Bol. Mus. Para. Emílio Goeldi. Ciências Humanas, Belém, v. 3, n. 2, p. 175-194, maio-ago. 2008

Dark Earths and manioc cultivation in Central Amazonia: a window on pre-Columbian agricultural systems?

Terras Pretas e o cultivo de mandioca na Amazônia Central: uma janela para os sistemas agrícolas pré-colombianos?

James A. Fraser[I]
Charles Roland Clement[II]

Abstract: Many commentators highlight the fertility of Anthropogenic Dark Earths (ADE), emphasizing their potential for sustainable agriculture. Some scholars believe that *terra mulata* (the less fertile, more extensive form of ADE) was created by means of agricultural practices used by large settled populations of pre-Columbian farmers. But what was it that these Amerindian farmers were growing? Until recently, scholarly consensus held that manioc does not perform well on ADE. New research on the middle Madeira River is showing, however, that this consensus was premature. In this region, the most common crop in ADE fields is bitter manioc. Farmers there have various landraces of manioc that they believe yield particularly well on ADE, and logically plant more of these varieties on ADE. Aspects of the behaviour and perception of manioc cultivation among 52 farmers at the community of Barro Alto were measured quantitatively on four *terra firme* soil types (Terra Preta, Terra Mulata, Oxisols and Ultisols). These farmers plant different configurations of landraces in different soils, according to their perception of the suitability of particular landraces and their characteristics to certain soil types and successional processes. This, in turn, shapes selective pressures on these varieties, as new genetic material incorporated from volunteer seedlings is more likely to contain traits present in the most prevalent landrace(s) in each soil type. Owing to localized population pressure at Barro Alto, manioc is under more intensive cultivation systems, with shorter cropping periods (5-10 months) and shorter fallow periods (1-2 years). The outcome of these processes is different co-evolutionary dynamics on ADE as opposed to non-anthropogenic soils. Further anthropological study of manioc swiddening in one of the richest agricultural environments in Amazonia can fill a gap in the literature, thus opening an additional window on the pre-Columbian period.

Keywords: Anthropogenic soils. Dark Earths. Agricultural Intensification. Manioc. Central Amazonia. Madeira River.

Resumo: Muitos comentaristas realçam a fertilidade da Terra Preta de Índio (TPI), enfatizando seu potencial para uma agricultura sustentável. Alguns estudiosos acreditam que Terra Mulata (uma forma menos fértil, porém mais comum de TPI) foi criada por meio de práticas agrícolas usadas por grandes populações sedentárias na época pré-colombiana. Mas o que estes agricultores ameríndios cultivavam? Até recentemente, o consenso acadêmico era de que mandioca não se adaptava bem em TPI. Novas pesquisas no Médio Rio Madeira estão demonstrando, porém, que este consenso era prematuro. Nesta região, a colheita mais comum em roças de TPI é mandioca amarga. Os agricultores têm diversas variedades crioulas (raças primitivas) de mandioca, que eles acreditam render especialmente bem em TPI e, logicamente, plantam mais destas variedades em TPI. Aspectos do comportamento e da percepção do cultivo de mandioca entre 52 agricultores da comunidade de Barro Alto foram observados quantitativamente em quatro tipos de solo da terra firme (Terra Preta, Terra Mulata, Latossolos e Argissolos). Esses agricultores plantam diferentes configurações de raças primitivas em diferentes ecótonos, de acordo com a percepção deles sobre o comportamento de cada raça primitiva e suas características em cada tipo de solo e situação da sucessão ecológica. Estas práticas, por sua vez, influenciam as pressões seletivas nessas raças, pois é mais provável que o material genético novo incorporado de mudas espontâneas contenha características presentes nas raças prevalentes em cada tipo de solo. Devido à pressão da população em Barro Alto, a mandioca é cultivada em sistemas mais intensivos, com períodos mais curtos entre plantio e colheita (5-10 meses) e períodos menores de pousio (1-2 anos). A conseqüência desses processos é uma dinâmica co-evolutiva em TPI, diferentemente de solos não-antrópicos. Mais estudos antropológicos do cultivo de mandioca em um dos ambientes agrícolas mais ricos da Amazônia podem encher essa lacuna na literatura, abrindo uma janela adicional sobre o período pré-colombiano.

Palavras-chave: Solos antropogênicos. Terra Preta. Intensificação Agrícola. Mandioca. Amazônia Central. Rio Madeira.

[I] University of Sussex. Department of Anthropology. Brighton, Inglaterra (james.angus.fraser@gmail.com).
[II] Instituto Nacional de Pesquisas da Amazônia. Coordenação de Pesquisas em Ciências Agronômicas. Manaus, Amazonas, Brasil (cclement@inpa.gov.br).

INTRODUCTION

Many commentators highlight the fertility of Anthropogenic Dark Earths[1] (ADE), emphasizing their potential for sustainable agriculture across the humid tropics (e.g., Glaser, 2007). In Amazonia, a scientific consensus has emerged, with scholars from diverse fields of inquiry agreeing that the origin of some of the ADE of the region (those soils known as *Terra Preta do Índio*) is a legacy of the habitational activities of Amerindian peoples (accumulation of household and kitchen waste, especially animal bones, yard sweepings burnt with low intensity fire, used palm thatch etc.) in the late pre-Columbian period. This has been termed the 'midden model' of ADE formation (Kämpf *et al.*, 2003). *Terra preta* is black or dark brown in colour, extremely fertile, with high levels of phosphorus, calcium and other nutrients, and large quantities of organic matter, especially charcoal, and pieces of ceramics (Lehmann *et al.*, 2003; Glaser and Woods, 2004). The oldest sites date to around 5.000 years (Meggers and Miller, 2006), but ADE only becomes widespread in the archaeological record around 2.000 years ago (Neves, 2008).

While the midden model is now almost completely uncontroversial, there is much debate and disagreement surrounding a second kind of ADE. *Terra mulata* is thought to have been formed through intensive agricultural practices involving low intensity burning and mulching (Sombroek, 1966; Woods and McCann, 1999; McCann *et al.*, 2001; Denevan, 2001, 2004, 2006; Mora, 2006). While some researchers have provided evidence of present day analogues of ADE formation through agriculture, both in Amazonia (Hecht and Posey, 1989; Hecht, 2003), on the coast of French Guiana (Rosaine, 2008) and in West Africa (Leach and Fairhead, 1995; Fairhead and Scoones, 2005), the matter remains largely unresolved. This means that despite ADE being associated with agricultural potential today, evidence[2] of their use for agriculture in the pre-Columbian era is still lacking (but for a promising start see Arroyo-Kalin, 2008a).

If ADE were used for agricultural purposes, we must first ask the questions: What crops were Amerindian farmers growing? Which cultivation practices did they use? And where were they planting? Manioc[3] (*Manihot esculenta*) emerged as the principal crop cultivated by Amerindian farmers as they became increasingly dependent on food production systems about three thousand years ago[4] (Lathrap, 1970; Piperno and Pearsall, 1998; Oliver, 2001). Manioc was probably domesticated between 10.000 and 8.000 years ago, given the presence of archaeological remains on the Pacific coast of Peru before 6.000 years ago (Pearsall, 1992), and this clonally propagated tuber-bearing herbaceous shrub was dispersed from its birthplace in Southwestern Amazonia throughout lowland South and Central America and the Caribbean by the time Columbus arrived. Accounts of first chroniclers of the Solimões River are full of references to an abundance of manioc and associated foodstuffs (see Sweet, 1974; Espinosa, 1948). Maize has been present in Amazonia for 6.000 years, but human bone isotopic evidence suggests that it only became a primary staple in the last few centuries before European contact (Arroyo-Kalin, 2008b).

Research on manioc agriculture in Amazonia has focussed principally on long fallow shifting cultivation in marginal environments (i.e., the old, heavily leached and infertile soils of the upland *terra firme*) (Carneiro, 1983;

---

1 We use "anthropogenic" rather than "Amazonian" to reflect the fact that these soils are a global phenomenon, rather than one that is restricted to the Amazon basin. See Graham (2006) for a discussion.

2 Studies are being planned on the phytoliths that exist buried in ADE sites. They can provide direct evidence as to what was grown on these soils, as well as to the plants used as mulch.

3 While the term 'cassava' is often used in English, 'manioc' is a more suitable name, as it is closer both to the scientific term *Manihot* and the Brazilian term *mandioca*. Its roots lie in the Tupi word *maniot*. The term 'cassava' comes from *casaba*, an Arawak word that refers to manioc bread, rather than the plant itself (Gade, 2002).

4 While maize arrived in Amazonia some 6.000 years ago, it did not become widely cultivated until the late-pre-Columbian chiefdoms of the major rivers (Roosevelt, 1980, 1999).

Chernela, 1987; Boster, 1984; Elias *et al.*, 2000b; Wilson and Dufour, 2002; Emperaire and Peroni, 2007). There have been few studies of manioc swiddening in richer environments (i.e., floodplain soils and ADE) despite the fact that sixteenth - and seventeenth-century accounts affirm that maize and manioc were the primary floodplain crops of the Amerindian nations, such as the Omagua and Tapajó Indians (Meggers, 1996). The pre-Columbian territories of these groups contain numerous large ADE sites today. Laura German studied the cultivation of crop assemblages (of which manioc formed a part) on ADE, but she concludes that these soils are unsuitable for manioc (German, 2001, 2003).

This lack of study in the richest agricultural environments makes ethnographic projection extremely problematic (Roosevelt, 1989) and may help explain why manioc is considered a *terra firme* crop that requires long-fallow shifting cultivation. An analogy with crop landrace definitions helps understand this situation: Anton Zeven (1998, p. 127) examined the history of the definition of this term and concluded that "an autochthonous landrace is a variety with a high capacity to tolerate biotic and abiotic stress, resulting in a high yield stability and an intermediate yield level under a low input agricultural system". Note that, by definition, a landrace is confined to low input agriculture, which, for a modern agronomist or plant breeder, means a marginal environment, like the nutrient poor soils of the Amazonian *terra firme*. Ethnographic projection from this definition would confine agricultural systems to marginal environments instead of the best ones available at any given time in the past. Landraces are so defined today because of the expansion of industrial agriculture that dominates the best agricultural landscapes; traditional agriculture is marginal today for the same reasons. As Anna Roosevelt (1989) cautions, the pre-Columbian period was quite different from the post-conquest period about which we have much more information. This contribution is designed to start to fill a gap in the literature on traditional manioc agriculture in one of the richest agricultural environments in Amazonia, thus opening an additional window on the pre-Columbian period.

