# Human "Adaptation" to Anthropogenic Environments: A Case Study from the Brazilian Amazon

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This paper explores how anthropogenic modifications of the environment condition human adaptive process for the Amazonian terra firme. The co-occurrence and cultivation of non-anthropogenic terra firme soils and Black Earth, a more fertile anthrosol resulting from the semi-permanent settlement of Amerindian groups, provide a unique opportunity for comparative research on the use of relatively "pristine" and "cultured" environments. Two years of ethnographic, ethnoscientific and agronomic research among *caboclo* farmers of the Central Amazon ground the analysis of cognitive and behavioral adaptations to anthropogenic and non–anthropogenic environments. Findings confirm that unique cognitive and behavioral adaptations characterize these two environments, and suggest that a dynamic and synergistic relationship exists between human cognition, human behavior and the non-human environment. This research supports recent historical ecological literature that discredits the adaptationist model and emphasizes the complexity and historicity of human-environmental relationships.

KEY WORDS: Human ecology, black earth, Rio Negro, anthrosol, shifting agriculture.

## INTRODUCTION

This research focuses on terra firme environments of Central Amazonian Brazil, where a long history of human ecological interpretation assists in exploring the nuances associated with human adaptative processes and models. Within this region, I focus on blackwater ecosystems, renowned for their oligotrophic (nutrient-poor) status and for the constraints this condition places on the productivity of terrestrial, aquatic and human ecosystems. The presence of readily-identifiable and relatively eutrophic anthropogenic soils facilitates the analysis of a resource that has long been considered a limiting factor to settlement and cultural development in the region -- terra firme soils. A comparative study to contrast adaptive strategies employed by contemporary residents in both anthropogenic and non-anthropogenic environments of the terra firme permits the testing of the following hypothesis:

> ***Hypothesis:*** *Humans adapt not only to pristine terra firme environments, but to biophysical conditions created through former anthropogenic influences on the environment and by the ecological processes which result from these interactions.*

## BACKGROUND

### Human Ecology of Amazonia: The Concept of Adaptation

This research is rooted in a long trajectory of human ecological interpretation of cultural developments in the nutrient-stressed ecosystems of Amazonia. For many years, the concept of adaptation has been employed by Amazonianists to explore relationships between the biophysical environment, material culture and cultural evolution. Early scholars were deterministic in their approach to cultural explanation, stressing an immutable environment to which humans must adapt. The quantity and quality of agricultural land (Lathrap 1970; Meggers 1971; Sanchez et al. 1982; Smith 1980) and protein scarcity (Chagnon and Hames 1979, Gross 1975) were among the factors cited for limiting human occupation and cultural development in the region.

This view of the environment has been sharply criticized for its tendency to downplay the complexity and plasticity of traditional patterns of social organization and resource use. The "upper limits" to cultural development came to be defined not only by environment, but by the technological and social elements available to exploit the environment. The concept of adaptation was expanded to include social and technological buffering (Denevan 1992; Roosevelt 1980; Myers 1992), as well as the role of political-economic factors in mediating productive opportunities and the latitude of human agency in specific environments (Anderson and Ioris 1992; Schmink and Wood 1992). Each of these permutations of human ecological theory provided a more comprehensive view of cultural developments in the region. Yet these models continued to view the environment in terms that excluded cultural and historical process.

### Historical Ecology

In the past decade, several volumes have been published to demonstrate how historical processes alter the environment itself (Balée 1998; Crumley 1994; Redman 1999), as well as human uses of the environment. This human ecological literature has brought us to question the idea of a "pristine environment" and, therefore, that of environmental determinants. While these approaches have given increasing attention to the role of historical over evolutionary determinants to human-ecological interactions, they tend to stress the

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"interpenetration of humans and the environment" (Balée 1998:14). This literature has catalyzed important changes in our conceptualizations of both the environment and human adaptive process, highlighting the nuances and complexities inherent in human-environmental interaction.

First, this discovery of biophysical contexts that are themselves artifacts of past human activity has had profound implications for our understanding of the natural world, and has led scholars to question their understanding of Amazonian environments. For example, the discovery of anthropogenic environments has contributed to the shift in terminology from "primary forest" to "mature forest," and to a more critical use of the term "natural." The recognition that environmental conditions result from both evolutionary and historical processes (Graham 1998) has also influenced our understanding of human adaptation. It is now known that, instead of responding to environmental stimuli through simple assimilation of environmental absolutes, humans both respond to cultured environments and actively structure the environments with which they interact.

Examples of culturally-modified environments include anthropogenic forests (Anderson and Posey 1989; Balée 1989), anthropogenic soils (Herrera et al. 1992; Mora et al. 1991; Smith 1980), "forest fields" (Posey 1982) and other types of "artifactual resources" (Balée 1992). Additional environmentally-modifying behaviors include organic waste deposition in lakes to create seasonally rich "patches" with increased fishing yields (Stocks 1983), and the management of fallow vegetation (Balée 1992; Denevan and Padoch 1987; Irvine 1989). These examples have stimulated recent debate within the historical ecological literature, where process, interactionalism and synergy have begun to replace determinist and additive understandings within descriptions of human-environmental interaction.

Whitehead takes this logic the furthest through his concept of "ecological praxis," which he defines as "the persistent features in the sociocultural repertoire of human physical and mental behavior that is overtly oriented to . . . structure usages of the environment" (1998:30). Whitehead seems to move beyond full interpenetration of culture and environment by privileging history and placing humans at the center of analysis of environmental process. This leads us to question what role the environment plays – if any – in human adaptation.

In this paper I wish to demonstrate that the environment does play a role in human adaptation, yet simultaneously corroborate recent findings of historical ecologists. In other words, I suggest that the relationship between human behavior and environment should be seen as interactional – that the environment changes through human behavior, and that these changes in turn structure adaptive process. I will demonstrate that while humans respond to the biophysical artifacts of past occupants, they are not always capable of recreating these changes. While new impacts are likely to result, the nature of human impacts on the environment is often historically contingent. Nevertheless, within any given milieu, as the environment changes, it is suggested that dynamic human responses are the norm.

## Traditional Swidden Agriculture as Environmental Adaptation

In the human ecological literature on Amazonia, traditional swidden agriculture on the terra firme is one of the most frequently used examples of human adaptation to environment. While recent evidence for complex agroforestry practices and more sedentary occupations (Denevan 1996; Heckenberger et al. 1999) tends to discredit historical analogy based on shifting agriculture, a look at contemporary swidden agriculture is nevertheless useful. First, it provides a glimpse of conditions under which this form of agriculture is practiced (technology, labor, etc.). Furthermore, as the predominant use of non-anthropogenic soils in the study region – and particularly among more traditional farmers – it is the only valid basis for comparison with agriculture on anthropogenic soils.

The role of geochemistry in constraining shifting agriculture on the terra firme has been illustrated by Jordan (1985b) in Figures 1 and 2. Figure 1 shows nutrient and plant biomass distributions in nutrient-rich (eutrophic) and nutrient-poor (oligotrophic) environments – the latter representing the Amazonian terra firme. In these environments, soil nutrients are limited and most system nutrients are locked up in the standing biomass, while in a more eutrophic ecosystem these are better distributed between soil and standing stocks.

**Figure 1.** Distribution of Roots and Nutrient Ions in the Soil of a Typical Amazon Rainforest and a More Nutrient-Rich Forest (from Jordan 1985b)

Impoverishment of the rooting zone, and of subsurface horizons that provide the bulk of nutrients for sustained agricultural practices in many temperate regions, have been described as constraints to agricultural productivity and sedentism on the terra firme. While the exact impact of these environmental properties on indigenous agriculture and cultural developments in Amazonia is still under debate, farmers consider the burning of plant biomass to be critical to production and the age of the fallow proportional to crop yields. These associations between minerals released through the burn, quantity of slash and crop yield are well-established for shifting cultivation systems (Brinkman and de Nascimento 1973; Harris 1971; Peters and Neuenschwander 1988; Nye and Greenland 1964; Ramakrishnan and Toky 1981; Rose Innes 1972), particularly in the first year of cropping (Andreae 1980).

Soil nutrient diagrams have been used to demonstrate the coupling of environmental conditions and agricultural productivity. Jordan (1985b) constructed one such diagram (Figure 2), in which nutrient stocks for diverse components of the shifting agricultural system (soil, standing biomass, etc.) throughout the production cycle are shown for a nutrient-poor region of Amazonia. It provides insight into the soil chemical dynamics influencing farmer decisions in the San Carlos site. In this diagram, it appears as if abandonment coincides with a decline in soil nutrient stocks. Jordan (ibid.) explains this as a response to the binding of phosphorus in the soil, rather than to the absolute depletion of soil nutrients.

**Figure 2.** Standing Stocks of Nutrients as a Function of Time in a Slash and Burn Plot in the Amazon Basin (above Abscissa) and Cumulative Nutrient Losses from the Soil (below Abscissa) (from Jordan 1985b)

The poor quality of terra firme soils and the dependence of shifting agriculture on standing stocks of nutrients were understood by many to underlie three fundamental characteristics of shifting agriculture on the terra firme:

1) the almost sole reliance on the burn to liberate system nutrients for agriculture,

2) itinerancy as a means of maintaining system integrity through time (through the liberation of nutrients from new areas of forest), and

3) dependence on bitter manioc as the staple crop, which is well-adapated to acid, nutrient-poor conditions (Meggers 1971; Jordan 1985a, 1989).

This model has been criticized on a number of accounts. Evidence for more permanent forms of agriculture on the terra firme prior to contact (Denevan 1996, 1992; Woods and McCann 1999) and for indigenous modification of soils (Smith 1980; Woods 1995) discredit the notion that ecosystem properties make shifting, manioc-based agriculture a necessity. Others argue that abandonment results from increased investment of labor to control weeds in older swiddens rather than soil fertility decline, or that it is a concept ill-suited to reflect the gradual change in management intensity that accompanies a swidden (Denevan and Padoch 1987). Still others suggest that a variety of important staple crops (yams, cocoyam, sweet potato, etc.) existed prior to the colonial period, and that these declined in importance as people began to focus on bitter manioc (Piperno and Pearsall 1998).

