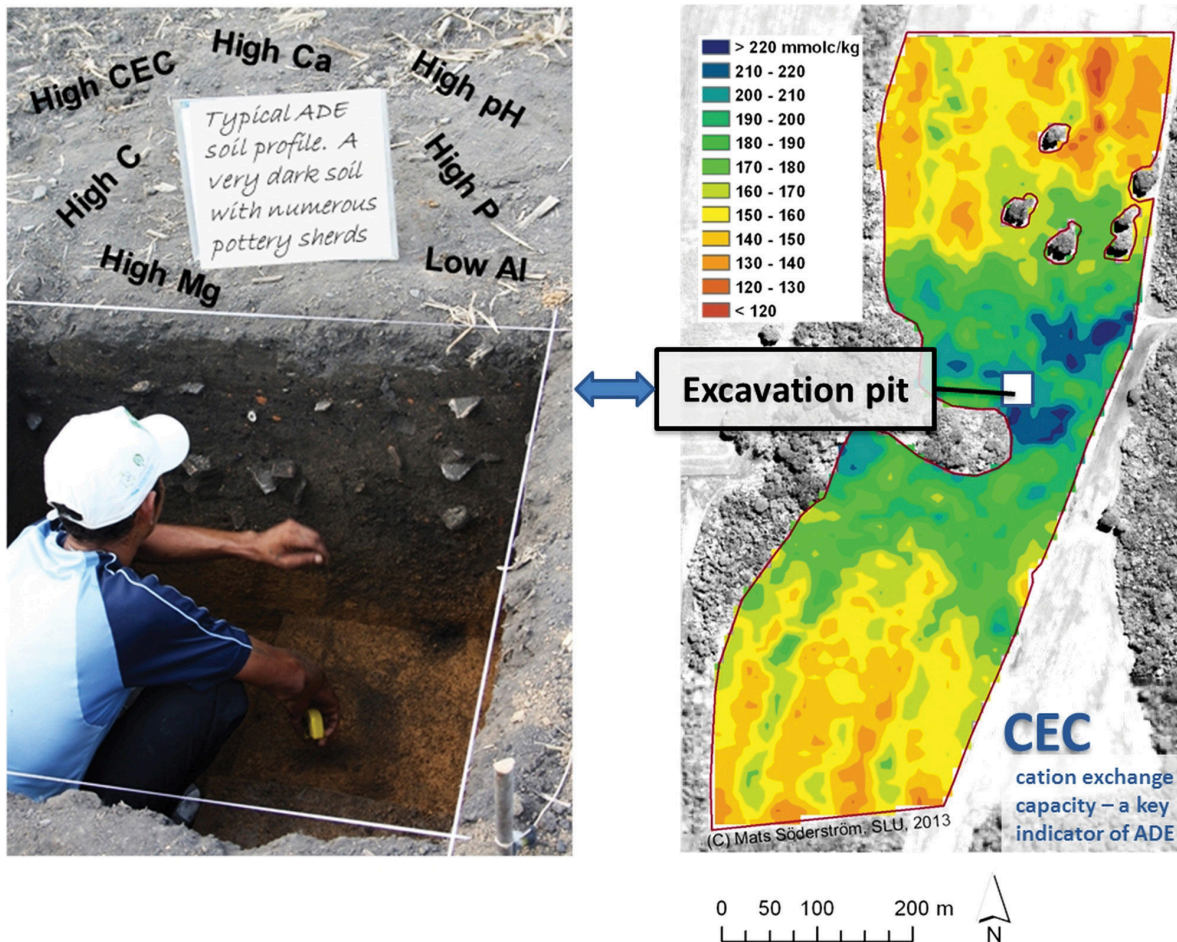


Fig. 8. Archaeological surveys and interpretation could be facilitated by combinations of geophysical sensor data. A map of topsoil CEC of the São Francisco ADE site (SF in Figure 1) was produced by a combination of sensor data. CEC was calculated indirectly in point locations by measurements of Ca with a PXRf instrument. These data were interpolated by cokriging using ECa (as measured by EM38) and data from the panchromatic band in a SPOT 6 satellite image as covariables. (Illustration: Mats Söderström).

values obtained could say something about the conditions in the topsoil; mixing of the upper soil through cultivation practices is likely beneficial in this case.

ADE mapping by remote and proximal soil sensors – summary and outlook

Thayn et al. (2010) discuss the possibilities and potential of using satellite based remote sensing for locating ADE in the Amazon Basin. Through differences in vegetation composition it may be possible to distinguish ADE soils from the poor soils that dominate the region; this approach still has not been developed. Another approach, indeed far more straightforward, is to use the same technique in areas with limited vegetation. In this project we showed that reflectance in an optical satellite image was rather well correlated with several of the soil properties that are indicators of

ADE in one of the study areas (Figure 6 and Table 2). This suggests that the same basic principle could be expanded and applied to a larger part of the satellite scene covering 260 km² in the northern part of the Belterra Plateau in order to locate and delineate soils with ADE characteristics. An example of this is shown in Figure 7, where part of a multispectral, high resolution SPOT 6 image from the 27th Nov 2012 was classified using unsupervised classification in combination with manual image interpretation of soils and land use. The soil in areas that has been transformed to open agricultural land, generally under mechanized cultivation and primarily for the production of soybean and maize (slightly more than 50 km² of such land in this image had very little vegetation at the time of the image acquisition – yellow in Figure 7), were classified according to the reflectance of the soil. In this case, 54 other locations on bare ground

had soils with similar reflectance characteristics as five ADE sites at least partly located in open agricultural land that were visited in the field.

All these potential ADE sites roughly covered 1.3 km² in total, the largest being larger than 20 ha. However, a validation in the field is still required to determine how many of these 54 sites really could be classified as ADE. The extent of each site is also very uncertain. For example, it is possible that recent or relatively recent burning yields similar reflectance characteristics as ADE soils, although other features such as form and appearance of the dark soil could be used to improve its classification. Nevertheless, it exemplifies the potential benefits of using this type of technique at least in deforested areas in order to rather rapidly study the occurrence and spatial distribution of ADE.