MANIOC AND DARK EARTHS IN THE PRE-COLUMBIAN PERIOD

The ADE sites that are found throughout the Amazon basin today are the legacy of the long-term sedentary activities of pre-Columbian Amerindian groups who cultivated principally manioc. That these two phenomena (manioc agriculture and ADE) co-existed we can be sure. The question is: what kind of relationship existed between them? The work of prominent scholars from disciplines such as paleoecology, geography and archaeology suggests links between sedentism, the intensification of manioc agriculture and the formation of ADE. Dolores Piperno and Deborah Pearsall (1998, p.125) propose that

> [...] this efficient, undemanding carbohydrate source [manioc] became an increasingly attractive crop as human populations grew and pressure on land increased (i.e., shortening fallow periods and decreasing time for recovery of soil fertility). Its increasing importance may correlate with evidence for the development and intensification of swiddening [...]

These scholars link the increasing dependence of people on manioc to population pressure, shorter fallow periods and intensive swiddening – different from the long-fallow shifting cultivation practised today. Other prominent students of agricultural origins in the Americas have argued that pre-Columbian agriculture, and therefore manioc cultivation, would have been qualitatively different from the long fallow shifting cultivation practised today owing to the lack of metal axes (Sauer, 1936, 1952, 1958; Carneiro, 1974, 1979a, 1979b; Denevan, 1992, 2001), and this is where the notion of *terra mulata* comes in (c.f. Denevan, 2004, 2006). Archaeologists have also suggested that there may be a correlation of soil improvement, or *terra mulata*, with intensive agriculture and sedentism (Eden *et al.*, 1984; Andrade, 1986, 1988, 1990; Mora *et al.*, 1989, 1991; Herrera *et al.,* 1998; Herrera, 1992; Mora, 2001, 2003, 2006; Schmidt and Heckenberger, 2008; Arroyo Kalin, 2008b). Arroyo-Kalin *et al.* (2008, p. 5) suggest that "the emergence of anthropogenic dark earths tracks the expansion and intensification of bitter manioc during the first millennium AD".

The degree to which *intentionality* was involved in the formation of ADE remains unresolved. Are all ADE purposeful indigenous creations, as suggested by Clark Erickson (2003, p. 486)? On the other hand, others believe that ADE is the unintentional by-product of settlement patterns (Kern, 1988, 1996; Smith, 1980; Kämpf *et al.*, 2003). A recent study provides a more nuanced hypothesis of ADE formation, offering a theoretical middle ground between the extremes of intentionality and unintentionality, which may help bridge the gap between the midden and agricultural models. Based on data from some 4.000 soil samples taken throughout a Kuikuru community in the upper Xingu River basin, Morgan Schmidt shows how ADE formation is occurring today as part of a process whereby the human activities of manioc cultivation and fishing create fertile middens and patches of improved soil. Schmidt observed Amerindian women picking up earth from fertile middens formed in the areas of habitation and taking it to manioc fields in order to enrich the soil there (Schmidt and Heckenberger, 2007). The authors conclude that in the past these areas of enriched soil may have had the effect of reinforcing the behaviour of the people who made them, initiating a "positive feedback loop of soil improvement and crop production that led to agricultural intensification in the region" (Schmidt and Heckenberger, 2008).

These introductory paragraphs have shown how scholars from various disciplines have emphasized links between manioc swiddening, sedentism and the formation of ADE. Laura German (2003) suggests links between ADE formation and use and intensified cultivation of crop assemblages. But no study has yet explicitly linked manioc cultivation with ADE, probably owing to a lack of data. This paper sets out to provide the missing data, drawing on empirical data from fieldwork that used qualitative and then quantitative methods to investigate manioc farming on ADE.

MANIOC AND DARK EARTHS TODAY

The interest in studying the relationship of manioc and ADE grew initially out of empirical rather than theoretical concerns. In the course of fieldwork seeking to explore the relationship between agriculture and ADE in general (Fraser *et al.*, 2008), the middle Madeira River and its affluent the Manicoré River were selected field locations, owing to an abundance of ADE sites and the settled, agricultural communities that have inhabited the *terra firme* bluffs where these soils are situated for generations. The Madeira River is a nutrient rich white water environment, with abundant floodplains and evidence of river movement within the floodplain (oxbow lakes, *paranás*, bluffs with ADE now far from the river etc.) (Figure 1). The people who live in these villages are referred to (both by each other and in the literature) as *caboclos.* This is the Amazonian peasantry, formed through the encounter between Amerindian peoples and successive waves of migrants from Europe and Brazil's Northeast, although today they are culturally much closer to the latter[5]. *Caboclos* are thought to have inherited some of the pre-Columbian indigenous knowledge and technologies, such as manioc farming and knowledge about plants (for a recent overview see Adams *et al.*, 2006).

This paper focuses on the community of Barro Alto. It is an ideal location for a comparison of agriculture on ADE with that of other soils because it has the most ADE farmers of all of the ADE sites on the middle Madeira and many others who plant on non- anthropogenic soils: it is the largest community in the municipality of Manicoré, numbering some 600 individuals. In Brazilian Amazonia

[5] It should not be assumed that the 'mix' has produced a homogenous class of people. Every community is different. For example, Monte Sião and Barreira do Capanã are more Indian, and Barro Alto and Água Azul are more Northeastern.

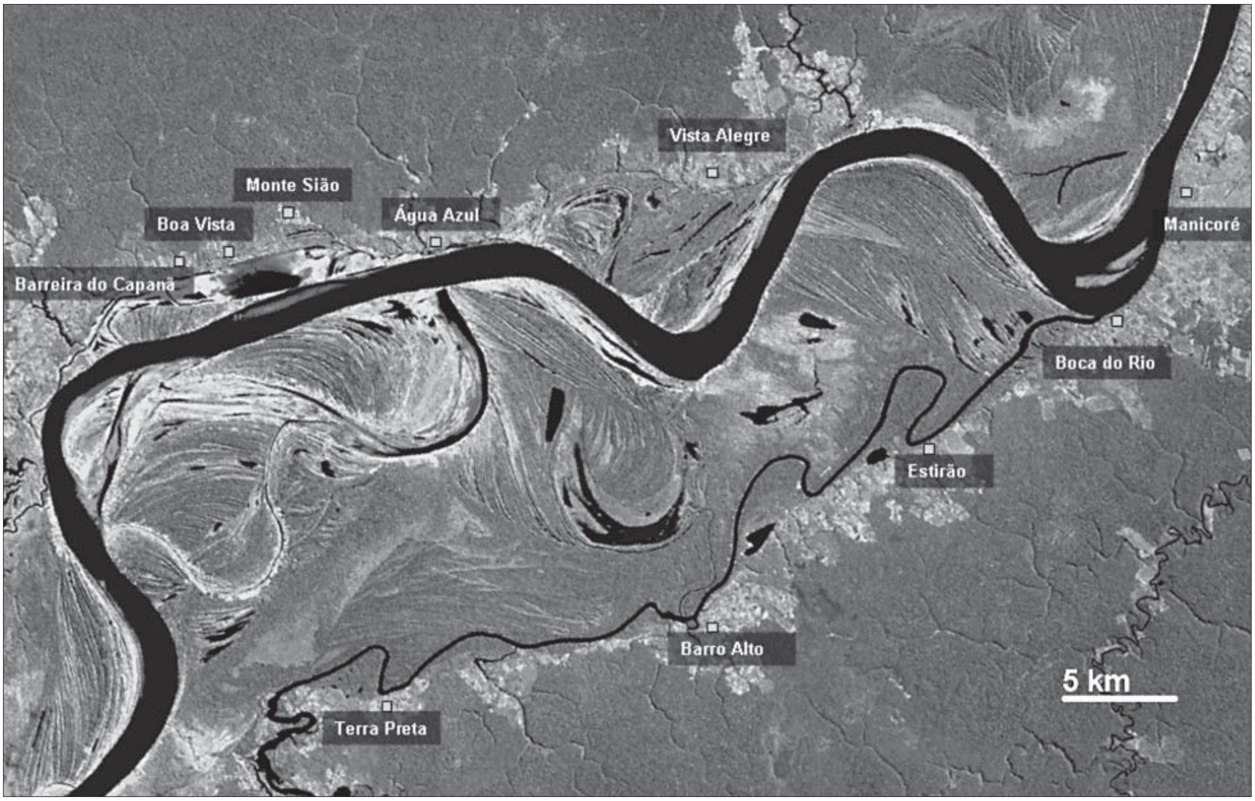

Figure 1. Location of communities participating in the research along the middle Madeira River and the Manicoré River, Amazonas, Brazil.

the most common crop for small-scale subsistence farmers on all soil types, including ADE, is bitter manioc. Why is this? Bitter manioc, which is processed into *farinha*, is *both* the fundamental carbohydrate energy source *and* often the most important market crop for caboclo populations throughout Brazilian Amazonia (Murrieta and Dufour, 2004; Piperata and Dufour, 2007; Piperata, 2007). The municipality of Manicoré is said to be the biggest producer of *farinha* in the whole of Amazonas state[6].

Bitter manioc yields well enough on poor soils (Oxisols and Ultisols) if adequately fallowed, but may also be cultivated more intensively and achieve higher yields in more fertile ecotones (ADE and the floodplain) Contrary to earlier studies[7], the present research found that bitter manioc is the most widespread crop on ADE fields. During repeated visits to Barro Alto from 2006 to 2008 only 5 of 50 ADE fields visited contained crops other than bitter manioc. When it had been established that bitter manioc was the most common crop on ADE, the question then became, what are the differences, if any, in manioc cultivation systems on Oxisols (Latossolos), Ultisols (Argissolos) and ADE (TP and TM)? As noted above, the standard model of *terra firme* manioc cultivation among both non-indigenous *caboclos* and indigenous peoples in contemporary Amazonia is long fallow shifting cultivation on nutrient poor upland soils. Fields are cleared from old

[6] Emerson França, mayor of Manicoré, personal communication, february 2008.
[7] German (2001, 2003) and Hiraoka *et al.* (2003) claim that bitter manioc does not yield well in ADE. Their findings can be explained by local agro-ecological trajectories (Fraser *et al*., 2008), rather than a universal trend. Other researchers, such as Bill Woods, Joe McCann, Manuel Arroyo-Kalin and Wenceslau Teixeira, have also noted high manioc yields in ADE.

fallow or mature forest, cultivated for up to three years, and then abandoned and allowed to re-grow. This is often presented as a successful adaptation that parallels natural successional processes (Hecht, 1982).