Jordan's approach to modeling swidden agriculture as a function of soil fertility is nevertheless useful for comparing agricultural practices on Black Earth and adjacent non-anthropogenic soils. First, abandonment as defined by a dramatic decrease in management intensity (often to negligible levels) is clearly observed in the study region. Furthermore, while a complex interplay of factors guides swidden abandonment, soil fertility decline ranks high among these factors for both Black Earth and Latosol[2] farmers. As such, the characterization of soil nutrient stocks at diverse stages in the swidden agricultural cycle provides a useful heuristic tool for explicating one important facet of decision-making within swidden management.

## Indian Black Earth

The anthropogenic environment selected for this comparative study is an anthrosol called *Terra Preta*, or Black Earth. In scientific circles it has been termed *Latosolo Amarelo Húmico Antropogênico* (Salgado Vieira 1988), although some debate exists over the legitimacy of its classification as a sub-class of spatially-predominant Latosols. Black Earth is generally found on the terra firme in small pockets of 1 to 6 hectares, although sites of up to 80 ha and in a broader range of environments may be found (Smith 1980).

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[2] Latosols are the predominant soils of the terra firme, and roughly correspond to the Oxisol soil order of the USDA classification system.

It is now unquestioned that Black Earth is cultural in origin (Heckenberger et al. 1999; Woods 1995; Woods and McCann 1999). Evidence includes high levels of calcium and phosphorous, spatial distribution (typically on high landforms where depositional processes could only be cultural), the presence of artifacts throughout the modified horizon, and the occurrence of Black Earth over buried horizons typical for the region's Latosols. Yet there is still debate over the specific processes and settlement characteristics leading to its formation. Research published since 1999 suggests that it results from intensive nutrient deposition and burning in areas of Amerindian habitation, and from chemical and biological processes that initiate once a threshold level of pH, nutrient retention capacity and biological activity is reached as a result of burning and organic waste (Glaser et. al 2001; McCann et al. 2000; Woods and McCann 1999).

Black Earth environments are anomalous in current ecological models of terra firme ecosystems due to relatively high soil nutrient stocks, improved indices of fertility (cation exchange capacity, pH, levels of toxic Al) and extreme amounts of soil phosphorous – a known limiting nutrient in Amazonian ecosystems (Jordan 1989, 1985b). While high nutrient stocks are characteristic of areas of human habitation, most nutrients are slowly leached out of the soil horizon under natural weathering processes. Phosphorous, on the other hand, tends to be fixed in the soil horizon through the formation of stable complexes with iron and aluminum oxides, thereby increasing plant-available stocks of the nutrient.

These environmental differences stand out for early cultural theory because they in effect ameliorate what some authors held as an important constraint to cultivation on the terra firme, and for pedological theory due to supposed linkages between climate, stable geological surfaces and the intensive weathering of terra firme soils (Buol et al. 1980; Cochrane and Sanchez 1980). Should these differences influence the cultivation system on the terra firme and defy expectations about system constraints and characteristics, then Black Earth phenomena must be understood as an anomaly in terms of *both* environmental conditions and adaptive processes. Alternatively, we might consider these examples further proof that a broader range of human-environmental interactions is possible, and employ the lessons learned to modify human ecological models themselves.

## METHODS

### Site Selection

Three preliminary criteria governed site selection: the presence of Black Earth, the importance of this anthrosol to family sustenance, and the sole use of local organic amendments or cultural practices for fertility management. The last of these was necessary due to the potential role of chemical fertilizers in altering the soil substrate that constitutes the anthropogenic environment under study. Two blackwater environments in the Central Amazon region were selected for in-depth ethnographic and agronomic research: the lower Negro River and the middle Urubú River. Research sites within these environments are illustrated in Map 1.

**Map 1.** Research Sites on the Negro and Urubú Rivers

To identify participant families within each site (lower Negro, middle Urubú), four additional criteria were employed: the family's dependence on local natural resources for livelihood, the role of agriculture as a primary economic activity, the comparative research framework and full consent. The comparative research framework merits special attention. Here, Black Earth site location was a strong determinant. For the lower Negro, access to Black Earth is not shared equally among local residents, given the more limited spatial distribution of this soil class and the tendency for use areas to be divided by formalized land tenure systems. With the exception of one upstream site on the Negro, researched to the exclusion of other geographically intermediate sites[3], the limited distribution of Black Earth sites made the selection of participants fitting the minimal criteria exhaustive for this region. Remaining collaborators were therefore selected according to the comparative research framework to derive an equal number of cultivation systems (i.e., a 1:1 ratio between Black Earth and Latosol farming systems).

The limited spatial extent of Black Earth resulted in a research framework based on both within-family and between-family comparisons (the adaptive strategies of single families cultivating both soils, and families cultivating one soil to the exclusion of the other, respectively). On the Urubú, most families had access to both Black Earth and non-anthropogenic soils. This selection process produced the following comparative research framework:

**Table 1.** Comparative Research Framework for Central Research Sites

### Identification of Black Earth Sites

I define a "Black Earth site" as the full geographical range of direct human-environmental interaction in a given homestead (encompassing the full range of environmentally-modifying behavior including productive, extractive and depositional activities) on sites with the archaeological and pedological properties (color, depth, exchangeable P, presence of potsherds, high organic matter content) distinguishing Black Earth in the literature (Falesi 1972; Herrera et al. 1992). I use the term "non-anthropogenic" to classify those sites exhibiting qualitatively or quantitatively distinct properties for any of the aforementioned parameters, and recognized as such by local informants.

The difficulty of clearly identifying Black Earth in transitional sites (those with a lesser degree of formation or anthropic modification) made it necessary to rely more strongly on local discriminations for these sites. While potsherds were nearly always present in abundance, serving as a clear indication of anthropogenic origins, soil color was often deceptive. The similar performance of crops on "legitimate" and marginal Black Earth, as observed by local residents, justified the classification of these sites as anthrosols. More conclusive determinations were later made through laboratory analysis of soil phosphorus.

### Comparative Research

To research distinctive adaptive processes in each environment, it was first necessary to characterize the anthropogenic environment in relation to the background context, and then to identify specific adaptive responses to these environmental differences. Table 2 summarizes the methods employed for each stage of research.

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[3] This individual was selected on the basis of his long-time use of Black Earth, and the saliency of this

**Table 2.** Summary of Research Methods

*Definition of the Anthropogenic Environment.* To understand the role of anthropogenic modifications of the environment in conditioning adaptive process, it was necessary to begin by identifying and characterizing the anthropogenic environment. The first step was to determine background fertility of Black Earth and adjacent, non-anthropogenic soils. I did this by first taking composite samples (Anderson and Ingram 1993) at two depths (0-10 cm, 10-30 cm) of the rooting zone in 33 Black Earth and Latosol swiddens at lower Negro and Urubú sites. Samples from each swidden were taken from five randomly-selected auger sites, which were cleared of litter and sampled at specified depths. Samples from these five sites were mixed thoroughly (by depth) to derive two composite samples per swidden. Sub-samples of approximately 750 grams each were collected for laboratory analysis. While a larger number of swiddens were ultimately researched both botanically and pedochemically, this represents the total number of swiddens under cultivation at the beginning of the field study (January 1998). Analyses of phosphorous and calcium, two important indicators of Black Earth (Pabst 1991; Woods and McCann 1999), assisted in the identification of anthrosols. Further analyses were carried out to assess fertility differences between the two soil classes.

To determine whether fertility differences catalyze differences in crop yield, I carried out a fertility experiment to contrast growth rate and yield of corn (*Zea mays*), a nutrient-demanding crop, on distinct soils. Planting bags were filled with soils from the swiddens of each participant family to capture the variability in soil quality, and brought to one site for observation (thereby eliminating the effects of environmental differences on crop yields).

*Adaptive Responses to Environmental Difference.* To identify adaptive response to anthropogenic environments, a comparative study was carried out in Black Earth and Latosol swiddens. I utilized both qualitative and quantitative methods to identify differences in cognitive and behavioral adaptations to Black Earth and Latosol environments. Distinctive cognitive adaptations to these two environments – including local perceptions of each

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cultivation system to the exclusion of other intermediate sites in the mind of local field guides.

environment and of the difference in adaptive strategies in these two environments – were researched through the following:

- Semi-Structured Interviews. Open-ended questions first targeted the most salient differences between Black Earth and Latosols. Collaborators were then asked to discuss the properties of each soil class, as well as the relative benefits of opening swiddens in each environment. From these interviews, all descriptor terms were compiled on the basis of their reference to: 1) inherent structural (physical, morphological) and functional (chemical) properties of each soil class, 2) more transient or dynamic properties and 3) the management of each class of soils.

- Elicitation of Soil Classification Systems. To research soil classification systems, I used a free listing technique (Bernard 1994) to elicit all soil classes, and all of the members of each soil class. Questioning continued until classes could be differentiated no further. The structure of local classification systems (hierarchy, etc.) was inferred from informant responses. Artifacts of the elicitation framework were reduced through further questioning to confirm class membership for each taxon. I then compared classification systems across informants and soil classes to determine: 1) the level of classification (folk generic, folk specific) of each soil class, 2) the tendency to further differentiate soil classes into folk specific taxa and 3) levels of informant agreement for each of these.

- Frame Interviews or Item-by-Feature Matrices. I generated systematic frame interviews from descriptor terms derived from interviews, and used these to generate item-by-feature matrices with a total of twelve informants (one from each of twelve homesteads) (D'Andrade 1995). Multidimensional scaling and consensus analyses were then carried out on the basis of informant agreement on each descriptor term, resulting in numerical and graphic representations of the taxa *Terra Preta* and *Terra Comúm.*

To research behavioral adaptations to anthropogenic Black Earth, I utilized techniques to study cropping practices, nutrient management behavior and time allocated to diverse activities. These include:

- Crop Performance Ratings. I generated an exercise to elicit informant ratings on the performance of diverse crops on Black Earth and Latosols to document one of the most salient differences in the management of these two soil classes. For this procedure, I compiled a list of common crops from field observations and of the most salient soils from the above free listing exercise. I then posed systematic questions to informants regarding performance of diverse crops on each soil class. Ratings differentiated crop performance into three categories: 2 (produces well), 1 (produces, but not well), and 0 (does not produce).