Since the sensors tested represent techniques that are working in different scales, an advisable approach is to combine them for efficient and cost-effective surveying. Satellite remote sensing may be useful for a regional survey of ADE soils, at least in areas with limited vegetation cover. Detailed soil investigations can then be carried out using different types of non-invasive geophysical field sensors; this should also be the case for ADE sites covered by primary or secondary forest. Of the instruments used in this project, the EM38 was particularly useful for rapid field scanning. The instrument can be used on-the-go to continuously register data in a rather large soil volume, also from below the topsoil. In fact, both output parameters ECe and MSa were in general positively correlated with e.g. SOC and soil P in topsoil samples. MSa works as an indicator of burning, which is useful in ADE surveys. The gamma ray sensor yielded less valuable data in these highly leached and weathered soils. It takes longer to collect data with a PXRF instrument. PXRF values are affected by only a very small amount of soil which makes it more difficult to collect representative data at a site. PXRF measurements in the field of total Ca or the correlated element Sr were well correlated with e.g. Ca, CEC and SOC in soil samples as determined in the laboratory. It is therefore plausible that a PXRF instrument can be calibrated to predict several ADE indicators indirectly and used in field surveys, bearing in mind that the soil must be very dry in that case since high (>20%) and varying soil

water content affects the output results. To reduce the number of costly laboratory analyses of soil samples, visNIR and especially MIR spectroscopy models can be used for rapid prediction of several soil properties on soil samples. The latter technique can potentially be used also in the field, but so far it is commonly applied on soil samples in a laboratory environment. Models for the soil properties SOC, CEC and Ca were again very efficient. In this project we showed that calibration models from one ADE site could successfully be deployed on soil samples from another site. This suggests that a spectral library of ADE soils can be used, minimizing the need for local calibration analyses. If local soil samples and analyses for calibration could be avoided then the technique may prove to be even more cost efficient in ADE surveys.

In one part of the CW project, we used a fuzzy clustering technique to combine data from the EM38 and gamma-ray sensors collected in an area dominated by mixed forest. One of the resulting classes coincided with soils with an ADE character (Figure 4). Another approach may be to combine detailed measurements with PXRF with remote sensing and on the go field sensors to acquire a spatial prediction model. The variability of the sensor data from both the EM38 and the PXRF demonstrated consistency with some soil properties typical as ADE indicators (Table 3 and 4). The satellite image also revealed the conditions in the uppermost soil layer in the ADE site on open, non-vegetated, agricultural land (Table 2). As an example, we applied a prediction model of CEC based on the correlation between soil CEC and Ca determined by PXRF on soil samples from Bom Futuro. This model was applied to PXRF field measurements at São Francisco. In Figure 8, a detailed map of CEC was created solely based on combined sensor data through co-kriging (Isaaks & Srivastava 1989). Here, ECe10 from the EM38 and NIR from a satellite image were used as co-variables in this process to achieve full spatial coverage.

The variability of the predicted topsoil CEC could be valuable in planning archaeological surveys and interpreting pre-Columbian settlements. We advise that methods for integrating multiple sensor systems are assessed further.

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Archaeological Research at Hinterland Sites on the Belterra Plateau, Pará

Per Stenborg

Introduction

As only limited previous archaeological fieldwork had been carried out at upland sites on the Belterra Plateau, preparatory fieldwork included the location and delimitation of archaeological sites through regional surveys (Stenborg et al. 2012). A recurrent pattern identified and documented in these surveys on the Belterra Plateau was the association between the location of archaeological sites and the presence of formations, such as hollows or depressions, of varying size in the landscape.

One of the specific aims of the fieldwork carried out within the Cultivated Wilderness project was therefore to improve our understanding of the relationship between such formations in the landscape and archaeological sites.

In 2011 detailed fieldwork was carried out at Bom Futuro; a site area situated on the Belterra Plateau about 40 km south of the city of Santarém in the State of Pará, Brazil (Figure 1).

Fieldwork at Bom Futuro consisted of extensive topographic mapping, archaeological excavation,

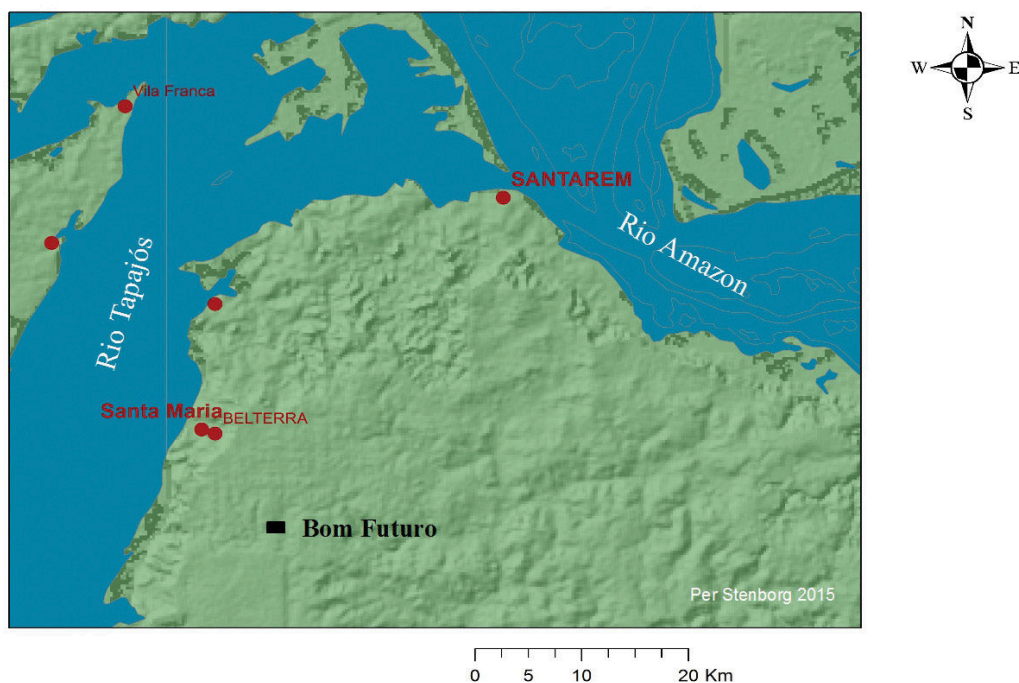


Fig. 1. The location of the Bom Futuro site area. By Per Stenborg 2015. Background relief map is based on the SRTM 1 arc second DEM (NASA Jet Propulsion Laboratory (JPL) 2014).



Fig. 2. The transect systems at Bom Futuro and Raimundo. By Per Stenborg 2015. Background image credit: Google et al. 2015.



Fig. 3 Areas of excavation in Bom Futuro 2011. The rectangles correspond to the areas show in the maps below. By Per Stenborg 2015. Background image credit: Google et al. 2015.

soil sampling and soil probing. Soil sampling, topographic mapping and soil probing were also undertaken at the nearby site of Raimundo (Figure 2), as well as at the site of Cedro to complement previous excavations (Cruz Gomes and Santos Lopes 2012; Schaan and Amaral Lima 2012; Schaan, this volume).

The mapping at Bom Futuro was carried out by the author using two sets of equipment. The contexts of excavation, transects and a number of open or recently cleared areas were measured with a total station. Additionally, a differential GPS was used for mapping larger or densely forested areas. Although the original GPS-data was recorded without real time differential correction, it was possible to obtain differential correction for the great majority of the recorded positions by means of post-processing. Total station as well as GPS measurements were recorded as point, line or polygon features. Position data was exported separately, hence the same datasets served as a basis for visualizing natural and cultural features accounting for the layout of the system of transects and excavation units, as well as for generating terrain models.