Manioc was domesticated from a wild subspecies adapted to the forest-savannah transition, where fire and drought are common, and is well suited to cultivation in a somewhat analogous system (Pujol *et al*., 2005a, 2005b). A large and growing body of research concerning manioc has advanced our understanding of domestication in manioc cultivation, and the selective pressures and co-evolutionary dynamics this entails. This work focussed our attention on the importance of sexual reproduction and the incorporation of seedling 'volunteers' in maintaining genetic diversity of manioc landraces. While the research being conducted is multi-disciplinary in orientation and spans diverse geographic locations, there are two important commonalities. All of their studies are undertaken in marginal environments of low soil fertility, and have focussed on long fallow shifting cultivation. This means that we run the risk of assuming that long fallow shifting cultivation is the only way manioc can be cultivated on the *terra firme*. In order to test whether or not manioc agriculture on ADE is different, we decided to compare it with standard long-fallow shifting cultivation practised by non-ADE farmers in the region.

Further investigation found that on the middle Madeira ADE farmers sometimes cultivate manioc under more intensive systems, with shorter cropping periods (5-10 months) and shorter fallow periods (1-3 years). This is most evident as a result of localized population pressure in the fields of the residents of communities with limited land and relatively large populations, such as Barro Alto and Água Azul. Additionally, bitter manioc is sometimes cultivated almost continuously along with other crops in ADE homegardens[8]. Farmers have manioc landraces that perform particularly well in ADE, and logically plant more of these varieties on ADE. We hypothesized that this leads to different selective pressures on manioc landraces, as new genetic material incorporated from volunteer seedlings favours traits (such as faster maturation and early fruiting) already prevalent in varieties selected for cultivation on ADE by local farmers. This paper presents perceptual and behavioural data to demonstrate how divergences in the practices of manioc farming on these different soils leads to different co-evolutionary dynamics on ADE as opposed to non-anthropogenic soils.

METHODOLOGY

Manioc was found to be the only crop in the overwhelming majority of ADE fields and the dominant crop[9] in all other fields on the *terra firme*. Only a handful of farmers sometimes planted crops other than bitter manioc in ADE and interviews revealed that this is because other crops are of marginal importance for livelihoods[10]. Hence, small-scale swidden agriculture on the *terra firme* of the middle Madeira is almost exclusively bitter manioc cultivation. This was the case not only in Barro Alto, but at the other central research location at Barreira do Capanã and Boa Vista, the Água Azul Coast and Vista Alegre. Quantitative

[8] We use homegarden in the accepted sense as an 'intimate, multi-story combinations of various trees and crops, sometimes in association with domestic animals, around homesteads.' (Kumar and Nair, 2004). On the middle Madeira these homegarden/agroforests are locally known as "Sitios." Almost continuous cultivation of bitter and sweet manioc and other crops in homegardens was observed in the following communities: Barreira do Capanã, Boa Vista, Monte Sião, Água Azul, Barro Alto and Terra Preta.

[9] Apart from the odd yam, banana or a few sweet manioc plants at the edge of some of the fields or in the *coivaras* (small patches of charcoal from secondary burns) these fields are completely dominated by bitter manioc.

[10] Watermelon is seldom cultivated because, while it fetches high prices outside of the floodplain season (in ADE it is planted in March to be harvested in June), it is seen to require high labour investment (applications of pesticide twice a week) and is a risky endeavour, as too much or too little rain, pests and theft can ruin whole fields. Beans are seldom cultivated because they are neither a large part of diet nor fetch particularly high prices in the market. Maize is rarely cultivated as it is seldom consumed and used only as animal feed. Both maize and beans compete in local markets with industrial produce from south Brazil, whereas all *farinha* consumed is produced locally and a significant part of local production is sold to traders who supply the burgeoning urban demand in large cities, such as Manaus.

methodology was developed to allow comparison of manioc cultivation across four soil types.

The first parameter is the Total Landrace Frequency Index (TLF). Farmers were asked how many *feixes* (bundles) of *maniva* (stem cutting used for propagation) of each landrace they planted in each field and what kind of soil the field contained. From this the % of total space occupied by each landrace was calculated. The mean of all of the fields in which the landrace was present was then divided by the number of fields in the particular soil type to give TLF for each landrace in each soil type. The TLF was calculated with data from 19 fields in *terra preta*, 19 in *terra mulata*, 21 in Ultisols and 33 in Oxisols gathered during various fieldtrips in 2007. The second parameter is the *Fraca/Forte* or Strength Index. Farmers were asked to place landraces they know well on an ordinal scale, from the most *fraca* (weak) to the most *forte* (strong). The Strength Index was then calculated from the average of 42 individuals' perceptions. Further data were collected to quantify whether primary forest was being cleared, the ages at which secondary vegetation was being cleared for planting, and the extent to which volunteer seedlings are being incorporated into landraces.

Case study: Barro Alto

Forty years ago the community was comprised of only eight families, numbering some sixty-two people. In 2007 there were nearly 600 people living in the community. This is an interesting anomaly in the general trend of rural-urban migration, which has seen an emptying out of rural Amazonia over the last forty or so years (Becker, 1995). The village is situated on a high *terra firme* bluff at a bend in the Manicoré River on an ADE site, with approximately 20 ha of *terra preta* and 30 ha of *terra mulata*. After being abandoned by its former Amerindian occupants, the site was re-occupied by migrants from the Northeast during the rubber boom; these new inhabitants engaged in small-scale rubber production and manioc farming. The land tenure of the community is comprised of four adjacent historic landholdings: Barro Alto, Raimiro, Parintintin and Liberdade. We will concentrate on Barro Alto and Liberdade. Land-tenure is linked to kinship and family histories within the community. Once a field is cleared from mature forest it comes under the ownership of the family who cultivated it. In this way families have come to own various *capoeiras*[11], and these are passed from father to son upon the death of the former. Manioc is cultivated on the ADE of all of these landholdings, apart from Parintintin where the ADE is occupied by the residential area, homegardens and agroforests.

The most intensive manioc planting takes place on the ADE belonging to the Barro Alto and Raimiro landholdings. According to community elders, this intensive cycle first began about thirty years ago, when the population began to grow. At Liberdade, manioc is planted on ADE, but longer fallows are used, owing to the fact that only a few people are allowed to plant there. The Oxisols and Ultisols that extend into the *centro* (meaning inland) are where a greater proportion of the population practice long fallow shifting cultivation. Around 100 ha of new fields are planted every year, cleared from young and old *capoeira*, and old growth forest (see Figure 2)

Local soil classifications

Residents of the community and the wider region classify soils according to their colour and texture, the stage of successional vegetation that covers them, and their known history of use. Soils are divided into two encompassing types, *barro* (clay) and *areia* (sand). As general types, the former coincide roughly with Latossolos (Oxisols) and the latter with Argissolos (Ultisols) of the Brazilian Soil Classification System (Embrapa, 2006)[12]. Clayey soils are easily recognised,

[11] "*Capoeira*" is the local term for second growth forest.
[12] The terms in parentheses are the equivalent names in the USA's Soil Taxonomy classification. http://soils.usda.gov/technical/classification

and called *barro amarelo*, *barro vermelho*, or *barro branco/tabatinga* depending on yellow, red or grey colouring. The residents also recognize that soils may be a mixture of these types, such as *areia misturado com barro*. *Terra Preta* is also unmistakable owing to its very dark colouring, ceramics, different successional processes and the distinct suite of volunteers associated with it. Texturally they are designated as either *solto* (loose) or *duro* (hard), or somewhere in between. Some volunteers, such as the *caiaué* oil palm (*Elaeis oleifera*) or a weed locally known as *maria-preta* or *rabo-de-gato* (*Acalypha brasiliensis*, Euphorbiaceae) are so ubiquitous on *terra preta* that they could be designated signature species rather than merely indicators. Certainly, local people strongly associate them with *terra preta*.

Terra mulata and sandy Ultisols are more ambiguous, however. In terms of soil colour and texture, they are easily confused, not only by over enthusiastic researchers, but also by locals. This ambiguity is reflected in the diversity of terms that were recorded as referring to them: *terra preta*, *terra preta misturada com areia*, *areia misturada com barro*, *areia preta* and *areião*. Ultisols are sometimes confused with ADE because of their dark colouring. *Terra mulata* are less often confused with Ultisols because of their obvious higher fertility. They yield maize and also exhibit some of the same kinds of weeds as *terra preta*. Thus it is through differences in fertility and successional processes that *terra mulata* can be differentiated from Ultisols.

Landraces, soils and successional processes: *forte* and *fraca*

In the vast majority of interviews, local people employed the terms *fraca* (weak) and *forte* (strong) to describe both the characteristics of different manioc landraces and soil fertility, the latter expressed as the stage of regrowth that the successional vegetation has reached. This was also the case in the other communities in the study area. Accordingly, *mandioca fraca* is seen as best suited to *capoeira fraca* or *terra fraca* and *mandioca forte* to *capoeira forte* or *terra forte*. The origins of the use of these terms are difficult to pin down, but the categories strong and weak are present in traditional agriculture in other areas of the world (e.g., Harlan, 1992, p. 148):

> Landrace populations are often highly variable in appearance, but they are each identifiable and usually have local names. A landrace has particular properties or characteristics. Some are considered early maturing and some late. Each has a reputation for adaptation to particular soil types according to the traditional peasant soil classification: e.g., heavy or light, warm or cold, dry or wet, *strong or weak*. (emphasis added).

Taking these local notions of the relative strength or weakness of natural agents as an entry point, this section describes people's understandings of landraces, soils and successional processes, and then looks at how these elements are interrelated.

Landraces

Mandioca fraca matures quickly, but is liable to rot or not soften when soaked if left in the ground for more than a year. The Tartaruga landrace is planted preferentially on ADE (Table 1). It seems likely that this and other *fraca* landraces originated in the floodplain. Tartaruga is planted in the floodplain in the communities of Verdum, Amparo and La Delicia, about four hours downstream from Manicoré, where it is considered a floodplain landrace. The characteristics exhibited by *fraca* landraces strongly suggest a floodplain origin (fast maturing, fast seeding but not long lasting in the ground), as they are traits that serve well in the floodplain. It is possible that having come from the floodplain these landraces are more capable of taking advantage of the greater nutrient levels in ADE. *Mandioca forte* on the other hand, matures slowly, but is more durable in the earth, lasting as long as three years or more. This is the type of manioc most often referred to in studies of long-fallow shifting cultivation systems.