• Botanical Plots. The monitoring of three botanical plots of 25 square meters each, established in active swiddens and monitored throughout one full year at three-month intervals, permitted quantitative assessments of cropping behavior. Together with survey measurements, these data were analyzed to derive botanical measures of the presence and abundance of each crop, resulting in measures for each plot, swidden and farm.

• Ground Survey Measurements. I carried out ground surveys to measure swidden size and orientation for each homestead.

• Participant Observation. Ongoing participant observation during accompanied visits to swiddens permitted detailed, first-hand observation of cropping and fertility management practices and spontaneous conversation on salient aspects of each system.

• Fertility Assessment of Fallow Systems. I collected composite samples using the same method as that used to characterize the anthropogenic environment (Anderson and Ingram 1993), this time to assess the fertility of distinct stages in swidden evolution. Several locales and times were targeted for soil fertility sampling: 1) swiddens in cultivation at the beginning of 1998 and brought under cultivation during the following year, 2) critical stages of the swidden cycle (the burn, abandonment, etc.) for many of these swiddens and 3) the forested vegetation near researched swiddens. This resulted in 68 sampling locales from the central study region, including both agricultural and forested landscapes.

I then classified these samples according to four stages of the production cycle: forested landscapes, burnt swiddens, cultivated swiddens and fallow (abandoned swiddens). Forested areas included both mature forest and old fallow, the former found on Latosols alone and the latter on both Black Earth and Latosols. Fallowed vegetation, on the other hand, refers to agricultural sites whose vegetation cover is no longer managed but from which farmers may continue to extract edible products. I further divided samples according to Black Earth and Latosols, resulting in a four-stage pedochemical characterization of each cultivation system.

Laboratory analyses targeted important indicators of soil fertility: pH, exchangeable cations ($Ca^{++}$, $Mg^{+++}$, $Na^{+}$, $K^{+}$), plant-available phosphorus ($PO_3^{-}$) and exchangeable aluminum ($Al^{+++}$).

- Time Allocation Studies. The time allocated to distinct economic activities was recorded for each of the twelve families over the course of one year, by sampling the activities carried out during the first week of every month. The logistical difficulties of sampling distant sites simultaneously required the help of field assistants. Four literate assistants documented the activities of participant families when I was absent, and reviewed the data with me upon my return. Weekly values were extrapolated for the entire month and graphed to show seasonal changes.

- Additional Production Parameters. Additional data were recorded for each swidden to correlate soil fertility parameters with the duration of fallow or swidden cultivation, and diverse stages of swidden evolution.

## RESULTS

### Characterizing the Anthropogenic Environment

*Soil Chemical Analyses*. The results of soil fertility analyses are tabulated in Table 4. The most significant difference between these two soil classes is found in levels of plant-available phosphorous. This element is known to be a limiting nutrient in forested Amazonian ecosystems (Jordan 1989), and often too for swiddens cleared from forest fallow (Norman 1979). Yet phosphorus shows a tenfold increase on Black Earth in relation to the region's Latosols, effectively eliminating what is known to be a constraining factor to agriculture. High levels of exchangeable and total phosphorus are characteristic for archaeological sites (Eidt 1977), and are the best chemical indication that these soils are, in fact, anthropogenic.

**Table 4.** Laboratory Results of Soil Fertility Analyses on Black Earth, Non-Anthropogenic and Transitional Soils of the Study Region

Concentrations of nutrient cations are also greater on Black Earth than on Latosols. Additional soil parameters affecting the plant's ability to utilize nutrients are more favorable on Black Earth. Exchangeable aluminum ($Al^{+++}$), a chemical form harmful to most plants when present in quantities above 0.5 $cmol_c \cdot dm^{-3}$ (Cravo, personal communication), is lower in Black Earth and transitional soils than on non-anthropogenic agricultural soils. Black Earth also tends to be more basic than adjacent soils, favoring nutrient availability and retention. Apparently minor differences in pH translate into significant differences in plant performance due to synergistic effects with aluminum and phosphorus, and ultimately with nutrient mobility (Davidescu and Davidescu 1982; van Raij 1991).

The anomaly represented by Black Earth chemistry should by now be evident. It is important to note, however, that despite evidence for heightened soil fertility on anthropogenic Black Earth, exchangeable potassium shows little improvement over the more predominant Latosols. At depths below 10 cm this trend is even reversed, in particular for transitional soils that would theoretically have a lower anthropogenic nutrient load yet are treated like the richer Black Earth from a management standpoint. One would expect this nutrient to lower the yields of certain potassium-demanding crops or the success of distinct cultivation strategies on Black Earth.

*Fertility Experiment.* Results of the fertility experiment nevertheless demonstrate significant yield differences between Black Earth (including transitional soils) and Latosols, as indicated in Graph 1. "Transitional soils" are those with a lighter color and lesser degree of anthropogenic modification than the prototypical "Terra Preta," yet with characteristics that indicate anthropogenic origins (a high concentration of artifacts, crop response, etc.). These too produce higher yields that are also comparable to the "legitimate" Black Earth. These comparable yields are unexpected given the higher fertility of Black Earth, yet the more intensive mining of soil nutrients in the darker anthrosols in recent history might have provoked a loss in nutrients that would somewhat equalize crop performance.

**Graph 1.** Maize (*Zea mays*) Yields as a Function of Soil Type

These data show that for this nutrient-demanding crop, yields are much higher for Black Earth and transitional soils than for non-anthropogenic soils despite the limited differentiation of soil potassium stocks. Most importantly, it would appear that anthropogenic soils demonstrate a higher average fertility than naturally-forming soils of the study region when measured by the performance of a nutrient-demanding crop.

### Cognitive Adaptations to Anthropogenic Environments

*Soil Classification Systems.* Folk classification systems highlight perceptual distinctions between classes of objects and between the criteria that differentiate these taxa perceptually (Berlin 1992; Stuessy 1990). While these classification systems do not necessarily reflect utilitarian distinctions (Berlin et al. 1981), they are useful to the discussion of adaptive processes in Black Earth environments for highlighting perceptually distinctive entities for which unique properties exist in relation to other related phenomena (i.e., other soil classes). At a most fundamental level it points to the recognition of differences between these two soils, and to the relative saliency of each soil taxon.

Among collaborators of lower Negro and Urubú sites, certain variability exists among soil classifications. This variability reflects in part the heterogeneity of the biophysical environment, and in part variations in perception based on individual differences and on a dynamic classification system that is context- and purpose-dependent. Certain patterns of variation nevertheless repeat themselves within informant responses and highlight important perceptual patterns in ethnopedological cognition.

Figures 3 and 4 depict the common (unbracketed terms), interchangeable (separated by backslashes) and optional (bracketed) taxa within the classification systems of middle Urubú and lower Negro sites, respectively. The inclusion of any given taxa in the first contrast set of the free listing exercise was taken as evidence for its folk generic status. Black Earth was invariably listed within these folk generic groupings, indicating a similar degree of cognitive saliency for this taxon.

**Figure 3.** Commonalities among Soil Classifications along the Middle Urubú

[a] Folk generic taxa.

**Figure 4.** Commonalities among Soil Classifications on the Lower Negro
[a] Refers to the most salient, or "folk generic" (Berlin 1992), taxa.
[b] Bracketed terms represent optional or covert categories.
[c] A variation of this classification system is to substitute Red Clay/Yellow Clay for these taxa, and in contrast to Sandy Soil.

In addition to the inclusion of anthrosols in contrast sets that include non-anthropogenic soils of greater geographical distribution, the differentiation of these anthrosols into subsets was nearly as prevalent as with Latosols. Those individuals who subdivided non-anthropogenic soils also tended to subdivide Black Earth, with the exception of two individuals who farm Latosols alone. The basis for differentiation varied across individuals and soil classes, with color, texture and fertility modifiers or descriptors mentioned for both Black Earth and Latosols (soil texture being the most common basis for the division of each into folk specific taxa). Finally, neither soil class was subdivided further (into a third tier of classification, for example). This similar treatment of Black Earth and non-anthropogenic soils suggests that they are perceived as distinctive entities, and that the level of cognitive saliency for anthropogenic and non-anthropogenic soils is similar.

*Ethnopedological Knowledge: Cluster Analysis and Multidimensional Scaling.* Two additional analyses generate a better understanding of the level at which distinct soil classes are differentiated from others in the minds of local residents: cluster analysis and multi-dimensional scaling. Both Figure 5 and Axis 1 of Graph 2a illustrate a higher-order differentiation between Terra Preta and other soil taxa. This is useful for demonstrating that in addition to being recognized as a distinctive entity, the properties that define the distinctiveness of Black Earth are also known by locals and organized into what might be considered a fully developed cognitive domain.

**Figure 5.** Perceptual Similarity of Soil Classes: Results of a Cluster Analysis of Ethnopedological Data

Multidimensional scaling of ethnopedological item-by-feature matrices generates graphical representations of the perceptual proximity of Black Earth and other common soil taxa. The graphical output of the multidimensional scaling procedure is a three-dimensional representation of multidimensional space (see Graphs 2a, b). Given that 61 features of five soil taxa were analyzed to produce the item-by-feature matrix (the MDS input), it becomes a three-dimensional representation of 61 dimensions. All axes of this graph represent each of these 61 soil features to some degree; however, each axis also differs according to those features that it best represents.

**Graph 2a.** Multidimensional Scaling of Soil Taxa: Axes 1 and 2

**Graph 2b.** Multidimensional Scaling of Soil Taxa: Axes 2 and 3

Black Earth is shown to differentiate from other soil classes primarily according to the features represented by dimension one, and is considered perceptually similar by other criteria (dimensions 2 and 3). The features best represented by Axis 1 will be those that discriminate Terra Preta from other soil taxa in the minds of local residents. From Table 5 (column 1), we see that the features of Black Earth that most differ from other soil classes include both desirable and undesirable characteristics. Fitosanitary problems (higher incidences of pests, disease), symbolic understandings (the "strong" eye), greater labor requirements for slashing and weeding and a shallow epipedon each limit incentives for Black Earth cultivation. However, its chemical properties (fertility, nutrient retention capability, etc.) and the lesser reliance on the burn to liberate system nutrients (allowing the soil to be cleared in the rainy season) are also strong incentives for its cultivation.