The maps illustrate the considerable difference between magnetic and “true” north in the area (a difference of approximately 15 degrees). Baselines, transects, trenches and squares were all roughly oriented in accordance with the magnetic compass. The transects were placed along an east-west baseline. At the main site area in Bom Futuro the baseline had a length of 640 m. Vertical to this line, lines were opened by clearing the brushwood at intervals of 40 m along the baseline. The easternmost transect was labelled “0 m west” and the westernmost “640 m west”. The length of each north–south transect at Bom Futuro was approximately 550 m. The transect system at Bom Futuro thus covered an area of 640×550 m, i.e. 352000 square meters or 35.2 hectares (Figure 3).

A similar but smaller system of transects was established about 1.2 km south-west of the main site area of Bom Futuro; an area that had been cleared for cultivation, providing good visibility of archaeological artifacts on the ground surface (the Raimundo property) (Figure 2). Transects were also established at the Cedro site, 17.5 km north-east of Bom Futuro.

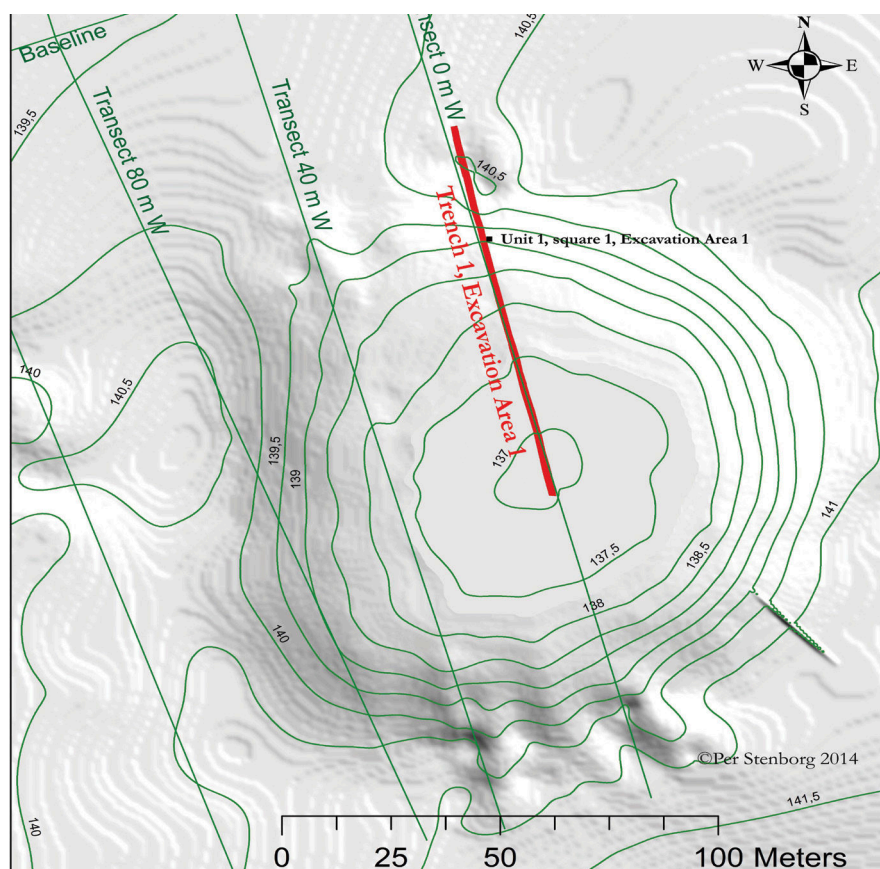


Fig. 4. Positions of unit 1, square 1 and trench 1 Excavation Area 1. By Per Stenborg 2012.

Excavations at Bom Futuro

In total four 1x1 m squares were excavated on the main site area of Bom Futuro. In Excavation Area 1 a single square was initially excavated in the slope of a large depression. This square was later supplemented by the excavation of a trench by means of a mechanical excavator (Figures 4 and 5). Two squares were excavated in a minor depression along with another square on a low platform associated in the area of the smaller depression in Excavation Area 2 (Figures 6 and 7).

Excavation Area 1

Summary of the results from the excavation of unit 1, square 1 in Excavation Area 10

The first excavation at Bom Futuro was carried out in order to investigate the soil layer sequence on the rim of a large round depression. Similar depression have been recorded in the vicinities of other archaeological sites on the Belterra Plateau; making this investigation relevant beyond the scope of its particular setting. For some years this area has been used for maize and soya production and has consequently been affected by mechanized agriculture. The layers of this 1x1 m square (unit 1, square 1 in Excavation Area 1) contained no thick soil deposits and almost no cultural material. The first layer was affected by modern agriculture (e.g. plowing work) and extended down to approximately 0.3 m below ground surface where a hard packed yellowish clayey layer entirely devoid of cultural impact appeared.

Additional trenching in Excavation Area 1

With the purpose of improving our knowledge about the formation processes, constitution and possible human modification of large depressions, such as those found in Excavation Area 1, a trench was excavated in the northern part of this depression using a mechanical excavator. The trench, with a total length of 105 m, was laid out in a south to north direction from the center of the depression towards and some 10 m past its edge (Figure 5). The trench coincided with the transect at 0 m west.

The position of the trench along the first transect implied that it could easily be integrated into the documentation system of both the archaeological fieldwork and the soil research. In this way it was possible to document the layer down to a depth of