Farmers also characterise manioc in terms of starch content, and this is expressed in terms of water content. The more starch, the less water and the more *farinha*.

Table 1. Perceptions and behaviours of bitter manioc farmers in the communities of Barro Alto and Liberdade, Manicoré, Amazonas, Brazil. The Strength Index is the farmers' perception of the relative strength of each landrace, where the weakest landrace is coded as one and the strongest depends upon the number the farmer comments on (the value in parentheses is the number of people who named the landrace). The Total Landrace Frequency Index is the proportion of each landrace planted in fields on the different soil types.

Landrace Name	Strength	Total Landrace Frequency			
		Ultisol	Oxisol	Terra Mulata	Terra Preta
Barro Alto					
Tartaruga	1.2 (25)	0,41	0,07	0,54	0,83
Roxinha	3.0 (22)	0,48	0,38	0,39	0,08
Arroz	4.3 (23)	0,17	0,21	0,04	0
Jiju	1.8 (13)	0,01	0,09	0,01	0
Aruari	2.8 (12)	0,02	0,12	0,02	0
Jabuti	4.7 (10)	0	0,07	0	0
Manaus	3 (1)	0,01	0	0,01	0,02
Pirarucu Amarelo	2 (1)	0,01	0,01	0	0
Pacu	-	0	0	0	0,01
Jabuti Grande	4 (1)	0	0,01	0	0
Nameless	-	0,01	0	0	0
Liberdade					
Roxinha	2 (5)	0,6	0,8	0,57	
Tartaruga	1 (5)	0,28	0,05	0,44	
Aruari	3 (1)	0,12	0,03	0	
Arroz	3.3 (3)	0	0,05	0,06	
Jiju	-	0	0,04	0,02	
Jabuti	-	0	0,03	0	
Bonitinha	-	0	0	0,01	

Farmers complain that some (generally *fraca*) landraces are *muito aguada* (very watery) and *quebra na farinhada* (*quebrar* here means to diminish in volume from *massa* to *farinha*). *Forte* landraces are said to contain the least water, and therefore they diminish the least during processing.

Soil fertility and succession

Local people deduce soil fertility from the stage that successional processes have reached at any given point in time. People say that "*Terra fraca é terra com capoeira baixa, terra forte é terra com capoeira alta*" (Weak soil is soil with low second growth, while strong soil is soil with tall second growth). Soil is said to be *cansado* (tired) from having been cultivated too much, and the resultant *capoeira fina* (thin secondary growth) provides an indicator of this. Farmers obviously do not understand soil fertility in terms of nutrients as soil scientists do, but in terms of their location in anthropogenic successional processes and their known history of use. Nonetheless, their understanding can also be explained by soil science, since the growth of *capoeira* is fuelled by nutrient pumping from deep soil horizons and by nutrient inputs from rainfall (Nye and Greenland, 1960).

This perception of soil fertility as being determined by age of *capoeira* and known history of use might have something to do with several generations of manioc farming under long fallow shifting cultivation. Soil fertility is expressed in a schema that makes sense for non-anthropogenic soils under long fallow shifting cultivation, but falters when it is used to explain the fertility of ADE. ADE is called *terra fraca* when it has been intensively cultivated (but still yields manioc, maize and watermelon) and an old *capoeira* on Oxisols is *terra forte* (even though it will not yield maize or watermelon).

Fraca and *forte:* preferences for landraces in different scenarios

Different manioc landraces are said to be better suited to different stages in the successional process. Many farmers claim that landraces belonging to the *fraca* category are better suited to fields cleared from *capoeira fina*; conversely *mandioca forte* is better suited to fields cleared from old *capoeira* or primary forest. "*Arroz* (a *forte* landrace) *é bom para mata*" (Arroz is good for the forest [soils]) they say, or "*Arroz só dá bem na terra forte*" (Arroz only does well in strong soil). People perceive certain landraces as more or less suitable to different soil types (Table 1), and to different stages in the successional process. The categories *fraca* and *forte* apply to both manioc and soil fertility, and are combined when people state "*mandioca fraca na capoeira fraca, mandioca forte na capoeira forte*" (weak manioc in weak second growth, strong manioc in strong second growth).

Divergent agricultural practices

Manioc is cultivated under more intensive, shorter cropping cycles on the ADE at Barro Alto and Liberdade than when cultivated on non-ADE soils[13] (Figure 2). In both Barro Alto and Liberdade, most manioc fields on ADE are cut from *capoeira fraca* (between one and five years of age). In both Barro Alto and Liberdade, several fields were cut from old growth forest on non-ADE (Primary forest first cut) and in Barro Alto numerous fields were cut from young *capoeira* soon after having been cut from old growth forest (Primary forest second cut).

The most commonly planted landrace at both Barro Alto and Liberdade on ADE is Tartaruga (Table 1). Farmers explain that this is because Tartaruga yields well on ADE, and is suited to *terra fraca*, which is essentially equivalent to short-fallow swiddening on ADE. Tartaruga is also the most *fraca* landrace, with most people beginning to harvest only six months after planting. The market is almost certainly also a factor in the preference for fast maturing landraces, as the main source of income from agriculture comes with the sale of *farinha*. The reader will note that Tartaruga is also popular on Ultisols, and this is because most of the fields included in the study are close to the village, have been intensively farmed and are therefore designated as *terra fraca* and planted with more *mandioca fraca* accordingly.

Roxinha is preferred on *terra forte*, whether it is ADE or non-ADE. People prefer to plant more Roxinha when they have *terra forte* available as it yields the yellowest *farinha*. In this case the market provides a strong selective pressure. The factor determining its distribution then emerges not from soil classification *per se*, but rather the perceived strength of the soil, which is established from the stage of successional growth. The case of Liberdade shows this, as more Roxinha is planted on *terra mulata* than Tartaruga (Table 1). This is because fewer people are allowed to plant at Liberdade, lessening population pressure and allowing longer fallow periods even on TM, which makes the TM *forte*.

A similar thing occurs at Barro Alto; Roxinha is equally popular on *terra mulata* and Oxisols, because the *terra*

13 German (2003, p. 326) also observed more intensive agriculture on ADE. Farmers on the lower Negro and Urubu Rivers fallowed ADE fields for an average of 4.5 years, whereas Oxisol fields were fallowed for an average of 11 years. In her study ADE fields remained in production for an average of 10.8 months, whereas Oxisol fields remained in production for 28 months. Furthermore, while 72.7% of Oxisol fields in her sample were cut from mature forest only 25.6% of ADE fields were cut from old second growth forest. A similar process can be observed at Barro Alto.

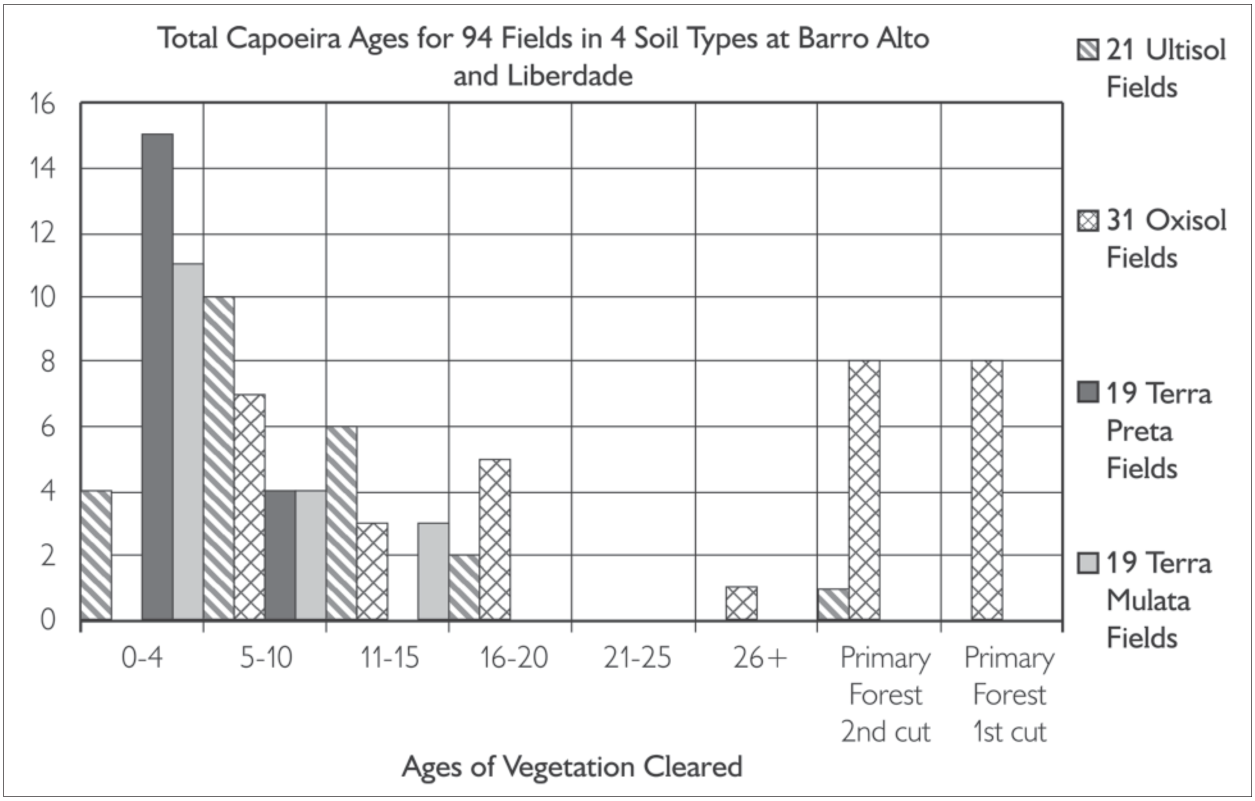

Figure 2. Frequency distributions of the age of *capoeiras* cut for manioc fields on all four soil types.

mulata is located further behind the village, cultivated less intensively and therefore subject to longer fallow periods. These factors lead farmers to categorise the *capoeiras* on the *terra mulata* as *forte*, and they therefore are perceived to be suitable for planting of the more *forte* landrace Roxinha. Arroz (the most *forte* landrace) is most evident in fields cleared from mature forest (the most *forte* kind of land).