**Table 5.** Feature Representation of Axes 1, 2 and 3 on the Multidimensional Plot

Graph 2b tempers this divergence of Black Earth from other soil taxa with features for which Black Earth overlaps with other soil classes (Axes 2 and 3). As such, the divergence of Black Earth from other soil taxa rests on the specific properties under analysis. Axes 2 and 3 most strongly represent "weaker" (natural, raw, etc.) and texturally-distinct soil classes, respectively. For each of these dimensions (axes), other soil classes are better fits for the features represented and therefore take the place of Black Earth as outliers. Despite this apparent indication that each soil is distinctive on the basis of certain characteristics and similar for others, results of the cluster analysis indicate that among the other cultivable soils in the region, Black Earth is the most distinctive in the minds of local residents. Furthermore, the higher number of features characterizing Axis 1 indicates that perceptual discriminations of Black Earth from other soil taxa are both detailed and complex.

In addition to generating novel ways of cognizing the anthropogenic environment, it appears that the frames of reference used to cognize Black Earth reflect, in part, traditional forms of environmental cognition. The distinction between "raw" and "burnt" soil, for example, is likely to stem from a cultivation system in which the liberation of nutrients through the burn is considered essential for restoring site productivity. "Raw" in this case is seen as the inherent state of the soil in its "natural" state. A "burnt" state results only from the domestication of soil, and is considered inherently transient. The importance of this idea of the burn as a transient property is seen in the reluctance of locals to see Black Earth as something that may be generated by the human hand. It is also evident in their sharp disagreement over whether Black Earth is inherently "burnt" – despite clear evidence of this (color, charcoal remains, etc.). These relatively enduring aspects of environmental cognition may also underlie the tendency for all Black Earth farmers burn their swiddens, despite a) ample evidence that cultivation is less burn-dependent than on Latosols and b) possibilities for alternative management practices that ensure the conservation of the unique chemical properties of Black Earth.

**Behavioral Adaptations to Anthropogenic Environments**

Behavioral data also indicate a divergence in the treatment of Black Earth and non-anthropogenic environments. These differences have been divided into three primary areas within which behavior is differentiated between these two cropping systems: cropping practices, fertility management practices and labor considerations.

*Cropping Practices.* Perhaps the most significant distinction in adaptive processes on Black Earth and Latosols is the differential selection of crops best adapted to each environment. During preliminary interviews, when asked to respond to open-ended questions on the difference between *Terra Preta* and the more spatially predominant soils (*Terra Comum*), informants almost invariably identified distinctive soil-crop associations as the most salient distinction. This is even more significant given the neutrality of the question regarding utilitarian versus intellectual distinctions. The question, "What are the differences between *Terra Preta* and *Terra Comum*?" makes no reference, for example, to specifically utilitarian concerns. The following commentaries attest to these distinctions:

> Clay is good for banana. Avocado and lemon produce more quickly [on clay soils] than on *Terra Preta*. On *Terra Preta* they grow more, but are slow to produce. This is the difference between plants on clay and *Terra Preta*. There are plants that are of clay and there are plants that are of Black Earth. Black Earth is good for vegetables and manioc, corn, beans. – Seu Assis

This statement perhaps best summarizes local perceptions about the performance of common crops on Black Earth and Latosols. However, the above description of the performance of bitter manioc on Black Earth differs considerably from the perceptions of most individuals, who see more disadvantages to planting this crop on Black Earth with respect to Latosols:

> So we planted [banana on Terra Preta], all the time we planted, but it didn't produce, it never produced, no. The plant grew, pretty even, and then when it began to fruit, it produced very small banana. Manioc, same thing. Lots of plant [vegetative growth], it grows a lot, but doesn't produce. Now this, like tomato, bell pepper, lettuce, cabbage...everything does very well. Without need for fertilizer of any type, na? Just itself, if you burn the soil, it produces very well. - Pelado
>
> *Terra Preta* is good for bell pepper, tomato, papaya, cucumber, West Indian gerkin, watermelon. [*Terra Comum*] is good for manioc, banana and pineapple. – Seu Aguinelo

These distinctions are confirmed through crop performance ratings. Table 6 summarizes average informant responses to crop performance ratings in which the performance of select crops on Black Earth and Latosols was rated as good (*da bem*), mediocre (*da um pouco*) and poor (*não da*). The numbers 2, 1 and 0 were used to code these responses, respectively.

**Table 6**. Informant Ratings of Crop Performance on Anthropogenic and Non-Anthropogenic Soils of Central Research Sites

Crops and edibles perceived to grow best on non-anthropogenic soils include banana, bitter manioc and the crops that I have classified as "transitional." On anthropogenic Black Earth, in contrast, grain and vegetable crops are known by locals to grow better, as well as *carirú* (*Phytolacca* sp.), coconut, papaya and star nut palm. These data corroborate descriptive commentaries on differences, yet are more representative of net differences beyond localized differences in perception and soil fertility. Recurring themes include improved performance of bitter manioc, banana and to some extent pineapple on Latosols, and of watermelon, papaya and vegetable crops on Black Earth.

The greater number of crops performing well on Black Earth in relation to Latosols should be interpreted with caution, given that this list of crops is only a subset of the total number of available crops. Yet the tendency for local residents to claim that Black Earth "produces everything" and to exaggerate how Latosols "only produce manioc" suggests that Black Earth is more capable of producing a broader range of culturally important crops. These data are useful for testing verbalized distinctions in crop-soil associations across all informants, for demonstrating differences in cognition between the two environments and for identifying those crop classes from which most benefits are derived through Black Earth cultivation.

More conclusive evidence may be found in actual cropping associations on Black Earth and Latosols. While differences between the ideal (maximizing yields by planting those crops that grow best on each soil class) and the real (actual cropping practices) reflect a number of factors other than soil fertility, data from botanical plots are useful for studying the net outcome of these influences on adaptive behavior.

For this analysis, I focus specifically on those plants that are cropped intentionally. While it is difficult with some species to decipher intentional cropping from voluntary invasion, farmers treat most species with clear distinctions, either planting them, weeding them out or managing them once they invade the swidden. The primary exception is papaya and a few native cultivars that germinate spontaneously in Black Earth swiddens. Where the origin of these species is unclear, I have included a note to this effect. Results of the classification of raw botanical data into categories based on morphological differences in the plants themselves and, to some extent, perceptual distinctions made locally, are presented in Table 7.

**Table 7.** The Relative Representation of Diverse Crop Classes in Latosol and Black Earth Swiddens (expressed as percentages of swiddens, swidden area and individual plants)

Several important patterns emerge here. First, there is a strong association between soil chemical and physical properties and crop choice. Local farmers complain that vegetable crops do not grow well on Latosols and most times produce nothing at all, while Black Earth is favored for these crops. This is most likely due to low soil fertility. Tubers and select fruit trees, on the other hand, often grow better on Latosols. It may be assumed that the selection of Latosols for the planting of fruit trees and tuber crops stems more from the limited availability of Black Earth and the tendency to favor these soils for crops that could not otherwise be grown. Yet local commentary suggests this is due to properties of the soil itself – that fruit trees and root crops often tend to grow better on Latosols. Improved performance of tuber crops on Latosols could be due to the higher sand content on Black Earth – causing the soil to dry rapidly, which may also hinder tuber growth. Yet it is likely that these differences also stem from soil fertility indices, given that bitter manioc tends to undergo a great amount of vegetative growth on Black Earth, thereby compromising tuber growth. The improved performance of native crops on less fertile soils might be explained as a result of domestication processes, in which specific physiological mechanisms were generated that allow these crops to better adapt to nutrient-poor conditions. However, I have yet to see this documented in the literature.

It is also important to note that grain crops are totally absent from Latosol swiddens, where yields are insignificant or absent. While individuals produce a maize crop during the first year after felling a mature forest in certain blackwater regions, maize and beans may only be grown on Black Earth in the study region. According to one local farmer, "If you were to plant a corn plant outside *Terra Preta*, it won't grow." The total absence of grain crops on Latosols indicates that Black Earth is not only desirable for the cultivation of these crops but *necessary*.

Factors other than soil fertility factor into cropping differences. One such factor is crop physiology. Tubers mature, on average, in about a year's time and fruit trees produce for a period of several years, while vegetable crops are often mature after only three month's time. The planting of short-cycle vegetable crops provides an advantage for Black Earth farmers, where colonization of swiddens by invasives generates an increasing disadvantage to the use of this soil with time (and from the moment of the burn). This is demonstrated by the following commentary:

> On *Terra Preta* weeds are more *cerrada* [dense, closed in]. You burn, and in two or three days the weeds are coming up. *Terra Preta* gives more weeds.
> - Aguinelo

This is much less the case for Latosols, where weeds colonize swiddens more slowly and are less dense, particularly when the swidden is cleared from mature forest.

*Fertility Management.* Another behavioral manifestation that differentiates Black Earth and Latosol swiddens is the management of nutrients. I have identified five nutrient management practices in the study site, some of which are much more prevalent than others: the use of the burn, residue management, crop rotation, spatial association and fallow management.

The practice of burning slashed forest or fallow vegetation and crop residues is very common in regional swiddens. Upon felling a primary forest or slashing a young fallow, farmers invariably burn the slashed plant material. A common technique, again aimed at clearing out larger stumps, branches and trees that were unsuccessfully burnt during the first burning event and at enhancing soil fertility, is the *coivara*. In this system, all unburnt material is gathered in piles that are then set on fire. The practice results in patches of soil with higher than average fertility (*covas*) and easier mobility within the swidden. The *coivara* may be carried out on Latosols or Black Earth; however, it is much more common in traditional manioc swiddens (i.e., on Latosols). This may stem from the lesser dependence on the burn on nutrient-rich anthrosols, or the tendency to achieve a more effective burn on Black Earth during the first burning event (due to the younger vegetation that is generally cleared for swiddens). This is an important difference in adaptive behavior, independent of the ultimate motive.