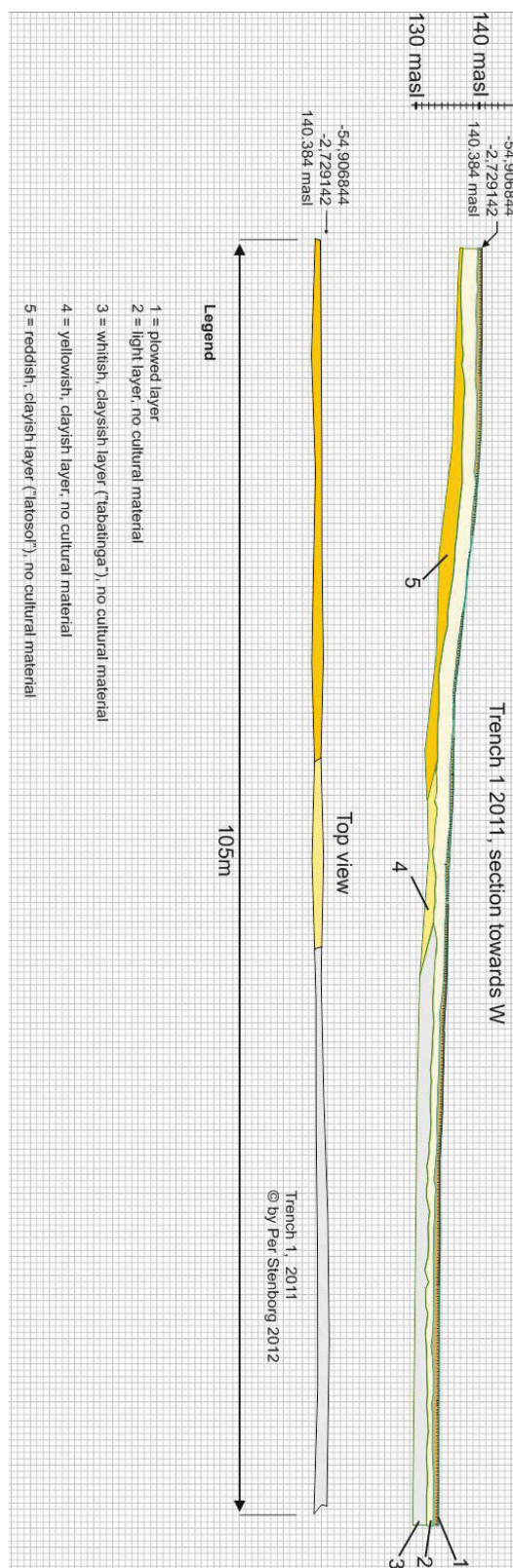


Fig. 5 Cross-section and Top View of Trench 1. By Per Stenborg 2012.

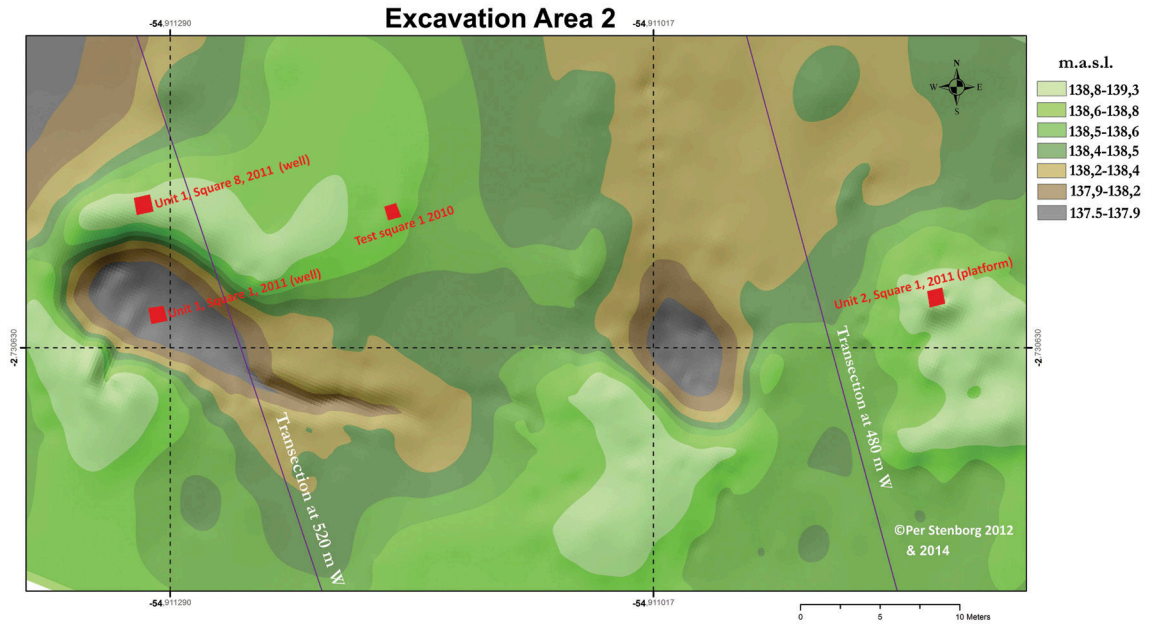


Fig. 6. Map showing the positions of units and squares in Excavation Area 2. The well or depression is found in the western part of the map (unit 1, squares 1 & 8) and the platform to the east (unit 2, square 1). The position of a test square excavated in 2010 is also shown (test square 1). By Per Stenborg 2014.

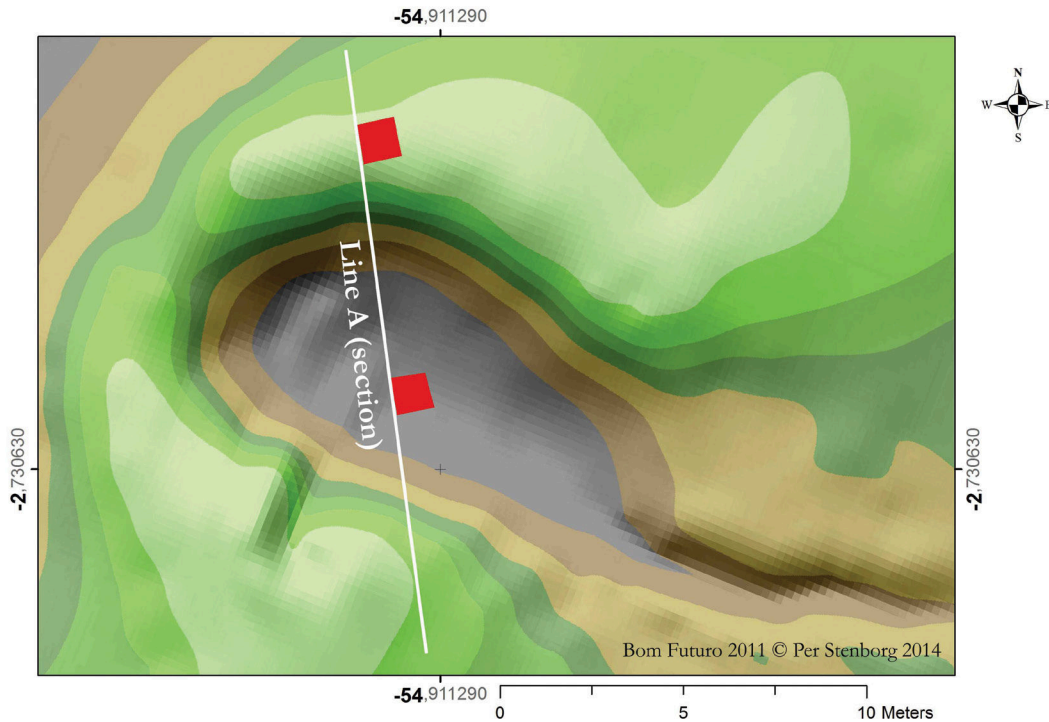


Fig. 7. Position of the squares – square 1 and 8 were excavated in the bottom and berm of a small depression. The line “A” represents the position of the section shown in the following figure. By Per Stenborg 2012.

approximately 2 m along the extent of the trench.