A comparison of average yields of ADE vs non-ADE shows that there is little difference in terms of sacks of *farinha* produced between a *capoeira fraca* on ADE and a *capoeira forte* on non-anthropogenic soil. Most farmers stated that half a hectare of manioc yields between 40 and 50 sacks in both cases. The important difference is that ADE fields are harvested after only six months, while fields on non-anthropogenic soils are only harvested after ten months. This means that production overall is higher on ADE, because two cropping cycles can fit into one cropping cycle on non-anthropogenic soils. How long ADE soils can resist this kind of intensive agriculture is still an open question, though observations suggest that they can be cultivated for longer periods of time than non-anthropogenic soils[14].

Another point of divergence is the different months of the year in which fields can be planted. Fields cleared from older *capoeira* or mature forest on Oxisols and Ultisols can only be planted a few months into the dry season (august/september at the earliest). This is because cleared vegetation needs a month or two of sun to dry enough to burn. Because manioc is being planted in *capoeira fina*

[14] German (2001) noted that the Açutuba site on the lower Negro River has withstood decades of intensive agriculture, although the fertility of the ADE is starting to degrade.

on ADE, this does not need to be the case (as also noted by German, 2001). Some farmers take advantage of the ability to plant earlier – February to June – to be able to harvest when there is little *farinha* from non-anthropogenic soils and prices are higher. This, combined with more replanting (up to four times without fallow in some cases), also contributes to the greater intensiveness of manioc agriculture on these ADE.

Intensive agriculture and feedback loops

It appears then that Tartaruga is planted most on the ADE at Barro Alto as it is best suited to cultivation under an intensive cropping system. Its characteristics as a *fraca* landrace (fast maturing, but not durable) fit into a situation where fields are cleared from *capoeira fraca*. How to interpret the greater intensiveness of manioc farming on ADE? There is obviously a paradox between the perception that one should not plant repeatedly in what is termed *capoeira fina* and *terra fraca*, and the behaviour of continuing to plant on the ADE despite its designation as *terra fraca*. In Barro Alto and other communities, farmers almost never plant in the *capoeira fina* on non-ADE soils.

The *capoeira* is *fina* on ADE at Barro Alto and the adjacent landholding called Raimiro not because the soils are exhausted, but because the *capoeira* is not given time to develop; the median fallow is in the less-than-5-years class (Figure 2). Judged by yields and nutrient information, the soils are more fertile than any non-anthropogenic soil in the region. The agricultural intensification that has occurred over the last thirty years has not yet exhausted the soils, which still yield manioc well (40-50 sacks per 0.5 ha), maize and exhibit elevated pH, P and Ca compared to the Ultisols and Oxisols surrounding the village (Table 2).

Factors contributing to this intensification are complex. Demographic pressure certainly plays an important role in shortening fallow periods and selecting for fast maturing landraces. But this could not happen without greater soil fertility: Farmers would not plant in ADE if yields were not sufficient to justify the time and effort expended in clearing, planting, weeding and harvesting manioc[15]. At Barro Alto, the ADE fields and young *capoeiras* are located much closer to the community, their proximity facilitating clearing, planting, weeding and harvesting. However, it takes three times as long to clear a four-year-old *capoeira* (which is all understory) than a fifteen to thirty year old *capoeira* (which has larger trees and much less understory). And ADE fields require much more weeding (up to five times) than non-ADE ones (once or twice between planting and harvest). The intensive cultivation of ADE cannot be explained by proximity alone, therefore, as more labour is required in their cultivation.

One way of explaining the farmers' behaviour is in terms of a short term positive feedback loop leading to a long term negative one. In this case it is the capacity of these soils to produce when cleared from *capoeira fina* that reinforces the behaviour of the farmer and makes him more likely to clear a field from *capoeira fina* in the *terra preta* again. As this cycle continues, agricultural intensification occurs, as observed by Morgan Schmidt and Michael Heckenberger (2008).

Feedback loops can be either positive or negative. Over the longer term, however, the action of the farmers will lead to soil degradation, as fallow periods are insufficient for soils to recuperate, and farmers do not use mulching or infield burning to restore fertility as their indigenous predecessors are thought to have done (Denevan, 2001). In a negative feedback loop, one change leads to a lessening of that change (i.e., eventual exhaustion of soils will mean that agriculture will become less intensive as it stops paying off *vis-a-vis* labour inputs). At Barro Alto, we already observe the effects of combined positive and negative feedback loops,

[15] In one example, an unfortunate farmer planted in *capoeira fraca* on Ultisols behind the community at Vista Alegre. The family harvested only 12 sacks of *farinha* from half a hectare. Vista Alegre has considerable *capoeira fina* on Ultisols, but no one plants manioc there, because it's not worth the effort.

Table 2. Chemical composition of several samples of Amazonian Dark Earth (0-20 cm) at Barro Alto, Manicoré River, middle Madeira, Amazonas*.

Farmer	pH	P avail.	K^+	Ca^{+2}	Mg^{+2}	Fe^{+2}	Zn^{+2}	C	M.O.
	H2O	mg/kg	cmolc.kg	cmolc.kg	cmolc.kg	mg/kg	mg/kg	g/kg	g/kg
Antônio	5.03	45.5	0.6	6.85	0.93	10.4	4.9	27.93	48.04
Selmo	3.77	41.7	0.4	0.38	0.3	50.6	0.6	18.35	31.57
Dico 1	5.46	97.8	0.10	8.56	1.25	12.8	6.3	32.72	56.27
Dico 2	5.50	84.7	0.5	8.98	0.99	20.7	2.4	27.13	46.67
Dico 3	5.34	284.0	0.6	5.75	1.22	22.6	3.8	40.70	70.00

* Please note that a full set of soil samples from Barro Alto is currently being analysed and will be presented in a future publication. These samples are included only to demonstrate the greater fertility of ADE even under intensive cultivation. The Oxisols of Central Amazonia normally have a P content of 1-5 and Ultisols normally have a P content of 1-7. Calcium content ranges from 0,01 to 0,5 in both soil types (Wenceslau Teixeira, Embrapa Amazônia Ocidental, personal communication, february 14, 2008). The nutrient values presented in the table correspond to the expected ranges for Terra Preta and Terra Mulata (see Teixeira and Martins, 2003; Madari *et al.*, 2003).

with farmers complaining ADE doesn't produce as much as it used to. At the moment the positive feedback loop dominates at Barro Alto, as intensive swiddening on ADE still pays off against labour requirements. This behaviour will eventually lead to yields that are too low to pay off labour requirements. This is the negative feedback loop. In the end, if not checked, negative feedback loops will put an end to ADE cultivation. This occurred at Vista Alegre after two decades of yearly watermelon cultivation and was observed by Laura German (2001) along the lower Negro River.

Selective pressures on manioc landraces

Manioc is a clonally propagated crop. Once harvested, the stems of mature plants are stored in the shade, and when planting is to take place, these stems are chopped into 10-15 cm sticks (called *manivas*), and planted in a shallow hole dug with a hoe. This clonal shoot develops from the same genetic material as the plant that was harvested. Hence, a landrace is comprised of one or more 'exceptional individuals' (Zohary, 2004). In a study in French Guiana, Marianne Elias and colleagues demonstrated that 72% of landraces were not monoclonal. Rather, landraces were made up of more than one clone, which when compared had very similar phenotypes but different genotypes. The clonal propagation of manioc serves to reproduce and conserve the desired characteristics of these few 'exceptional individuals', most of which are quite heterozygous and may exhibit greater vigour and resistance to pests and diseases because of this. The problem with clonal reproduction is that only a fraction of the original population is reproduced, and this leads to a genetic 'bottleneck' resulting in a steady loss of diversity. However, manioc has retained its ability to reproduce sexually, and it is through incorporation of new clones, which appear as volunteers, that genetic diversity is maintained (see Elias *et al.* 2001a, 2001b; Martins, 2001).

Once a plant matures, it flowers, is pollinated (the main agents of pollination are bees; Silva *et al.*, 2001), its fruits grow, mature and burst, dispersing the seed. The germination ecology of manioc is thought to be pre-adapted to slash and burn systems, owing to its having evolved in transitional forest-savanna ecosystems predominant in Amazonia in the pre-Holocene period (Pujol *et al.*, 2002). Seeds are capable of surviving 50 years or more in *capoeiras* and shifting cultivation creates a mosaic of seed banks lying dormant in successional vegetation (Pujol *et al.*, 2007). In the process of a field being cut and burnt anew, seeds germinate (stimulated by the high temperatures) and appear as seedling 'volunteers' in the fields about a week or so later, often before the clones have been planted. These seedlings grow from new genetic material, often different from the clones planted into the new field. Many farmers allow these seedlings to grow and later, intentionally or unintentionally, they are incorporated into landraces to which they bear a phenotypic resemblance. This process serves to bring new genetic material into landraces and maintain their vigour over time. The outcome of the practice of selective incorporation of volunteer seedlings is that landraces come to be formed of various clones that are morphologically similar but with distinct genotypes. Seedlings recruited from seed banks and incorporated into landraces transform pure clonality into a mixed clonal/sexual reproductive system. Seed banks and how farmers use them play a crucial role in maintaining genetic diversity in landrace populations (Pujol *et al*., 2007). A corollary of this is that the more widespread, popular and well known a landrace becomes, the greater the likelihood that seedlings will be incorporated, leading to increased genetic diversity.

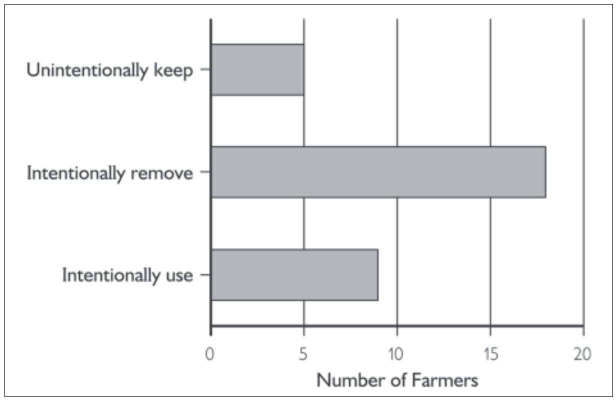

Figure 3. Frequencies of manioc seedling management practices at Barro Alto and Liberdade, Manicoré River, Middle Madeira, Amazonas.

Local practices that shape selective pressures

Farmers were found to intentionally incorporate, unintentionally incorporate, or remove seedling volunteers from fields (Figure 3). These three categories of behaviour were constructed on the basis of insights from anthropological fieldwork in the middle Madeira River region. While there is no space here for a full analysis of local understandings of sexual reproduction, suffice it to say that they vary between individuals, families and communities, and appear to be based on personal experiences rather than a common understanding. All farmers recognised the morphological differences, stating that the seedlings grow straight up without growing branches[16], and that the seedling grows only one tuber that goes straight down, and is difficult to pull up.