From both ethnopedological data and observations on cultural practices used to manage swiddens, it is evident that the higher fertility of Black Earth makes the burn less critical on these soils. This is evident in the clearing of swiddens from younger fallow, in the tendency to burn Black Earth swiddens in the rainy season (when burning is less intense, and therefore only feasible for opening young fallow), and in local beliefs that Black Earth is distinctive in its inherently "fertilized" state – both in its ability to economize soil amendments and in its tendency to maintain strength after the burn (Table 5). Nevertheless, the burn is always preferred to alternative forms of fertility management in Black Earth swiddens, and might be considered an artifact of strongly ingrained modes of cognition and behavior rather than a manifestation of flexible adaptive processes.

Residue management includes the treatment of weeds, crop residues and slash from early successional vegetation. Most individuals recognize the value of weeding and leaving residues to decompose in situ, yet burn even small amounts of plant material upon clearing, weeding or harvesting a manioc swidden. A few farmers have developed more specialized techniques to manage residues on Black Earth, such as gathering plant residues in small piles or rows and later planting in the decomposing slash. On one large-scale farm where Black Earth has been farmed intensively by a single family for over 40 years, residues are made into compost and applied together with chemical fertilizer. The failure to observe these practices in traditional manioc (Latosol) swiddens may be explained by crop-specific requirements, by the greater need for the burn to liberate nutrients on Latosols or by modified adaptive strategies that seek to maintain higher levels of soil organic matter on Black Earth. These practices are by no means generalized across all Black Earth farmers, however, and should not be considered representative of the population under study. They are more common for individuals with a long history of Black Earth cultivation, and can therefore be understood as incipient (i.e., practices that are adaptive, yet slower to be adopted by the population at large).

Spatial association is another technique that differentiates adaptive processes on Black Earth from those on Latosols, and is also common in traditional agricultural systems (Hecht and Posey 1989; Johnson 1974). I use it to refer to the purposeful association of particular crops with particular zones where these crops grow best to make an efficient use of nutrients throughout the farm. In both Black Earth and Latosol swiddens, individuals fail to recognize innate differences in soil quality or strength as they move through the swidden. One possible exception involves a low-lying area (footslope) that was selected for a fruit garden. Individuals do, however, recognize differences in burning effectiveness and even in crop performance, although these differences are always associated with the burn rather than as properties of the soil itself. Associations between particular crops and *covas* (the nutrient-rich patches resulting from the *coivara*) are carried out on both Black Earth and Latosols. However, the crops chosen for these patches differ by soil class. On Latosols, yam, banana and sweet potato are invariably selected for these patches. On Black Earth, yam may also be planted, yet where West Indian gerkin, watermelon or other vegetable crops are planted, the crops selected for these patches are not differentiated from the rest of the swidden. The difference in derived benefits therefore becomes one of yield rather than a more varied diet. The only other spatial association I observed involves the matching of certain crops and soil classes, a practice that has already been discussed at length.

Crop rotation or sequential cropping is very common in traditional agricultural systems (Francis 1986; Ramakrishnan 1992), yet less common for shifting cultivation systems where the same crops are often grown on a suitable plot for several consecutive years (Ruthenberg 1980). It is nearly absent in traditional manioc swiddens of the study site. The only practice that resembles rotation in these soils is the planting of more nutrient-demanding species such as yam, sweet potato and banana in the first year of cultivation and eliminating these crops in successive plantings. The lesser importance of crop rotation perhaps stems from the fact that so few crops grow well on these infertile soils, particularly in areas receiving no special treatment other than the initial burn.

Sequential cropping on Black Earth is also limited; however, one farmer with a great deal of experience farming Black Earth swears by the practice. "Manioc tires the soil," he states. "After planting maize and beans, which may be planted together, then it is possible to plant manioc again." This farmer claims he is able to extend the utility of his swiddens well beyond that of his neighbors through crop rotation. Other commentaries attest to the extended utility of a swidden when using crop rotation:

> There are people that think that *Terra Preta* becomes weakened, but really she is weakened only for one thing, but remains strong for another. – Rosa
>
> Manioc tires the soil. A neighbor of mine planted only manioc [on *Terra Preta*] and complains that it doesn't produce as it used to. It tired. I said to him, "That is not the way it's done. You have to go slowly. Plant manioc, and afterwards another crop, like that." – Waldecir

This nutrient management practice is again isolated to a few individuals, serving to differentiate adaptive processes on Black Earth and Latosols for more experienced Black Earth farmers. The incipient use of alternative fertility management practices on Black Earth suggests that adaptation to Black Earth environments is an ongoing process, and that predominant use patterns are failing to achieve desired results associated with site sustainability. Black Earth farmers continue to devise complex strategies – "soft technologies," as it were (Hecht and Posey 1989) – to adapt to an environment that is itself changing through historical process. These ongoing changes in environment represent a strong challenge to human adaptability.

With the exception of strong associations between specific crops and the soil classes where these grow best, fallowing is perhaps the most widespread and significant nutrient management practice. The management of fallow also strongly differentiates adaptive behavior on Black Earth and Latosols. I use the term "fallow management" to refer to the cyclical practice of clearing, planting and abandoning (with or without subsequent harvesting) fallow in agricultural plots.

Differences in adaptive strategies between anthropogenic Black Earth and adjacent ecosystems may be deciphered through the comparison of select parameters that have frequently been employed to characterize these systems. These include identification of distinct phases in the swidden fallow cycle and the vegetation, soil fertility and duration of each phase (Jordan 1985b, 1989; Kass and Somarriba 1999).

Data on total time in production, age of cleared fallow vegetation and percentage of swiddens cleared from primary forest were collected for each class of swiddens and are presented in Table 8. It is evident from these data that individuals manage cultivation and fallow cycles differently for each soil class. First, the length of the production cycle on Black Earth is less than one-third that of Latosols. When excluding the practices of a farmer who mined a swidden intensively for six years straight (a strong outlier), these differences increase to a magnitude of 6:1. The maxima and minima reflect this same distinction. Second, the age of cleared fallow vegetation is only about 2 ½ times greater on Latosols, a figure that would be much higher if mature forest were included in the calculation.

**Table 8.** Fallow Dynamics Contrasted for Black Earth and Latosol Swiddens

While maximum fallow age varies by only 50% (10 vs. 15 years), the ratio of minimum fallow age for Black Earth:Latosol is much higher (1:32). This would suggest that farmers have much more control over the minimum fallow age for clearing a swidden than the maximum. The latter tends to reflect available resources rather than choice, given that mature forest is often limited in availability (due to distance or absolute quantities). The stronger dependence on the burn to liberate nutrients in Latosol swiddens would indicate a high demand for older fallow on these soils. While the higher percentage of swiddens cleared from mature forest on Latosols supports this idea, it also reflects the limited availability of mature forest on Black Earth. The higher demand on Latosols is, however, supported by local commentary suggesting that Black Earth recuperate more quickly than Latosols through fallowing:

> To my knowledge, work on *Terra Preta* is hot, [the soil] is strong. But after she tires a lot, working with her, she becomes weak. But she has the contribution that she recuperates again, understand? . . . It's not a lot of work, she recuperates soon. Just letting the weeds grow a little. All is well, she continues the same way [as before]. And clay, after tiring, there are no conditions [to continue]. Here on the Negro River, when the clay tires, it's very tired.
> – Marinho

> Yellow Soil, with fewer years she is clean [in the understory], but she is less recuperated than *Terra Preta*. – Honorato

> The *Terra Preta* there doesn't tire, no. It's because she is *Preta*. . . . For example, . . . clear a fallow this year. Then, you harvest the manioc, she becomes *cerrado*, because [the weeds] grow quickly on *Terra Preta*. Three years from now, you can slash. She produces the same way as before. You can clear the area, because she produces pretty again. – Luzia

Soil chemical data assist in the interpretation of swidden dynamics and farmer decision-making. By referring back to Figure 2, we see how the soil nutrient stocks in traditional terra firme swiddens begin at a low level in the forested vegetation, increase dramatically with the burn and gradually decrease as a swidden nears abandonment. This graphical representation is only a gross interpretation of soil chemical dynamics due to its failure to differentiate among soil nutrients. Yet it provides a conceptual framework for examining the soils of the study region, for breaking sampled areas down according to production stage and for contrasting the soil nutrient dynamics in Latosol and Black Earth swiddens.

It was impossible to emulate the detail with which Jordan's study was carried out due to the limited one-year duration of my field observations, and the fact that nutrient measurements were only carried out on the soil itself. However, it is possible to intuit important temporal aspects of soil chemistry in these two swidden systems by separating samples by soil class and cultivation stage (forested, burnt, cultivated, abandoned), and by reconstructing soil nutrient stocks throughout the life cycle of the swidden.

Data in Table 9 demonstrate that for each stage of the production cycle, Black Earth swiddens are consistently higher in soil nutrient stocks and pH and lower in toxic aluminum than adjacent Latosols.

**Table 9.** Fertility Indices for Diverse Phases of the Production Cycle on Black Earth and Latosols

This difference in soil fertility appears to have a strong influence on local perceptual and behavioral orientations toward the two environments. Not only is Black Earth more fertile before the burn, but also immediately following the burn – despite the lesser contribution of standing stocks of nutrients to post-burn fertility when the younger vegetation is cleared. This data suggests that the minimum age of vegetation for the swidden to produce a healthy crop and for soil organic matter to reach equilibrium (see Ramakrishnan and Toky 1981) is higher on Latosols. According to local estimations and the literature (Ruthenberg 1980), this minimum age is approximately 10 years for Latosols:

> Here on the Negro River, when the clay tires, it's very tired. For it to contribute to improvement in the soil, . . . much times goes by. The fallow vegetation has to be 10, 20 years old . . . and on *Terra Preta*, the most is with one year, two years, she is good again, since the weeds grow quickly. – Marinho

> Manioc, at least in [Latosols] . . . reaches a year. Then we harvest but we don't [throw] fire on the soil anymore; but she produces. In the third year, she still produces. In the fourth year she doesn't produce. . . . You must give it a period

> of two or three years. Now for the manioc to do *well*, you need a fallow of some ten years. – Marinho

One might question whether the biomass on Black Earth would be comparable to ten-year fallow vegetation on Latosols. Although Black Earth vegetation "closes in" more quickly in early successional stages, locals observe a much slower increase in biomass as succession advances on Black Earth. This is evidenced in the comment of a long-time farmer of Black Earth: "On *Terra Preta*, the fallow is slow to 'thicken.'"