The excavation revealed significant differences concerning the layers in different parts of the trench. The (ploughed) surface layer darkened by organic matter in the center of the depression was followed by a light yellow horizon overlying a compact

whitish, clayey stratum, locally called “Tabatinga”. This layer was found to continue to at least a depth of 5 m in the center of the depression. The whitish (“Tabatinga”) layer was depleted in iron as the result of waterlogging and reducing conditions during the rainy season (Georg Irion, personal

communication 2011). Further upslope the color of the corresponding layer turned more orange – indicating a lower degree of water exposure. In this part of the trench there was a thin plinthic layer in the subsoil. In the northernmost sector of the trench the soil had a reddish color throughout indicating more freely draining conditions (Eriksson et al. 2012).

Excavation Area 2

Summary of the work in Excavation Area 2

A second excavation was undertaken in a much smaller, walled depression about 0.5 km west of Excavation Area 1 (Excavation Area 2 in Figure 3). In Area 2 there are several smaller depressions, surrounded by clearly distinguishable rounded banks or berms (see Figure 6). Similar features have been found at other sites on the Belterra Plateau (e.g. at Cedro, see Schaan, this volume). In order to investigate this type of feature one square was excavated in the center of such a depression, while



Fig. 8. The wall of square 1 towards the West at a depth of 0.98 m. The layer of grey sediment is somewhat deeper in the north than in the south, two large pottery fragments in a horizontal orientation can be seen near the SW corner at a depth of 70 and 75 cm (c.p. Figure 09, below). Photo by Imelda Bakunic.

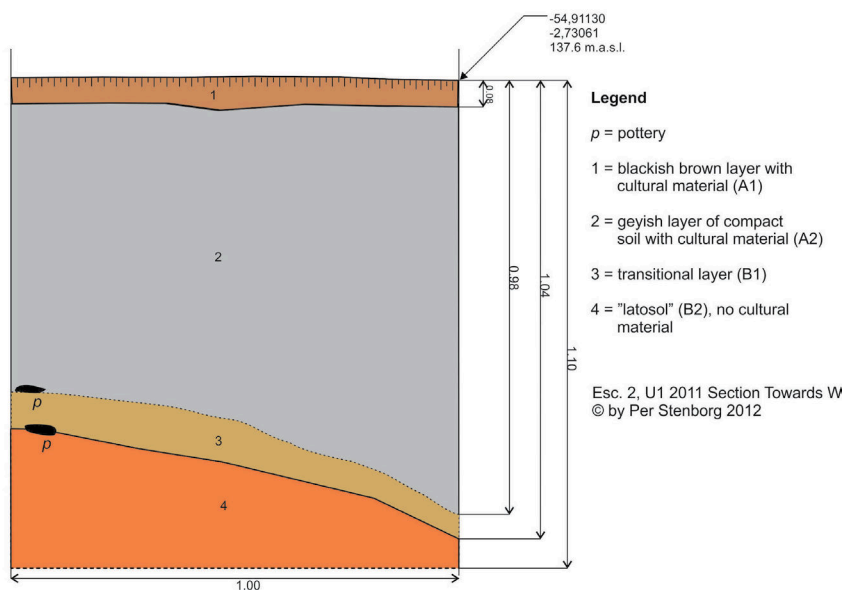


Fig. 9 Cross-section of square 1 of unit 2, towards the West. By Per Stenborg 2012.

Table 1. Vertical distribution of pottery in square 1 (u1).

| Depth below surface (cm) | Number of pottery fragments | Number of fragments per 0.1 cubic meter of soil |
|--------------------------|-----------------------------|-------------------------------------------------|
| 0-7 | 138 | 197 |
| 7-11 | 7 | 17.5 |
| 11-21 | 12 | 12 |
| 21-31 | 2 | 2 |
| 31-41 | 6 | 6 |
| 41-51 | 3 | 3 |
| 51-61 | 1 | 1 |
| 61-71 | 16 | 16 |
| 71-81 | 46 | 46 |

a second square was placed at the highest point of the surrounding bank (Figure 7).

The pattern found contrasted sharply with that found in Area 1. The first 1x1 m square (square 1) was excavated in the center of the depression and contained deep layers and relatively high amounts of cultural material. The material consisted almost exclusively of coarse undecorated pottery, most probably of utilitarian types. A particular observation was that most of these sherds were found in a horizontal orientation. Pottery was found to a depth of about 0.8 m below present ground level (Figures 8 and 9).

A second 1x1 m square (square 8) was excavated in the berm surrounding the depression. In this case the material was more varied and occurred as concentrations of pottery, charcoal and to some extent also lithics. Pottery types included fine, decorated pottery as well as coarse pottery. The pattern of horizontal positions of fragments observed in unit 1 was not repeated in unit 8.

Table 2. Vertical distribution of pottery in square 8 (u1).

| Depth below surface (cm) | Number of pottery fragments | Number of fragments per 0.1 cubic meter of soil |
|--------------------------|-----------------------------|-------------------------------------------------|
| 0-7 | 37 | 53 |
| 7-10 | 42 | 140 |
| 10-20 | 96 | 96 |
| 20-30 | 103 | 103 |
| 30-40 | 270 | 270 |
| 40-50 | 132 | 132 |
| 50-54 | 58 | 142 |
| 54-64 | 61 | 61 |
| 64-74 | 75 | 75 |
| 74-81 | 4 | 6 |

Cultural material was found to a depth of 0.7 m (Figures 10 and 11).

Additionally, a square (Unit 2, Square 1) was excavated in the center of a platform situated east of the enclosed depression. This excavation aimed at investigating whether the platform represented the remains of a dwelling (Figures 12 and 13).

Results from the excavation of unit 1, square 1 in Excavation Area 2

Although cultural material was found in all layers down to a depth of approximately 0.8 m below the present surface of the ground, the occurrence of pottery was very unevenly distributed between the layers, as shown in Table 1.

Below the top/turf layer (*c.* 7 cm), which contained large quantities of pottery, only a small amount of pottery was encountered down to a depth of about 70 cm. Between 70 and 80 cm the frequency rose significantly. A great portion of the fragments encountered at this depth were



Fig. 10. Picture of square 8 after excavation, showing the profile towards the North. Lenses of clay, charcoal and soot can be seen in the lower part of the profile. Photo by Per Stenberg 2011.