At one extreme are the people who intentionally take cuttings from those volunteers they consider to be most healthy or attractive[17], and plant them separately to see 'what kind of manioc it is', 'if it yields really big tubers' or 'if it has a really yellow tuber'. People in this intentional category differ in how they name the resulting variety of manioc. A greater proportion of people believe that the seedlings always yield clones of an existing variety (this was also the finding of Marianne Elias and colleagues (2001a), who state that 67% of seedlings were found to be close enough to known landraces to be assigned to them). If it does not closely resemble a type present in their community, they will try to find the name with relatives or friends from other communities. Other people recognise that clones taken from the seedling are always different from existing qualities of manioc. They often seem loath to name them, calling them a 'kind from seed', *maniva*

[16] Some people on the Manicoré River call seedlings *capitão* because of their tendency to tower over the other manioc plants. Some people snap the stems of seedlings, which they claim causes them to *esgalhar* (branch out) like normal manioc plants, and also yield multiple tubers, rather than just one.

[17] This suggests parallels to Pujol, David and McKey (2005a), who demonstrated how Amerindian farmers in French Guiana both maintain heterozygosity (through clonal reproduction) *and* genetic diversity (through incorporation of only the healthiest seedlings). This selection may have something to do with size asymmetry between heterozygous and inbred seedlings.

achada, or *maniva nativa*. Naming may also occur when the new clone is passed from one farmer to another. Often the original name may be forgotten, and the name of the person who gave the type of manioc is used (for example *Glai* and *Capão*).

The second category is that of unintentional incorporation. During the course of fieldwork it became apparent that many people, while not intentionally selecting and planting from seedlings, did not remove (some or all of) them during weeding. Rather these people simply harvest them together with the rest. In most instances they do not separate the *maniva* of the seedlings from the rest of the clones. This leads to the unintentional incorporation of clones from the seedlings. The perplexing (for the farmer) result of this is that unknown types of manioc appear in the middle of what they thought were blocks of one kind of manioc only.

The third category is formed from those who purposefully remove the seedlings during weeding. When asked why they do this, they often state that the seedlings '*não presta*' (they are no good) because they only yield a single tuber, and are hard to remove from the ground.

Another interesting tendency was that some farmers plant landraces either fully mixed, partially mixed or separately. At Barro Alto and Liberdade 18 farmers mix the manioc in their fields and ten maintain them separate. Some farmers cited agronomic reasons for this (landraces are said to affect one another's growth when interplanted). Some said that when they plant in a *capoeira fina*, Roxinha will yield better when interplanted with Tartaruga than if planted alone[18]. Others said they did it in order not to lose the landraces they harvested first[19]. The unintentional genetic outcome of this is that planting different landraces mixed together greatly facilitates inter-landrace pollination, which should enhance heterozygosity and may lead to healthier seedlings.

Agricultural systems and co-evolutionary processes

The preceding section demonstrates that farmer selection of landraces is contingent on their perceptions of different types of soil (TP/TM/Ox/Ul) and vegetation, especially successional (young, middling, old *capoeira* and primary forest). Tartaruga is the most commonly planted landrace on ADE, especially when it is being intensively cultivated. Arroz is most common in fields cleared from older *capoeira* and primary forest on non-ADE soils. Roxinha comes somewhere in between *fraca* and *forte*, and is only planted on ADE when the soil has been fallowed for more than 10-15 years.

The selective pressures brought to bear through farmer decisions are shaped by other factors besides perceptions of soil type and age of fallow. These include the market (quick harvesting, yellowest *farinha*), social relations and kinship. The social shaping of selective pressures is evident in the fact that close kin are the most important sources of labour and manioc cuttings. Manioc farming is therefore ecologically, economically and culturally shaped. As a result of these selective pressures, different configurations of landraces are planted on different soil and fallow types. This means that certain selective pressures are brought to bear on manioc landraces. The seedlings resulting from pollination will be more likely to favour certain traits which were selected for by farmer agency (such as fast yielding, yields well in a certain soil, or produces very yellow *farinha*) and others that result from natural selection (e.g., fast seeding).

Many of today's most prominent scholars see the relationships that people have with cultivated plants as a

[18] People explained that Roxinha would feel 'embarrassed' by Tartaruga's faster growth and the Roxinha plants would therefore grow faster themselves in order to keep up.

[19] When planted in separate blocks, landraces are harvested separately, the fastest maturing first and being harvested first. A field is harvested over a period of months, however, and when the time comes to plant a new one, there may be no *maniva* left from the first landraces harvested.

form of co-evolved mutualism. Co-evolution is not only genetic, but an outcome of an interplay between genes, the organism, its environment and culture (Rindos, 1984; Piperno and Pearsall, 1998; Zeder, 2006).

The different selective pressures described above are a part of divergent co-evolutionary dynamics in two agricultural systems. Human action shapes the genetic material of plants, but in engaging with these plants and their particular characteristics, humans are themselves subtly moulded by the plants (Rindos, 1984; Zeder, 2006). For example, planting more fast-maturing but less-durable Tartaruga in ADE means that it will be harvested earlier than if slower maturing landraces were planted. This alters labour patterns and also the precise moment when replanting occurs. Tartaruga was observed to seed earlier, something that people on the middle Madeira understand as a sign of maturation.

Farmers choose different soils and landraces in order to maximise yield *vis-a-vis* a plethora of social and natural externalities, including labour requirements, the market and seasonality. The different kinds of agricultural systems that emerge from this process are not the intentional, but are rather the unintentional outcomes of the interplay between human (understandings, preferences related to agriculture, selection for perceived landrace characteristics) and natural agencies (greater soil fertility, more weeds).

FINAL COMMENTS

This case shows that manioc is the most important crop for both ADE and non-ADE farmers in the communities studied along the middle Madeira River. It follows that ADE is often used for manioc cultivation, even if it would be logical to plant more nutrient demanding crops in them. Other crops are simply of little importance.

This is probably also the case for other *caboclo* residents of rural Amazonia away from urban centres, roads and frequent river transport. This is less true for new colonists on the agricultural frontier, however. Papaya farmers in Iranduba, so often shown as an example of 'ADE agriculture', are not representative of the reality of most rural Amazonians (see Fraser *et al.*, 2008). Iranduba, Rio Preto da Eva and other municipalities close to Manaus should be considered peri-urban, not rural. Most traditional farmers in Amazonia do not reside in locations so privileged for agricultural production, let alone do they have access to roads and trucks. Cultivation of other crops is often simply considered too risky (in terms of pests, inadequate rainfall) and logistically unfeasible (getting crops to a buyer without spoiling) to be worth it.

We suggest here that the intensification of manioc agriculture at Barro Alto demonstrates that it is possible to reduce fallow periods without a reduction of yield on ADE, at least in the short term. The case of Barro Alto shows how the presence of pre-Columbian human-enriched soils, along with population pressure and market demand for *farinha*, has led to a positive feedback loop of agricultural intensification. It shows how somewhat different agricultural systems have emerged on different soils, and how the distinctive configurations of landraces associated with each soil leads to divergent selective pressures on manioc landraces.

The study of manioc and ADE is important not only for our understanding of contemporary agriculture, but also shows that this would have been possible in the pre-Columbian period. The current archaeological consensus is that manioc was one of the most important crops in the pre-Columbian era (at least until the chiefdoms of the final pre-contact phase, who may have had maize as their staple), and that it fuelled the population expansion that is responsible for the thousands of ADE sites which exist in central Amazonia today (see Lathrap, 1970; Oliver, 2001; Arroyo-Kalin, 2008b). Anthropological and archaeological theory suggests that manioc farming in the past was more intensive than today, and this may have resulted in the formation of *terra mulata*. The case presented here can in no way be read as a reconstruction of Amerindian agriculture, but it demonstrates, for the first time, that intensive manioc agriculture is possible on ADE. This case opens a window onto the past, raising a hypothesis that can be tested by on-going archaeological work in Central Amazonia.

ACKNOWLEDGEMENTS

James Fraser thanks James Fairhead, University of Sussex, and Johannes Lehmann, University of Cornell, for their support in earlier stages of the research, as well as the Leverhulme Trust (Grant Number F/00 230/U) for funding his fieldwork on the middle Madeira on which this chapter is based. He would also like to thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq for approving the Expedição Científica EXC 022/05C. We thank Laura German, now at the World Agroforestry Centre, for useful criticism and suggestions. We thank two anonymous reviewers for their helpful advice and criticisms. We also thank Carolina Taqueda and Lucia Munari, of the Instituto de Biociências, Universidade de São Paulo, for assistance with formatting. All errors of fact or judgment are the authors.

REFERENCES

ADAMS, C.; MURRIETA, R. S. S.; NEVES, W. A. (Orgs.). **Sociedades Caboclas Amazônicas**: Modernidade e Invisibilidade. São Paulo: AnnaBlume/Fapesp, 2006.

ANDRADE, A. Sistemas agrícolas tradicionales en el medio Río Caquetá. In: CORREA, F. (Org.). **La Selva Humanizada:** Ecología Alternativa en el Trópico Húmedo Colombiano. Santa Fé de Bogotá: Instituto Colombiano de Antropología, Fondo FEN Colombia and Fondo Editorial CEREC, 1990. p. 59-81.

ANDRADE, A. Desarrollo de los sistemas agrícolas tradicionales en la Amazonia. **Boletín del Museo del Oro**, v. 21, p. 39-59, 1988.

ANDRADE, A. Investigaciones Arqueológicas de los Antrosoles de Araracuara. **Fundación de Investigaciones Arqueológicas Nacionales**, n. 31, p. 1-103, 1986.

ARROYO-KALIN, M. Terras Pretas and Terras Mulatas from the central Amazon region: a geoarchaeological perspective. Paper presented at the World Archaeological Congress 6, Dublin, 4th July 2008a. Disponível em: <http://www.wac6.org/livesite/precirculated/2529_precirculated.pdf>.

ARROYO-KALIN, M. **Steps towards an ecology of landscape**: a geoarchaological approach to the study of anthropogenic dark earths in the Central Amazon region, 2008b. Thesis (PhD) - University of Cambridge, Cambridge, UK, 2008b.

ARROYO-KALIN, M.; CLEMENT, C. R.; FRASER, J. A. Extensive to intensive, or first fruits and then roots? Bitter/sweet thoughts on agricultural intensification in pre-Columbian Amazonia. Paper presented at the World Archaeological Congress 6, Dublin, 4th July 2008. Disponível em: <http://www.arch.cam.ac.uk/~maa27/Arroyo-Kalin-et_al_RAA_ShiftingCultivation%20Paper_Extensive_2_Intensive.pdf>.