The tendency to clear swiddens from young fallow on Black Earth may again stem from the limited availability of mature forest in environments that have been subject to repetitive clearing. Yet a fundamental difference in the chemical "dynamics of Terra Preta" (Pabst 1991) and Latosols also make the shortening of fallow on Black Earth feasible. In any swidden, soil fertility immediately following the burn rests on initial soil stocks and the total amount of nutrients released from burnt vegetation (which in turn rests on the biomass of cleared vegetation and the effectiveness of the burn). On Black Earth, the rapid increase in biomass in early successional stages and heightened levels of soil fertility throughout the swidden cycle together tend to counteract the effects of a shortened fallow cycle. This lesser dependence on the burn to achieve acceptable crop growth holds true despite higher nutrient demands of typical "Black Earth crops." The following statement provides a glimpse of emic understandings of these nutrient dynamics:

> The soil there [Common Soil] has a difference from this one, that she has to be, the swidden has to be well-burnt for us to be able to plant. . . . Here [on Black Earth] you can slash that young fallow vegetation, plant anything and she germinates, and produces. Because *Terra Preta* is strong, stronger than there. This is why I say that it has a strength, a difference of something. – Rosa

This limited dependency on the burn appears to contradict evidence that potassium may be a limiting nutrient in some Black Earth swiddens. This nutrient plays a central role in crop growth due to high rates of consumption by plants (see van Raij 1991), yet Black Earth sites of the study region were shown to have limited soil potassium stocks. According to researchers at EMBRAPA, most crops require a minimum of 40 mg·dm$^{-3}$ of potassium, a level reached only in the upper 10 centimeters of recently-burnt and cultivated Black Earth soils (Table 9). At the time of abandonment, potassium stocks in Black Earth are only 53% of this declared minimum. Informant accounts of the poor performance of certain crops upon fruiting (when the highly mobile potassium reserves are translocated to new fruits, van Raij 1991), despite excellent stem and leaf growth, further corroborate this limiting role played by potassium. Complaints about fruiting were common for squash, West Indian gerkin and papaya, crops for which intentional planting in areas of high fertility is common.

Higher nutrient stocks in forested and abandoned Black Earth sites, the younger age of fallow vegetation cleared for Black Earth swiddens and local understandings of the taxa *Terra Preta* and *Terra Comum* each support the conclusion that relative to Latosols, Black Earth contributes much more to post-burn soil fertility than the liberation of nutrients from standing stocks. In the case of exchangeable potassium, the burn is likely to play an important role in pushing soils over a critical threshold for the preferred nutrient-demanding crops. This is particularly likely given the rapid accumulation of potassium in early secondary vegetation (Norman 1979) and the possibilities for potassium levels to increase severalfold through the burn (Sanchez 1977; Nye and Greenland 1960).

Additional evidence that soil fertility decline is an important factor in swidden abandonment for both Black Earth and Latosols comes from qualitative observations. Farmers almost unanimously state that they abandon Latosol swiddens when the soil "tires," and often complain about declining crop yields just prior to abandonment. Yet a comparison of Black Earth and Latosol cultivation strategies indicates this fertility decline to be relative and crop-specific. A closer look at swidden dynamics shows us that distinctions in cultivation and fallow dynamics on Black Earth and Latosols have several important causes and implications in addition to soil fertility.

Data on the fallow cycle indicate that the rate of cultivation, abandonment and re-clearing on Black Earth is significantly higher than for Latosol swiddens. Furthermore, the cycle occurs at higher levels of soil fertility on Black Earth, as indicated by soil chemical data at diverse stages of the swidden. Explanations for this are several. First, there is a tendency to restrict re-planting on Black Earth to nutrient-demanding "Black Earth crops." While Latosols are cultivated until yields of the least demanding crop (bitter manioc) show a sharp decline, bitter manioc is not a crop that warrants an extension of the cultivation period on Black Earth. When the more nutrient-demanding grain and vegetable crops decline in yields, Black Earth is abandoned. This in effect puts a limit on the level to which soil nutrient stocks may drop, and maintains soil fertility at a higher level than on Latosols.

There are several reasons for this difference. First, the faster invasion of weeds on Black Earth makes the cultivation of short-cycle crops more viable, and corroborates findings that weed control plays an important role in swidden abandonment. The labor required to extend the cultivation cycle on Black Earth contrasts sharply with the relative ease with which new Black Earth swiddens may be brought into production. This is because the particular combination of high soil fertility and rapid successional processes on Black Earth make areas of young fallow viable for agriculture. The effort required to clear the minimum 10-year fallow on Latosols is much greater than that required to clear young fallow on Black Earth, since the slashing of undergrowth is sufficient to clear the latter while slashing and felling are both required to clear Latosol swiddens. Together, these factors cause the cost-benefit assessment to more quickly switch in favor of swidden abandonment on Black Earth.

In summary, cropping duration depends on a number of factors, including soil fertility, the particular crops to be planted (exerting an influence through their growth cycle and nutrient requirements) and the colonization of invasive species (which influences both labor inputs and the speed at which adjacent sites recuperate). Fallow duration, on the other hand, depends on levels of soil depletion upon abandonment, the rate at which site biomass is recuperated, the availability and accessibility of primary forest, labor limitations and the crops to be planted upon clearing. Each highlights important feedbacks between behavioral and biophysical processes.

The swidden cycle is conditioned both by design (cultural practices and preferences) and the natural dynamic of fallow vegetation on each soil, each of which impact swidden management. Herein lies an interesting distinction, in that the increased rate of the swidden cycle on Black Earth represents a truly systemic difference – grounded not only in farmer choice, but in the dynamics of the environment itself, and in the mutual influence of these factors. Important implications of these management systems include faster expansion of agriculture into surrounding forest on Latosols (due to the long recuperation time required of fallow), and the maintenance of higher fertility indices on Black Earth. The continued ability to clear swiddens from areas of young fallow on Black Earth despite the tendency to plant nutrient-demanding crops could result, in part, from management practices that in effect keep soil nutrient stocks at higher levels in Black Earth swiddens. This complexity in human adaptive processes and the dynamic feedback between behavioral and biophysical processes offers important insights into the range of factors that jointly influence human adaptation and human-environmental interactions on the terra firme.

It is important to note that while within-field fertility is managed through a number of cultural practices, there are no significant off-site inputs of nutrients. This situation presumably differs a great deal from the practices leading to Black Earth formation, which require significant nutrient inputs from the surrounding environment in conjunction with intensive and/or sustained burning (Glaser et al. 2001; McCann et al. 2000; Woods and McCann 1999). Black Earth farmers themselves attest to the impossibility of creating Black Earth, as evident in the common expression, "*Se a Terra Preta fosse feito pelo homem, tudo mundo fazia*" ("If *Terra Preta* were made by man, everyone would be making it"). Others have noted that contemporary occupations of caboclos fail to produce significant deposits of Black Earth even after more than 50 years of continuous occupation (Heckenberger et al. 1999).

Despite these perceptions, we know that Black Earth is anthropogenic. This disjuncture may be partially attributed to a lack of knowledge of Black Earth formation processes, a hypothesis that is supported by the above statements and the fact that individuals still have much to learn about managing these soils sustainably. Yet an equally plausible interpretation is the absence of historical conditions (settlement patterns and density, political economic setting, etc.) that once made formation of Black Earth feasible. As such, contemporary fertility management practices are limited to soil maintenance, and possibly as well to novel trajectories in pedological evolution.

*Labor Considerations and Time Allocation*. In addition to the influence of cost-benefit assessments on the fallow cycle, important differences may be found in the overall importance given to productive activities in each environment and the actual time allocated to each. Tropical agriculture is characterized by low labor productivity, causing farm labor to be the most critical farming input to most systems (Ruthenberg 1980). While Black Earth represents an important resource for some farmers, others fail to cultivate these soils or do so only seasonally, and all farmers recognize limitations associated with the cultivation of *each* soil class. Should these concerns and limitations prove to be different for each cultivation system, the resulting patterns in labor allocation are also likely to be different.

Computations of the average number of hours allocated to distinct activities on a monthly basis (across all informants and homesteads) point to patterns that we would expect for traditional economic activities in the region – i.e., high labor investments in Latosol cultivation and fishing (Table 10). The limited time dedicated to hunting is an exception, and likely results from drastically diminished game populations resulting from over-hunting in recent decades. This has caused many families in the Lower Negro region to abandon this traditional economic activity altogether. These data also demonstrate that families are willing to dedicate as much time to Black Earth cultivation as to any other economic activity.

**Table 10.** Net Monthly Hours Allocated to Diverse Economic Activities

To determine how the presence of anthropogenic Black Earth influences family labor allocation to agricultural activities, I divided collaborators into two categories: those farming Black Earth (with or without additional swiddens on Latosols) and those farming Latosols alone. This permits an assessment of the influence of Black Earth cultivation on time allocation criteria, and on the allocation of valuable time and energy. Results of this activity are plotted in Graph 3.

**Graph 3.** Percentage of Time Allocated to Agricultural Activities by Black Earth Farmers (who may or may not maintain Latosol swiddens, as well) and Latosol-Only Cultivators

It is important first to note that the uppermost curves (clear triangles, solid squares), representing time allocated to Black Earth (by farmers with access to both soils) and Latosols (by individuals who have access to Latosols alone), show similar peaks of activity. This suggests that these activities are not complementary with respect to temporal demands placed on farm labor.

While Black Earth may be cultivated year-round, the favored season is during the rainy months when market prices for exotic vegetable crops are higher. This is because fertile floodplain soils of whitewater regions are inundated during this season, causing seasonal shortages and price increases that provide incentives for Black Earth farming despite high incidence of pests and disease during this season. The near-overlap of curves in the time allocated to each activity indicates that this peak in Black Earth activity compromises rather than complements other important subsistence activities. In theory, this should limit adaptability to Black Earth, given the cultural and historical importance of manioc cultivation in sustaining regional populations (Boster 1983; Carneiro 1985; Clark and Uhl 1987). In fact, what occurs is the opposite, pointing to the high importance of Black Earth in these integrated production systems. It may also highlight a certain redundancy in the role of Black Earth and Latosol production during this season – namely, the sale of crops and crop derivatives (manioc flour vs. market-oriented vegetable crops) for family income.