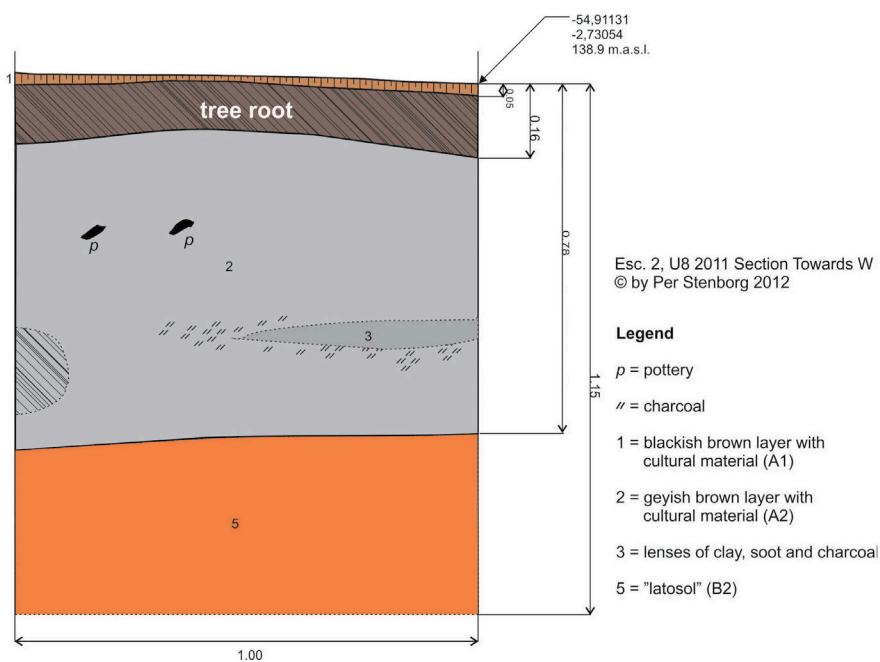


Fig. 11. Cross-section of excavation 2, square 8 towards the West. By Per Stenberg 2012.

large sherds of coarse pottery found in a horizontal orientation. No more pottery was encountered below a depth of about 80 cm.

Results from the excavation of unit 1, square 8 in Excavation Area 2

In this square, which was excavated in the berm, the pattern of distribution of material between layers was markedly different from that found in square 1. Several concentrations of pottery consisting of

similar ceramic types, in some cases also re-joinable fragments, were encountered in the layers between 20 and 60 cm below the ground surface of square 8. Other concentrations consisted of charcoal, soot, and burned clay (Table 2).

An important observation was the presence of two thin lenses; one of clay and the other consisting of charcoal, ash and soot. These lenses were clearly visible in the sections (See Figures 10 and 11).

Results of the excavation of unit 2, square 1 in Excavation Area 2

This square was excavated in the center of a small platform situated some 30 m east of the investigated depression (unit 1). About 10 m west of this platform, there was a second minor depression. Additional platforms could be discerned in the terrain immediately to the east as well as to the south and north of the two small depressions (Figure 6).

The cultural layer, which extended down to approximately 55 cm below the present surface,

contained high amounts of pottery, as well as some lithics, charcoal, soot and burned clay (Figures 12 and 13). The pottery was dominated by undecorated, coarse, utilitarian types. In contrast to the pottery found in unit 1, the pottery in this cultural layer was highly fragmented and largely consisted of micro-fragments (Isendahl 2012).



Fig. 12. Section of excavation 3, towards the West. Photo by Christian Isendahl.

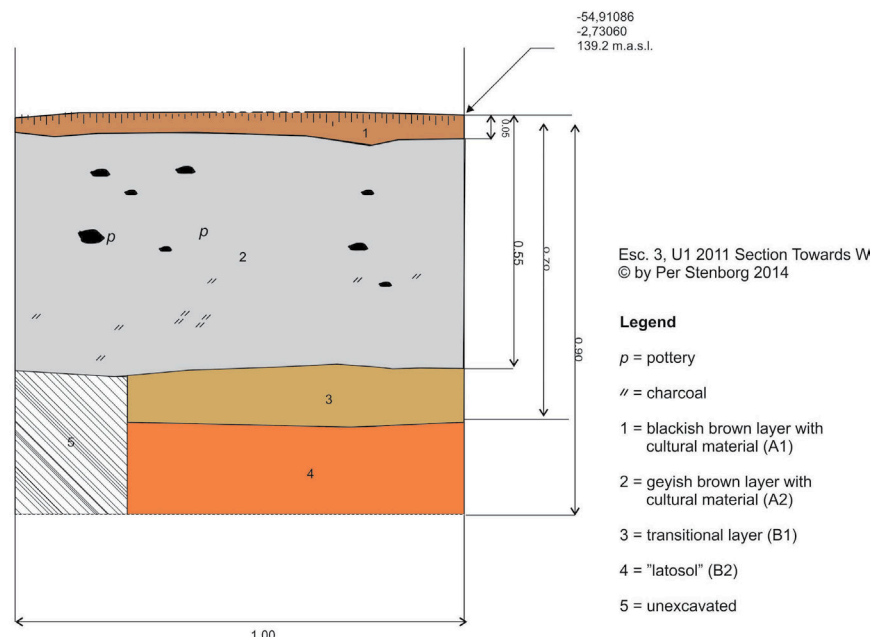


Fig. 13. Cross-section of the square excavated in a small platform, towards the West. By Per Stenborg 2014; after a drawing by Christian Isendahl.

Discussion of the results of the investigations in Excavation Area 2

The excavations, as well as the precision mapping of the topography of this area, gave strong support to the hypothesis that this was used as a domestic or dwelling area. The investigations of the enclosed depression in the western part of the area showed that this formation was largely artificially constructed (Figure 14). The berm surrounding the depression has been built up by muddy sediments moved from the bottom of the depression. This work also produced the thin lenses of light clay, seen in the profile walls of the square excavated in the berm. This process of moving clay can also be compared with that used in poddling and pugging of clay. Such treatment will break up the structures of the clay and reduce its water permeability (Jan Eriksson, personal communication). Coating the ground of the reservoir with poddled clay may have been a technique used to improve the reservoir's ability to hold water. Secondary refuse materials, mainly broken pottery, charcoal and ashes were also (re-)used as a construction material in the construction of this berm. Below this imposed material a thin lens of charcoal and ashes covered what appeared to be the old ground level. This lens may hence originate from an initial clearing and burning of the vegetation in the area.

In square 1, excavated through the layers in the bottom of the depression, the layers below the uppermost 7 cm, down to a depth of about 70 cm, were found to contain comparably little pottery. The lowermost 10 cm of the cultural layer contained a significantly higher amount of pottery compared to all other layers except for the uppermost 7 cm. A reasonable interpretation is that sediments down to approximately 70 cm below the surface accumulated through water transport and deposition after the settlement was abandoned. Many of the ceramic fragments found in this square were comparably large sherds; found in a horizontal orientation. These sherds may, accidentally – or through water transportation – have ended up on what was then the bottom of the reservoir. The low degree of fragmentation of this pottery seems to suggest that the reservoir held water when the settlement was in use. While the process of filling up this depression through waterborne transport of sediments after abandonment of the settlement

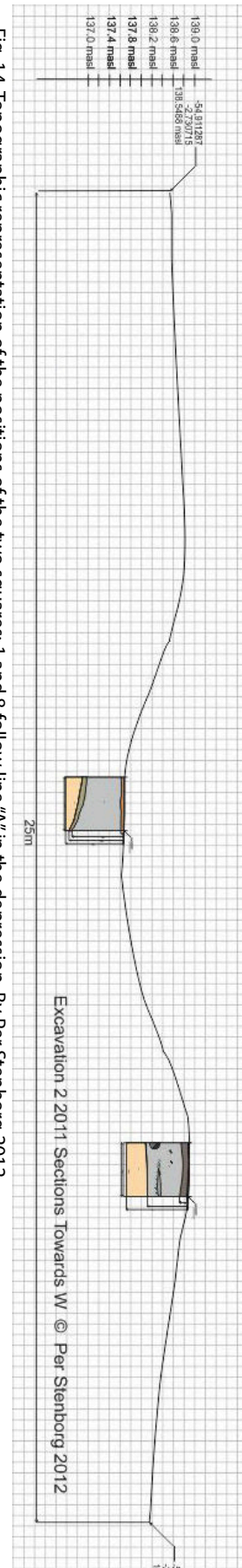


Fig. 14. Topographic representation of the positions of the two squares: 1 and 8 follow line "A" in the depression. By Per Stenborg 2012.