BECKER, B. K. Undoing myths: The Amazon – an urbanized forest. In: CLÜSENER-GODT, M.; SACHS, I. (Orgs.). **Brazilian perspectives on sustainable development of the Amazon region**. Paris: UNESCO, and Carnforth, UK: Parthenon Publ. Group, 1995. p. 53-90. (Man and the Biosphere, 15).

BOSTER, J. S. Classification, cultivation, and selection of Aguaruna cultivars of *Manihot esculenta* (Euphorbiaceae). In: PRANCE, G. T.; KALLUNKI, J. A. (Eds.). **Ethnobotany in the Neotropics**. New York: New York Botanical Garden, 1984. p. 127-173. (Advances in Economic Botany, v. 1).

CARNEIRO, R. L. The cultivation of cassava among the Kuikuru of the Upper Xingu. In: HAMES, R. B.; VICKERS, W. T. (Orgs.). **Adaptive Responses of Native Amazonians**. New York: Academic Press, 1983. p. 65-111.

CARNEIRO, R. L. Tree Felling with the Stone Axe: An experiment carried out among the yanomamo indians of Southern Venezuela. In: KRAMER, C. (Org.). **Ethnoarchaology: Implications of Ethnography for Archaeology**. New York: Columbia University Press, 1979a. p. 21-58.

CARNEIRO, R. L. Forest Clearance among the Yanomamo, Observations and Implications. **Antropológica**, v. 52, p. 39-76, 1979b.

CARNEIRO, R. L. On the use of the stone axe by the Amahuaca Indians of Eastern Peru. **Ethnologische Zeitschrift Zurich**, v. 1, p. 107-122, 1974.

CHERNELA, J. M. Os cultivares de mandioca na área do Uaupés (Tukano). In: RIBEIRO, B. (Org.). **Suma Etnológica Brasileira**. Petrópolis, RJ: Vozes, 1987. v. 1, p. 151-158.

DENEVAN, W. M. Pre-European forest cultivation in Amazonia. In: BALEÉ, W.; ERICKSON, C. (Orgs.). **Time and complexity in historical ecology**: Studies in the Neotropical lowlands. New York: Columbia University Press, 2006. p. 153-163.

DENEVAN, W. M. Semi-intensive pre-European cultivation and the origins of anthropogenic Dark Earths in Amazonia. In: GLASER, B.; WOODS, W. I. (Orgs.). **Amazonian Dark Earths**: Explorations in space and time. Berlin: Springer, 2004. p. 135-141.

DENEVAN, W. M. **Cultivated landscapes of native Amazonia and the Andes**. 1. ed. Oxford: Oxford University Press, 2001.

DENEVAN, W. M. Stone vs. metal axes: The ambiguity of shifting cultivation in prehistoric Amazonia. **Journal of the Steward Anthropological Society**, II., v. 20, p. 153-165, 1992.

EDEN, M.; WARWICK, B.; HERRERA, L.; McEWAN, C. *Terra preta* soils and their archaeological context in the Caquetá Basin of southwest Colombia. **American Antiquity**, v. 49, p. 125-140, 1984.

ELIAS, M.; PENET, L.; BERTOLINO, P.; VINDRY, P.; McKEY, D.; PANAUD, O.; ROBERT, T. Unmanaged sexual reproduction and the dynamics of genetic diversity of a vegetatively propagated crop plant, cassava (*Manihot esculenta* Crantz), in a traditional farming system. **Molecular Ecology**, v. 10, p. 1895-1907, 2001a.

ELIAS, M.; McKEY, D.; PANAUD, O.; ANSETT, M. C.; ROBERT, T. Traditional management of cassava morphological and genetic diversity by the Makushi Amerindians (Guyana, South America): perspectives for on-farm conservation of crop genetic resources. **Euphytica**, v. 120, p. 143-157, 2001b.

ELIAS, M.; PANAUD, O.; ROBERT, T. Assessment of genetic variability in a traditional cassava (*Manihot esculenta* Crantz) farming system, using AFLP markers. **Heredity**, v. 85, p. 219-230, 2000a.

ELIAS, M.; RIVAL, L.; McKEY, D. Perception and Management of Cassava (*Manihot esculenta* Crantz) Diversity among Makushi Amerindians of Guyana (South America). **Journal of Ethnobiology**, v. 20, p. 239-265, 2000b.

EMBRAPA. **Sistema Brasileiro de Classificação de Solos**. 1. ed. Rio de Janeiro: Embrapa Solos, 2006.

EMPERAIRE, L.; PERONI, N. Traditional Management of Agrobiodiversity in Brazil: A Case Study of Manioc. **Human Ecology**, n. 35, p. 761-768, 2007.

ERICKSON, C. Historical ecology and future explorations. In: LEHMANN, J.; KERN, D. C.; GLASER, B.; WOODS, W. I. (Orgs.). **Amazonian Dark Earths:** Origin, properties, and management. Dordrecht: Kluwer Academic Publishers, 2003. p. 105-124.

ESPINOSA, V. **Compendio y descripción de las Indias Occidentales**. Washington, DC: Smithsonian Institution, 1948. (Smithsonian Miscellaneous Collections, v. 108).

FAIRHEAD, J.; SCOONES, I. Local knowledge and the social shaping of soil investments: critical perspectives on the assessment of soil degradation in Africa. **Land Use Policy**, v. 22, p. 33-41, 2005.

FRASER, J.; CARDOSO, T.; JUNQUEIRA, A. Historical ecology and dark earths in whitewater and blackwater landscapes: comparing the Middle Madeira and Lower Negro rivers. In: WOODS, W. I.; LEHMANN, J. (Orgs.). **Terra Preta Nova** – a tribute to Wim Sombroek. Berlin: Springer, 2008. No prelo.

GADE, D. W. Names for *Manihot esculenta*: Geographical Variations and Lexical Clarification. **Journal of Latin American Geography**, v. 1, n. 1, p. 55-74, 2002.

GERMAN, L. A. Historical contingencies in the coevolution of environment and livelihood: contributions to the debate on Amazonian Black Earth. **Geoderma**, v. 111, p. 307-331, 2003.

GERMAN, L. A. **The dynamics of terra preta**: An integrated study of human-environmental interactions in a nutrient-poor Amazonian ecosystem, 2001. Unpublished thesis (Ph.D) - University of Georgia, Athens, 2001.

GLASER, B. Prehistorically modified soils of central Amazonia: a model for sustainable agriculture in the twenty-first century. **Philosophical Transactions of the Royal Biological Society B**, v. 362, p. 187-196, 2007.

GLASER, B.; WOODS, W. I. (Orgs.). **Amazonian Dark Earths:** Explorations in space and time. Berlin: Springer, 2004.

GRAHAM, E. A neotropical framework for terra preta. In: BALEÉ, W.; ERICKSON, C. (Orgs.). **Time and complexity in historical ecology**: Studies in the Neotropical lowlands. New York: Columbia University Press, 2006. p. 57-86.

HARLAN, J. **Crops and Man**. Madison, WI: American Society of Agronomy/Crop Science Society of America, 1992.

HECHT, S. B. Indigenous soil management and the creation of Amazonian Dark Earths: Implications of Kayapó practices. In: LEHMANN, J.; KERN, D. C.; GLASER, B.; WOODS, W. I. (Orgs.). **Amazonian Dark Earths:** Origin, properties, and management. Dordrecht: Kluwer Academic Publishers, 2003. p. 105-124.

HECHT, S. B. Agroforestry in the Amazon Basin: Practice, theory and limits of a promising land use. In: HECHT, S. B. (Ed.). **Amazonia: Agriculture and Land Use Research**. Cali, Colombia: Centro Internacional de Agricultura Tropical (CIAT), 1982. p. 331-72.

HECHT, S. B.; POSEY, D. A. Preliminary Results on Soil Management Techniques of the Kayapó Indians. In: POSEY, D. A.; BALÉE, W. (Orgs.). **Resource management in Amazonia:** Indigenous and folk strategies. Advances in Economic Botany. New York: New York Botanical Garden Press, 1989. v. 7. p. 174-188.

HERRERA, L. F.; MORA, S.; CAVELIER, I. Araracuara: Selección y Tecnología en el Primer Milenio A. D. **Colombia Amazónica**, v. 3, n. 1, p. 75-87, 1998.

HERRERA, L. F. The Technical Transformation of an Agricultural System in the Colombian Amazon. **World Archaeology**, v. 24, n. 1, p. 98-113, 1992.

HIRAOKA, M.; YAMAMOTO, S.; MATSUMOTO, E.; NAKAMURA, S.; FALESI, I. C.; BAENA, A. R. C. Contemporary Use and Management of Amazonian Dark Earths. In: LEHMANN, J.; KERN, D. C.; GLASER, B.; WOODS, W. (Orgs.). **Amazonian Dark Earths:** Origin, properties, and management. Dordrecht: Kluwer Academic Publishers, 2003. p. 387-406.

KÄMPF, N. O.; WOODS, W.; SOMBROEK, W.; KERN, D. C.; CUNHA, T. J. F. Classification of Amazonian Dark Earths and other ancient anthropic soil. In: LEHMANN, J.; KERN, D. C.; GLASER, B.; WOODS, W. (Orgs.). **Amazonian Dark Earths**: Origin, Properties, Management. Dordrecht: Kluwer Academic Publishers, 2003. p. 78-98.

KERN, D. C. **Geoquímica e pedogeoquímica de Sítios Arqueológicos com Terra Preta na região de Caxiuanã-PA**, 1996. 124 p. Tese (Doutorado em Geologia e Geoquímica) - Centro de Geociências, Universidade Federal do Pará, Belém, 1996.

KERN, D. C. **Caracterização Pedológica de Solos com Terra Preta Arqueológica na Região de Oriximiná, Pará**, 1988. Dissertação (Mestrado em Ciências do Solo) - Universidade Federal do Rio Grande do Sul, Porto Alegre, 1988.

KUMAR, B. M.; NAIR, B. K. R. The Enigma of Tropical Homegardens. **Agroforestry Systems**, v. 61, p. 135-162, 2004.

LATHRAP, D. W. **The Upper Amazon**. New York: Praeger, 1970.

LEACH, M.; FAIRHEAD, J. Ruined settlements and new gardens: gender and soil ripening among Kuranko farmers in the forest-savanna transition zone. **The IDS Bulletin**, v. 26, p. 24-32, 1995.