Another striking pattern is the near symmetry in curves contrasting both 1) the time allocated to Black Earth with that allocated to Latosols by Black Earth farmers (solid and clear squares), and 2) the time allocated by each class of farmers to Latosol cultivation (clear squares, clear triangles). Each of these patterns seems to contradict expectations on subsistence priorities. Farmers have made a conscious decision to focus household activities on Black Earth over the cultivation of Latosols, or to neglect management activities on Latosols during periods of high activity on Black Earth. In effect, practices that "domesticate" novel anthropogenic environments partially substitute traditional modes of subsistence, as also evidenced in the percentage of land dedicated to traditional manioc cultivation practices by Black Earth and Latosol-only farmers (Table 11). These trends may be understood by the fact that time allocation tends to be a zero-sum game in which trade-offs must be made, and/or by other perceived benefits of Black Earth cultivation relative to traditional farming activities.

**Table 11.** Land Dedicated to Traditional Manioc Farming by Black Earth (BE) and Latosol-Only (LAT) Farmers (based on annual figures)

The ability to cultivate bitter manioc in conjunction with exotics on Black Earth despite the apparent decrease in productivity of this staple may reduce the influence of labor constraints on the complementarity of tradition (i.e., a manioc-based diet) and market-based cultivation practices (which target non-traditional crops). Yet this ability to intercrop does not fully compensate for lost manioc yields, as evidenced in the area figures of Table 11. Furthermore, the cultivation of bitter manioc on Black Earth has further constraints, as indicated by local commentary:

> I don't have much knowledge of many *Terras Pretas*, but this one there, I have worked a long time on her, but manioc doesn't "have conditions" because it requires a lot of labor. I was saying today, it takes three, four weedings for you to harvest some manioc . . . Vegetables, if they were with 90 days, you harvest all of it. And vegetables, you work in a small area. Not with manioc. Manioc must be a large area. Vegetables no, in a half-day, you weed it all. – Pelado

> Manioc produces on *Terra Preta*, it doesn't keep from producing, but it's very work-intensive. – Aguinelo

These comments illustrate the difficulty of cultivating traditional root crops on Black Earth, where labor demands are great due to the faster increase in weed invasion with time. The greater abundance of bitter manioc in Latosol swiddens (Table 12) further supports this influence of crop performance and labor constraints on farmer perceptions.

**Table 12.** The Abundance of Bitter Manioc in Black Earth and Latosol Swiddens

While the cultivation of other culturally- or economically-important crops on Black Earth justifies intercropping with bitter manioc, opening a Black Earth swidden for manioc alone does not. This is confirmed by the paucity of Black Earth swiddens cleared solely for manioc and other traditional cultivars. Reasons for this difference presumably include the labor invested in clearing a swidden, which is kept to a minimum when only one swidden is cleared (i.e., on one soil class) rather than one on each soil class.[4] This is evident in the fact that only one of the 43 Black Earth swiddens (2.3 %) observed over a one-year period had manioc present without other characteristic Black Earth crops.

Furthermore, the soil in this swidden was a transitional soil resembling non-anthropogenic soils more than Black Earth. This status was confirmed by low plant-available phosphorus in the swidden relative to other, more "legitimate" Black Earth sites (0.5 to 12 $mg \cdot dm^{-3}$ with depth).

## DISCUSSION

The data clearly demonstrate that former anthropogenic modifications of the environment condition adaptive process. This confirms the role of environmental structure, function and dynamics in human adaptation, yet the mere existence of Black Earth suggests that the environment is neither static, nor modifiable only temporarily until reverting back to steady-state conditions. Minimally within human scales of reference, anthropogenic Black Earth should be seen as an example of human behavior having profound and lasting impacts on the environment.

In line with recent work in historical ecology, findings confirm the limitations of many earlier conceptualizations of environment, of culture, and of the nature of human-environmental interactions. In contrast with ahistorical approaches to environment in earlier Amazonian scholarship, it is evident that we must acknowledge the dynamic, the historical and the "cultural" in nature. Secondly, our ideas of culture itself change in recognition of ecological praxis. Rather than directly assimilate environmental absolutes into adaptive behavior, humans transform the environment itself and respond to the environmental artifacts of past societies. While humans are not always capable of re-creating environmental modifications produced by past societies, they continue to influence the environment in ways that reflect the historical milieu in which they act. Modified cognitive frameworks and incipient changes in fertility management suggest that as the environment goes through these continual changes, dynamic human responses are the norm.

This situation calls us to question the idea of adaptation itself. Given evidence that the relationship between nature and culture is interactional rather than unidirectional, dialectical and synergistic rather than deterministic, historical as well as evolutionary, conventional treatment of human adaptation in isolation from other, more complex human-environmental

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[4] Of eight Black Earth farmers, five nonetheless clear separate swiddens on Latosols to plant manioc, presumably to increase yields and decrease labor inputs to the cultivation of traditional staple crops.

manifestations is obsolete. The concept of adaptation is important in highlighting the tendency of humans to adjust environmental usage to the properties of the environment – as derived from both historical and evolutionary processes. Yet it is limited for acknowledging the ongoing impacts of these behavioral adjustments on the biophysical environment itself, as well as the synergy between human behavior and environment. While I disagree with the postulate that history determines all, historical ecology is a most useful framework for positing understandings of human-environmental interaction that are less biased towards nature and that acknowledge the true interpenetration of environment and livelihood.

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**Table 1.** Comparative Research Framework for Central Research Sites

| Family | Latosol Cultivation | Black Earth Cultivation | No. Swiddens (Latosol/BE) |
|---|---|---|---|
| 1 | Yes | Yes | 1/4 |
| 2 | Yes | (Yes) | 3/9 |
| 3 | No | Yes | 0/7 |
| 4 | No | Yes | 0/1 |
| 5 | Yes | No | 3/0 |
| 6 | Yes | No | 3/0 |
| 7 | Yes | No | 4/0 |
| 8 | Yes | No | 1/0 |
| 9 | No | Yes | 0/2 |
| 10 | No | Yes | 0/7 |
| 11 | Yes | Yes | 2/11 |
| 12 | Yes | Yes | 3/3 |
| ***Total:*** | **8** | **8** | **20/44** |

**Table 2.** Summary of Research Methods

A. Characterizing the Anthropogenic Environment

- Local identification of Black Earth sites

- Composite soil samples on Black Earth and Latosols

- Fertility experiment with *Zea mays*

B. Identifying Specific Adaptive Responses to the Modified Environment

- Comparative study between Black Earth and Latosol cultivation systems

Cognitive Data:
- Semi-structured interviews
- Elicitation of soil classification systems
- Frame interviews to target ethnopedological understandings
- Crop performance ratings

Behavioral Data:
- Participant observation of cultural practices
- Botanical plots
- Ground surveys
- Composite sampling at different stages of the swidden cycle
- Time allocation study

**Table 3.** Laboratory Results of Soil Fertility Analyses on Black Earth, Non-Anthropogenic and Transitional Soils of the Study Region

| Soil Type | Depth (cm) | pH, $H_2O$ | $Ca^{++}$ $(cmol_c \cdot dm^{-3})$ | $K^{+}$ $(mg \cdot dm^{-3})$ | $Mg^{++}$ $(cmol_c \cdot dm^{-3})$ | $Na^{+}$ $(mg \cdot dm^{-3})$ | Avail. P $(mg \cdot dm^{-3})$ | $Al^{+++}$ $(cmol_c \cdot dm^{-3})$ |
|---|---|---|---|---|---|---|---|---|
| **Latosols** | 0-10 | 4.02 | 0.43 | 35.5 | 0.34 | 12.44 | 7.07 | 2.44 |
| | 10-30 | 4.05 | 0.08 | 22.38 | 0.12 | 7.69 | 3.17 | 2.17 |
| **Transitional Soils** | 0-10 | 4.53 | 1.01 | 25.33 | 0.37 | 5.33 | 39.63 | 0.67 |
| | 10-30 | 4.25 | 0.16 | 9.33 | 0.07 | 2.33 | 3.25 | 1.35 |
| **Black Earth** | 0-10 | 5.26 | 5.21 | 41.86 | 1.27 | 17.71 | 77.96 | 0.42 |
| | 10-30 | 4.74 | 2.39 | 20.86 | 0.42 | 7.29 | 54.58 | 1.12 |

**Table 4.** Feature Representation of Axes 1, 2 and 3 on the Multidimensional Plot

| ***Axis 1*** | | **Axis 2** | | **Axis 3** | |
|---|---|---|---|---|---|
| *Feature of Soil Class* | $r^2$ | *Feature of Soil Class* | $r^2$ | *Feature of Soil Class* | $r^2$ |
| Pest & disease problems | | Raw | 0.979 | Slippery/smooth | 0.934 |
| 0.992 | | Weak when worked | 0.958 | Wild | 0.929 |
| Problems with "strong" eye | 0.985 | Tires quickly | 0.922 | Sticky | 0.917 |
| Labor int. to weed fallowed plot | 0.980 | Variab. in "strength" w/in swidden | 0.898 | Clayey | 0.903 |
| Always fully recuperates w/fallow | 0.980 | --------------- | | Cold | 0.897 |
| Labor intensive to weed | 0.977 | Necessary to use the burn | 0.829 | Sticks | 0.853 |
| Maintains "strength" after burn | 0.956 | Deep | 0.821 | --------------- | |
| Night's dew moistens soil | 0.956 | Natural (of nature) | 0.809 | Hard | 0.823 |
| Dries quickly | 0.955 | Weak | 0.806 | | |
| Economizes soil amendments | 0.946 | | | | |
| Can burn during the rainy season | 0.923 | | | | |
| Weeds up ("closes") quickly | 0.922 | | | | |
| Produces in a raw state | 0.904 | | | | |
| Labor-intensive to slash | 0.885 | | | | |
| Grows crops quickly | 0.885 | | | | |
| Fertilized | 0.879 | | | | |
| Soft | 0.858 | | | | |
| Shallow | 0.854 | | | | |
| --------------- | | | | | |

[a] I have included an arbitrary cut-off line at 0.850. Those features falling above this line under each axis are better represented ($r^2 > 0.850$) by the axis than those features falling below this line.