Table 3. Vertical distribution of pottery in square 1 (u2).

| Depth below surface (cm) | Number of pottery fragments | Number of fragments per 0.1 cubic meter of soil |
|--------------------------|-----------------------------|-------------------------------------------------|
| 0-10 | 215 | 215 |
| 10-20 | 172 | 172 |
| 20-30 | 199 | 199 |
| 30-40 | 244 | 244 |
| 40-50 | 170 | 170 |
| 50-60 | 66 | 75 |
| 60-70 | 12 | 16 |
| 64-74 | 6 | 8 |
| 74-81 | 4 | 5 |

(or at least the abandonment of the reservoir) may have gone on for several centuries, the high concentration of fragmented pottery found in the topmost layer indicate that intensified activity linked to renewed human settlement in the area during the 20th century led to the movement of surface material over the settlement.

The investigation of a platform-formation situated about 30 m to the east of the excavated depression gave support to the hypothesis that it represented the remains of a dwelling. The cultural layers contained high quantities of highly fragmented pottery, a pattern which may be the result of frequent trampling on the floor inside the habitation. Sweeping and other cleaning activities may primarily remove bigger pieces from broken artifacts, while micro-fragments are easily trampled into the floor where they would become stuck and hidden (primary refuse). The high frequency of cultural material continued down to a depth of 55 cm in this square; this layer may have been built up through accumulation of material inside the dwelling throughout its period of use. In two parts of the square the cultural layer continued down into the yellowish “latosol”. Although disturbances from roots and burrowing animals were found in parts of the square, at least one of these pits may have been the result of human activities associated with the occupation of this settlement.

Dates

A total of 17 samples from the Bom Futuro site have been dated. The ambition was to combine several dating methods, therefore both radiocarbon

(14C) and optically stimulated luminescence (OSL) dating have been used (Table 4). The samples all originate from the sector referred to as Excavation Area 2 in this text. Two samples were taken from a test-square excavated in 2010, while the remaining 15 samples all came from the excavations undertaken in 2011. The 2011 investigations in Excavation Area 1 showed that that sector has not been significantly affected by past human activity; virtually no datable material was found.

Based on the received dates, we may conclude that the settlement in the Excavation Area 2 was inhabited during the late pre-contact period, corresponding to the period of the so-called Santarém phase pottery, and that the occupation probably continued into the contact period (post A.D. 1542). A radiocarbon date of a sample from a thin lens of charcoal and ashes encountered below the berm constructed around the water reservoir (sample CW2011:018, from unit 1, square 8) suggests that an initial clearing up and burning of vegetation occurred sometime between A.D. 1290 and A.D. 1420. This would temporally coincide with the proposed period of regional expansion of the Santarém phase pottery (Quinn 2004; Roosevelt 1999; Schaan 2012; Schaan and Amaral Lima 2012).

Placed into a broader context, the Bom Futuro site — along with several other sites on the Belterra Plateau (e.g. Cedro and Amapá) appears to have been established in the course of an expansion process, which began around A.D. 1100 and which continued up to the time of European contact in the 16th century.

| Submitted by | Sample no | Type | Lab. No. | Unit, Square | Depth below surface (cm) | Result | Ranges (for 14C: cal. 2 sigma = 95.2% conf.) |
|--------------|-------------|-------------|-----------------|---------------------|--------------------------|-----------------------|--------------------------------------------------|
| Stenborg | CW2010:009 | OSL | Risø 112307 | U1 2010 square 1 | 22,5 | 0.23ka ± 0.01 | A.D. 1771 – A.D. 1779 |
| Stenborg | CW2010:010 | OSL | Risø 112308 | U1 2010 square 1 | 32,5 | 0.46ka ± 0.03 | A.D. 1521 – A.D. 1581 |
| Schaan | BFT2010-001 | Radiocarbon | Beta- 324178 | U1 2010 square 1 | 20-25 | 350 +/- 30 BP | A.D. 1493 – A.D. 1646 |
| Stenborg | CW2011:014 | Radiocarbon | Ua-46302 | U1 2011 square 1 | 41-51 | modern carbon content | un-datable |
| Stenborg | CW2011:015 | Radiocarbon | Ua-46303 | U1 2011 square 1 | 91-98 | modern carbon content | un-datable |
| Stenborg | CW2011:016 | Radiocarbon | Ua-46304 | U1 2011 square 8 | 47 | 497 +/- 30 | A.D. 1410 – A.D. 1477 |
| Stenborg | CW2011:017 | Radiocarbon | Ua-46305 | U1 2011 square 8 | 58 | 540 +/- 30 | A.D. 1400 – A.D. 1450 |
| Stenborg | CW2011:018 | Radiocarbon | Ua-46306 | U1 2011 square 8 | 68 | 586 +/- 30 | A.D. 1322 – A.D. 1347 or A.D. 1387– A.D. 1438 |
| Stenborg | CW2011:1 | OSL | Risø 132301 | U1 2011 square 1 | 47 | 0.37ka ± 0.02 | A.D. 1624 – A.D. 1664 |
| Stenborg | CW2011:2 | OSL | Risø 132302 | U1 2011 square 1 | 47 | 0.42ka ± 0.03 | A.D. 1564 – A.D. 1624 |
| Stenborg | CW2011:3 | OSL | Risø 132303 | U1 2011 square 1 | 74 | 0.108ka ± 0.008 | A.D. 1898 – A.D. 1914 |
| Stenborg | CW2011:4 | OSL | Risø 132304 | U1 2011 square 8 | 35 | 0.55ka ± 0.03 | A.D. 1434 – A.D. 1494 |
| Stenborg | CW2011:5 | OSL | Risø 132305 | U1 2011 square 8 | 45 | 0.41ka ± 0.03 | A.D. 1574 – A.D. 1634 |
| Stenborg | CW2011:6 | OSL | Risø 132306 | U1 2011 square 8 | 60 | 0.50ka ± 0.03 | A.D. 1484 – A.D. 1544 |
| Stenborg | CW2011:7 | OSL | Risø 132307 | U1 2011 square 8 | 70 | 0.50ka ± 0.03 | A.D. 1484 – A.D. 1544 |
| Stenborg | CW2011:9 | OSL | Risø 132308 | U2 2011 square 1 | 35 | 0.45ka ± 0.03 | A.D. 1534 – A.D. 1594 |
| Stenborg | CW2011:10 | OSL | Risø 132309 | U2 2011 square 1 | 45 | 0.50ka ± 0.03 | A.D. 1484 – A.D. 1544 |

Table 4. Radiocarbon and OSL dates from Excavation Area 2, Bom Futuro. Radiocarbon dates have been calibrated with the Oxcal v4.2.4. software, using the SHCal13 calibration curve.