LEHMANN, J.; KERN, D. C.; GLASER, B.; WOODS, W. (Eds.). **Amazonian Dark Earths:** Origin, properties, and management. Dordrecht: Kluwer Academic Publishers, 2003.

MADARI, B.; BENITES, V. M.; CUNHA, T. J. F. The effect of management on the fertility of Amazonian Dark Earth Soils. In: LEHMANN, J.; KERN, D. C.; GLASER, B.; WILLIAM, I. W. (Orgs.). **Amazonian Dark Earths:** Origin, properties, and management. Dordrecht: Kluwer Academic Publishers, 2003. p. 407-432

MARTIN, G. J. **Ethnobotany:** a methods manual. London: Chapman & Hall, 1995.

MARTINS, P. S. Dinâmica evolutiva em roças de caboclos amazônicos. In: VIEIRA, I. C. G.; SILVA, J. M. C.; OREN, D. C.; D´INCAO, M. A. (Orgs.). **Diversidade biológica e cultural da Amazônia.** Belém: Museu Paraense Emílio Goeldi, 2001. p. 369-384.

MEGGERS, B. J. **Amazonia:** Man and culture in a counterfeit paradise. 2. ed. Washington: Smithsonian Institution Press, 1996.

MEGGERS, B. J.; MILLER, E. T. Evidência Arqueológica para el comportamiento social y habitacional en la amazonía prehistórica. In: RÍOS, G. M.; MORA, S.; CALVO, F. C. (Orgs.). **Pueblos y paisajes antiguos de la selva amazónica**. Washington, DC: Taraxacum, 2006. p. 325-348.

McCANN, J. M.; WOODS, W. I.; MEYER, D. W. Organic matter and Anthrosols in Amazonia: interpreting the Amerindian legacy. In: REES, R. M.; BALL, B.; WATSON, C.; CAMPBELL, C. (Orgs.). **Sustainable management of soil organic matter.** Wallingford: CAB International, 2001. p. 180-189.

MORA, S. **Amazonía:** Pasado y presente de un territorio remoto. Bogotá: Uniandes, 2006.

MORA, S. **Early inhabitants of the amazonian tropical rain forest.** A study of humans and environmental dynamics. University of Pittsburg, Latin American Archaeological Reports. Alberta: University of Calgary, 2003.

MORA, S. Suelos negros y sociedad: ¿un sistema agrícola de entonces, un sistema agrícola de agora? In: HIROAKA, M.; MORA, S. (Orgs.). **Desarrollo sostenible en la Amazonía** ¿Mito o realidad? Quito: Abya-Yala, 2001. p. 31-45.

MORA, S.; HERRERA, L. F.; CAVALIER, I. **Cultivars, anthropic soils and stability.** A preliminary report of archaological research in Araracuara colombian amazonia. Pittsburgh: Univ. Pittsburgh, 1991. (Latin American Archaeology Reports, n. 2).

MORA, S.; CAVELIER, I.; HERRERA, L. F. Itinerancia, intensificación y rastrajos: un caso amazónico. **Revista de Antropología y Arqueología**, v. 5, n. 1-2, p. 135-151, 1989.

MURRIETA, R. S. S.; DUFOUR, D. L. Fish and farinha: protein and energy consumption in Amazonian rural communities on Ituqui island, Brazil. **Ecology of Food and Nutrition**, v. 43, n. 3, p. 231-255, 2004.

NEVES, E. Prehispanic chiefdoms of the Amazonian floodplain or long-term history and political changes in the Amazonian floodplain. In: SILVERMAN, H.; ISBELL, W. (Orgs.). **Handbook of South American Archaeology**, 2008. No prelo.

NYE, P. H.; GREENLAND, D. J. **The soil under shifting cultivation**. Harpenden, UK: Commonwealth Bureaux of Soils, 1960. (Technical Communication, 51).

OLIVER, J. The archaeology of forest foraging and agricultural production in Amazonia. In: McEWAN, C.; BARRETO, C.; NEVES, E. (Orgs.). **Unknown Amazon, Culture in nature in ancient Brazil.** London: British Museum Press, 2001. p. 50-85.

PEARSALL, D. M. The Origins of Plant Cultivation in South America. In: COWAN, C. W.; WATSON, P. J. (Orgs.). **The Origins of Agriculture** – An International Perspective. Washington, DC: Smithsonian Institution Press, 1992. p. 173-206.

PIPERATA, B. A. Nutritional Status of Ribeirinhos in Brazil and the Nutrition Transition. **American Journal of Physical Anthropology**, n. 133, p. 868-878, 2007.

PIPERATA, B. A; DUFOUR, D. L. Diet, Energy Expenditure, and Body Composition of Lactating Ribeirinha Women in the Brazilian Amazon. **American Journal of Human Biology**, n. 19, p. 722-734, 2007.

PIPERNO, D. R.; PEARSALL, D. M. **The origins of agriculture in the lowland Neotropics**. San Diego: Academic Press, 1998.

PUJOL, B.; RENOUX, F.; ELIAS, M.; RIVAL, L.; McKEY, D. The unappreciated ecology of landrace populations: conservation consequences of soil seed banks in cassava. **Biological Conservation**, v. 136, p. 541-551, 2007.

PUJOL, B.; DAVID, P.; McKEY, D. Microevolution in agricultural environments: how a traditional Amerindian farming practice favours heterozygosity in cassava, *Manihot esculenta* Crantz, Euphorbiaceae. **Ecology Letters**, v. 8, p. 138-147, 2005a.

PUJOL, B.; MÜHLEN, G.; GARWOOD, N.; HOROSZOWSKI, Y.; DOUZERY, E. J. P.; McKEY, D. Evolution under domestication: contrasting functional morphology of seedlings in domesticated cassava and its closest wild relatives. **New Phytologist**, v. 166, p. 305-318, 2005b.

PUJOL, B.; GIGOT, G.; LAURENT, G.; PINHEIRO-KLUPPEL, M.; ELIAS, M.; HOSSAERT-McKEY, M.; McKEY, D. Germination ecology of cassava, *Manihot esculenta* Crantz, Euphorbiaceae, in traditional agroecosystems: Seed and seedling biology of a vegetatively propagated domesticated plant. **Economic Botany**, v. 56, p. 366-379, 2002.

RINDOS, D. **The origins of agriculture** – An evolutionary perspective. San Diego: Academic Press, 1984.

ROOSEVELT, A. C. The Development of Prehistoric Complex Societies: Amazonia, a Tropical Forest, In: BACUS, E.; LUCERO, L. (Orgs.). **Complex Polities in the Ancient Tropical World**. Oxford: American Anthropological Association, 1999. p. 13-33. (Archaeological Papers of the American Anthropological Association, 9).

ROOSEVELT, A. C. Resource management in Amazonia before the conquest: Beyond ethnographic projection. In: POSEY, D. A.; BALÉE, W. (Orgs.). **Resource management in Amazonia:** Indigenous and folk strategies. Advances in Economic Botany. New York: New York Botanical Garden Press, 1989. v. 7, p. 30-62.

ROOSEVELT, A. C. **Parmana**: Prehistoric maize and manioc subsistence along the Amazon and Orinoco. New York: Academic Press, 1980.

ROSAINE, S. Guiana's Chiefdoms. Did they really exist? Paper presented at the Society for the Anthropology of Lowland South America (SALSA) Conference. Oxford June 18th 2008.

SAUER, C. O. Man in the Ecology of Tropical America. In: **Proceedings of the Ninth Pacific Science Congress**, Bangkok, v. 20, p. 104-110, 1958.

SAUER, C. O. **Agricultural Origins and Dispersals**. New York: American Geographic Society, 1952.

SAUER, C. O. American agricultural origins: A consideration of nature and agriculture. In: LOWIE, R. H. (Org.). **Essays in Anthropology in Honor of A. L. Kroeber**. Berkeley: University of California Press, 1936. p. 279-298.

SCHMIDT, M.; HECKENBERGER, M. Amerindian Anthrosols: Amazonian Dark Earth Formation in the Upper Xingu. In: WOODS, W. I.; LEHMANN, J. (Orgs.). **Terra Preta Nova** – a tribute to Wim Sombroek. Berlin: Springer, 2008. No prelo.

SCHMIDT, M.; HECKENBERGER, M. Formação de Terra Preta na Região do Alto Xingu: Resultados Preliminares. Unpublished Report to EMBRAPA. 2007.

SILVA, R. M.; BANDEL, G.; FARALDO, M. I. F.; MARTINS, P. S. Biologia Reprodutiva de Etnovariedades de Mandioca. **Scientia Agricola**, v. 58, n. 1, p. 101-107, 2001.

SMITH, N. Anthrosols and human carrying capacity in Amazonia. **Annals of the Association of American Geographers**, v. 70, n. 4, p. 553-566, 1980.

SOMBROEK, W. **Amazon Soils:** a reconnaissance of the soils of the Brazilian Amazon region. Wageningen: Centre for Agricultural Publications and Documentation, 1966.

SWEET, D. G. **A Rich Realm of Nature Destroyed: the Middle Amazon Valley, 1640-1750**, 1974. Thesis (PhD) - University of Wisconsin, Madison, 1974.

TEIXEIRA, W. G.; MARTINS, G. C. Soil physical characterization. In: LEHMANN, J.; KERN, D. C.; GLASER, B.; WOODS, W. (Orgs.). **Amazonian Dark Earths:** Origin, properties, and management. Dordrecht: Kluwer Academic Publishers, 2003. p. 271-286.

WILSON, W. M.; DUFOUR, D. L. Why Bitter Cassava? Productivity of Bitter and Sweet Cassava in a Tukanoan Indian Settlement in the Northwest Amazon. **Economic Botany**, v. 56, n .1, p. 49-57, 2002.

WOODS, W. I.; McCANN, J. M. **The anthropogenic origin and persistence of Amazonian Dark Earth**. In: Conference of Latin Americanist Geographers. Austin, TX: University of Texas Press, 1999. p. 7-14.

ZEDER, M. A. Central Questions in the Domestication of Plants and Animals. **Evolutionary Anthropology**, v. 15, p. 105-117, 2006.

ZEVEN, A. C. Landraces: a review of definitions and classifications. **Euphytica**, v. 104, p. 127-179, 1998.

ZOHARY, D. Unconscious Selection and the Evolution of Domesticated Plants. **Economic Botany**, v. 58, n. 1, p. 5-10, 2004.

Recebido: 29/01/2008
Aprovado: 28/07/2008