Summary

The archeological fieldwork revealed similarities as well as differences between the investigated settings. In Excavation Area 2 (the smaller depression and plateau) our investigations showed that this whole area had been considerably transformed by human action in the past. It is reasonable to consider that the area was used as a settlement area. The minor depression may have served as a water supply covering the needs of a group of households. Even if this depression existed as a natural landscape formation prior to human settlement – it has been heavily modified through human action. The berm surrounding the depression contained refuse material (charcoal, potsherds, soot etc.) as well as material that had apparently been moved from the bottom of the depression and deposited on the berm. This pattern seems to be in accordance with land modification processes such as the construction of a water reservoir, improvement of

the water holding capacity of a reservoir and its maintenance; it is likely that in this case the human transformation involved at least the latter two activities. Material transported by rain water would have accumulated at the bottom of the depression through deposition necessitating periodic clearing out and maintenance of the reservoir.

In contrast, the investigations of a much larger depression (Excavation Area 1, including Trench 1) scarcely revealed any cultural material. This supports the assumption that these large depressions (some of which have a diameter of several hundred meters) are essentially geological formations (cf. Gounou 1950:220; Stenborg et al. 2014:153f; Valverde 1972:69). The sediments investigated in trench 1, nevertheless, displayed obvious signs of long term water influence. It is reasonable to make the assumption that the presence of such formations – which act as natural collectors of surface water – were crucial for the choice of a settlement's location.

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Christian Isendahl is Senior Lecturer in Archaeology at the Department of Historical Studies, University of Gothenburg, Sweden. He is interested in issues of long-term sustainability and resilience and applies a historical ecological lens to study urbanism, farming systems, water management, and socio-political organization in the past, particularly in the Maya lowlands, the Andes, and the Amazon. He has a strong interest in exploring, detailing, and discussing how archaeological research can generate knowledge about the past and about long-term processes that provide practical insights for addressing contemporary challenges.

Denise P. Schaan is best known for her innovative research on Marajó Island, mouth of the Amazon River, and more recently for her leading role in the Western Amazonia geoglyph research,

which have attracted worldwide attention. Since 2010, she has directed the Cultivated Wilderness Project together with Per Stenborg, focusing on the ethnohistoric Tapajó occupation in the Lower Amazon. Schaan completed a Master Program in Archaeology in 1996 in Brazil, and earned her Ph.D. degree at the University of Pittsburgh in 2004. In 2005, she joined the Faculty of the Department of Anthropology of the Federal State University of Pará, in northern Brazil, where, in 2010, together with other colleagues, she created the first Four Field Anthropology Graduate Program in the country. Schaan has published 30 scientific articles, 32 book chapters, and 12 books focusing on Amazonian archaeology. Her book “Sacred Geographies of Ancient Amazonia” (Left Coast Press, 2012) offers a comparative perspective, based on a historical ecology approach, to understand Amazonian social formations at the eve of the European contact.

Per Stenborg is Associate Professor and researcher at the Department of Historical Studies, University of Gothenburg; where he also currently is the director of studies in archaeology. Over the last 25 years he has carried out several archaeological research projects in different parts of South America. From 2008 he has been collaborating with Denise Pahl Schaan, regarding the archaeology of the Santarém Region in Brazil, and he has been project director of the Cultivated Wilderness Project. He has also done research about how archaeology and cultural heritage management may use digital and computer-based technologies in presenting and communicating their results and products and how — in turn — these technologies change the archaeological

practice and the understanding of history. Research interests: Late-pre-Columbian and early post-contact periods in various parts of South America; possibilities to use archaeological information to complement as well as to challenge other kind of information; use of GIS, 3D-technology and other spatio-temporal methods in reconstructing and visualizing past conditions and their development over time.

Mats Söderström is Associate Professor and researcher at the Department of Soil and Environment at SLU (the Swedish University of Agricultural Sciences), and associate researcher at CIAT (Centro Internacional de Agricultura Tropical). One of the pioneers in Sweden in the field of precision agriculture. His interests include geographic information systems, geostatistics and spatial analyses, remote and proximal sensing of soil and crops. In the CW project his focus was on digital soil mapping and the use of sensors and pedometrics for mapping of key soil properties of Amazonian Dark Earths.

Joanna Troufflard is a French-Brazilian Ph.D. student in anthropology at the University of Florida. Her Ph.D. project addresses ceramic industries from indigenous people that lived in the Belterra plateau during late precolonial and early colonial times. She has participated in several projects in the Brazilian Amazon, especially in the Pará and Acre states. Her main research interests are precolonial archaeology, Brazilian Amazon, historical ecology, public archaeology, ceramic analysis, Archaeological Dark Earths (ADE), and collection studies.

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This book is one of the outcomes of the project *Cultivated Wilderness: Socio-economic development and environmental change in pre-Columbian Amazonia* (www.cultivated-wilderness.org). The project has particularly focused on the previously relatively unknown prehistory of the Amazonian hinterland. Our work has revealed that pre-Columbian settlements in the Santarém region in the State of Pará, Brazilian Amazonas, were not (as formerly often assumed) limited to the vicinities of permanent water courses, such as rivers and lakes. On the contrary, the majority of region's archaeological sites are found in an upland area known as the Belterra Plateau, situated south of the present city of Santarém. Series of radiocarbon and luminescence dates link these sites to an expansion of human settlement occurring during the period A.D. 1300–1500. The period appears to have been associated with major transformations of the prehistoric societies, significant population growth and the development of new types of water management and agriculture.

The workshop *Beyond Waters: Archaeology and Environmental History of the Amazonian Inland* formed part of the *IX Sesquiannual Conference of the Society for the Anthropology of Lowland South America* (SALSA), held in Gothenburg, Sweden in June 2014. The presenters and participants at the workshop included members of the Cultivated Wilderness-project, as well as partners and colleagues from several countries in Latin America and Europe. The contributions of the present volume span a wide range of subjects and fields, including archaeology, soil science, landscape archaeology, paleobotany, stylistic studies, historical information and digital mediation, broadening the thematic scope of the book.



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