**Table 5.** Informant Ratings of Crop Performance on Anthropogenic and Non-Anthropogenic Soils of Central Research Sites

| | **Terra Preta** | | **Terra Comum** | |
|---|---|---|---|---|
| Crop | (Mean) | (St. Dev.) | (Mean) | (St. Dev.) |
| ***Black Earth Crops*** | | | | |
| Bell Pepper | 2.00 | 0.00 | 0.32 | 0.64 |
| Cariru [a] | 2.00 | 0.00 | 0.20 | 0.42 |
| Coconut | 2.00 | 0.00 | 0.55 | 0.69 |
| Cucumber | 2.00 | 0.00 | 0.50 | 0.67 |
| Maize | 2.00 | 0.00 | 0.29 | 0.62 |
| Okra | 2.00 | 0.00 | 0.35 | 0.67 |
| Onion | 1.64 | 0.67 | 0.40 | 0.66 |
| Papaya | 2.00 | 0.00 | 0.50 | 0.80 |
| Red Bean | 2.00 | 0.00 | 0.38 | 0.64 |
| Squash | 1.92 | 0.29 | 0.50 | 0.67 |
| Sweet Pepper | 2.00 | 0.00 | 0.50 | 0.81 |
| Tomato | 2.00 | 0.00 | 0.10 | 0.32 |
| Watermelon | 1.90 | 0.32 | 0.22 | 0.36 |
| West Indian Gerkin | 2.00 | 0.00 | 0.88 | 0.80 |
| ***Latosol Crops*** | | | | |
| Banana | 0.42 | 0.67 | 1.41 | 0.70 |
| Bitter Manioc | 0.75 | 0.87 | 1.88 | 0.31 |
| ***Transitional Crops*** | | | | |
| Lemon | 1.42 | 0.90 | 1.42 | 0.79 |
| Pineapple | 1.45 | 0.82 | 1.71 | 0.62 |
| Star Nut Palm [a] | 1.83 | 0.39 | 1.92 | 0.29 |
| Sugar Cane | 1.50 | 0.80 | 1.13 | 0.88 |
| Sweet Manioc | 1.33 | 0.65 | 1.55 | 0.79 |
| Yam | 1.50 | 0.80 | 1.88 | 0.31 |
| | ***Avg. Mean*** | ***Avg. S.D.*** | ***Avg. Mean*** | ***Avg. S.D.*** |
| | 1.72 | 0.37 | 0.82 | 0.19 |

[a] These species are voluntary edibles rather than intentionally-planted domesticates.

**Table 6.** The Relative Representation of Diverse Crop Classes in Latosol and Black Earth Swiddens (expressed as percentages of swiddens, swidden area and individual plants)

| *Crop Class:* | % of Black Earth Swiddens with Presence of Each Crop Class | % of Latosol Swiddens with Presence of Each Crop Class | % of Area with the Presence of Crop X on Black Earth | % of Area with the Presence of Crop X on Latosols |
|---|---|---|---|---|
| **Vegetable Crops** | 28.19 | 4.39 | 74.43 | 9.25 |
| **Fruit Trees** | 5.91 | 23.77 | 20.20 | 58.89 |
| **Tuber Crops** | 12.32 | 36.69 | 42.74 | 100.00 |
| **Edible Graminea** | 0.57 | 3.93 | 1.83 | 8.43 |
| **Grain Crops** | 11.70 | 0.00 | 51.77 | 0.00 |
| **Non-Edible Utilitarian Spp.** | 3.29 | 5.99 | 15.96 | 38.84 |
| **Voluntary Edibles** | 38.02 | 25.23 | 91.28 | 85.31 |
| **Bitter Manioc** | 7.67 | 28.59 | 36.81 | 98.38 |

| *Crop Class:* | % of Individuals of Each Crop Class on Black Earth (% total plants) | % of Individuals of Each Crop Class on Latosols (% total plants) |
|---|---|---|
| **Vegetable Crops** | 26.18 | 0.66 |
| **Fruit Trees** | 17.86 | 7.43 |
| **Tuber Crops** [a] | 32.74 | 80.03 |
| **Edible Graminea** [b] | 0.53 | 0.55 |
| **Grain Crops** | 11.65 | 0.00 |
| **Non-Edible Utilitarian Spp.** | 0.82 | 1.22 |
| **Voluntary Edibles** | 4.74 | 1.74 |
| **Bitter Manioc** | 30.22 | 77.52 |

[a] Bitter manioc is included in this crop class, yet has been isolated below to indicate the specific role of this culturally-important crop.

[b] Excludes *Zea mays*, which has been classified as a grain crop.

**Table 7.** Fallow Dynamics Contrasted for Black Earth and Latosol Swiddens

| Parameter | Black Earth | Latosol |
|---|---|---|
| | (months) | |
| *Fallow age*: | | |
| Average age of cleared fallow | 51.5 | 131.1 |
| (std. dev.) | 36.7 | 29.8 |
| Maximum age of cleared fallow | 120 | 180 |
| Minimum age of cleared fallow | 3 | 96 |
| *Total Time in Production:* | | |
| Average | 8.7 | 28.7 |
| (std. dev.) | 11.1 | 10.6 |
| Maximum | 60 | 50 |
| Minimum | 1 | 12 |
| Average (outlier removed) | 4.6 | 28.7 |
| % Swiddens Cleared from Primary Forest: | 25.6 | 72.7 |

**Table 8.** Fertility Indices for Diverse Phases of the Production Cycle on Black Earth and Latosols

| **Productive Phase and Soil Type** | **Ca$^{++}$** (mmol$_c$·dm$^{-3}$) | **K$^{+}$** (mg·dm$^{-3}$) | **Mg$^{++}$** (mmol$_c$·dm$^{-3}$) | **Na$^{+}$** (mg·dm$^{-3}$) | **Avail. P** (mg·dm$^{-3}$) | **pH** ($H_2O$) | **Al$^{+++}$** (mmol$_c$·dm$^{-3}$) |
|---|---|---|---|---|---|---|---|
| **Forested** 0-10 | 0.30 | 18.00 | 0.40 | 4.00 | 3.35 | 3.89 | 14.30 |
| **Latosol** 10-30 | 0.10 | 11.00 | 0.30 | 2.50 | 2.18 | 4.01 | 15.90 |
| **Burnt** 0-10 | 0.35 | 39.33 | 0.30 | 11.00 | 5.98 | 4.06 | 2.78 |
| **Latosol** 10-30 | 0.08 | 25.67 | 0.10 | 7.42 | 2.92 | 4.11 | 2.22 |
| **Cultivated** 0-10 | 4.60 | 36.95 | 3.20 | 12.58 | 7.88 | 4.09 | 22.20 |
| **Latosol** 10-30 | 0.90 | 21.70 | 1.10 | 7.60 | 3.38 | 4.07 | 21.00 |
| **Abandoned** 0-10 | 0.90 | 22.50 | 0.80 | 16.00 | 4.77 | 4.13 | 29.20 |
| **Latosol** 10-30 | 0.20 | 12.50 | 0.40 | 12.75 | 2.09 | 4.26 | 20.30 |
| **Old Fallow** 0-10 | 3.81 | 25.80 | 0.81 | 13.60 | 81.94 | 4.79 | 1.07 |
| **Black Earth** 10-30 | 2.74 | 12.20 | 0.35 | 7.90 | 25.21 | 4.79 | 1.41 |
| **Burnt** 0-10 | 6.00 | 53.14 | 1.47 | 15.43 | 105.84 | 5.20 | 0.67 |
| **Black Earth** 10-30 | 3.23 | 25.43 | 0.54 | 8.14 | 123.68 | 4.91 | 1.25 |
| **Cultivated** 0-10 | 48.50 | 43.23 | 12.10 | 17.54 | 94.75 | 5.19 | 4.60 |
| **Black Earth** 10-30 | 21.60 | 21.23 | 3.90 | 7.31 | 56.89 | 4.68 | 11.90 |
| **Abandoned** 0-10 | 56.50 | 30.36 | 12.00 | 16.36 | 118.76 | 5.04 | 4.90 |
| **Black Earth** 10-30 | 37.60 | 16.91 | 5.10 | 9.64 | 47.99 | 4.94 | 8.00 |

**Table 9.** Net Monthly Hours Allocated to Diverse Economic Activities

| Economic Activity | Average Time Allocated (hours/month) |
|---|---|
| Black Earth Cultivation | 16.5 |
| Latosol Cultivation | 15.2 |
| Fishing | 12.3 |
| Carpentry | 10.7 |
| Personal/Communal Activities | 10.7 |
| Timber Extraction/Sale | 7.5 |
| Day Labor | 3.0 |
| Liana Extraction/Processing | 0.7 |
| Ranching (cattle) | 0.5 |
| Charcoal Processing | 0.4 |
| Agriculture, Home Gardens | 0.3 |
| Hunting | 0.2 |
| Livestock (other) | 0.2 |

**Table 10.** Land Dedicated to Traditional Manioc Farming by Black Earth (BE) and Latosol-Only (LAT) Farmers (based on annual figures)

| | **Total Land** (Ha) | **BE Area** (Ha) | **LAT Area** (Ha) | **Area with Manioc** (Ha) | **Area with Manioc** (%) |
|---|---|---|---|---|---|
| **Black Earth Farmers** | 0.98 | 0.64 | 0.34 | 0.50 | 51 |
| **LAT-Only Farmers** | 0.85 | 0.00 | 0.85 | 0.85 | 100 |

**Table 11.** The Abundance of Bitter Manioc in Black Earth and Latosol Swiddens

| **Crop** | **Abundance, Black Earth** | | **Abundance, Latosols** | |
|---|---|---|---|---|
| | % Swiddens | % Plants | % Swiddens | % Plants |
| Bitter Manioc | 41.9 | 30.2 | 92.0 | 77.5 |

**Figure 1.** Distribution of Roots and Nutrient Ions in the Soil of a Typical Amazon Rainforest and a More Nutrient-Rich Forest (from Jordan 1985)

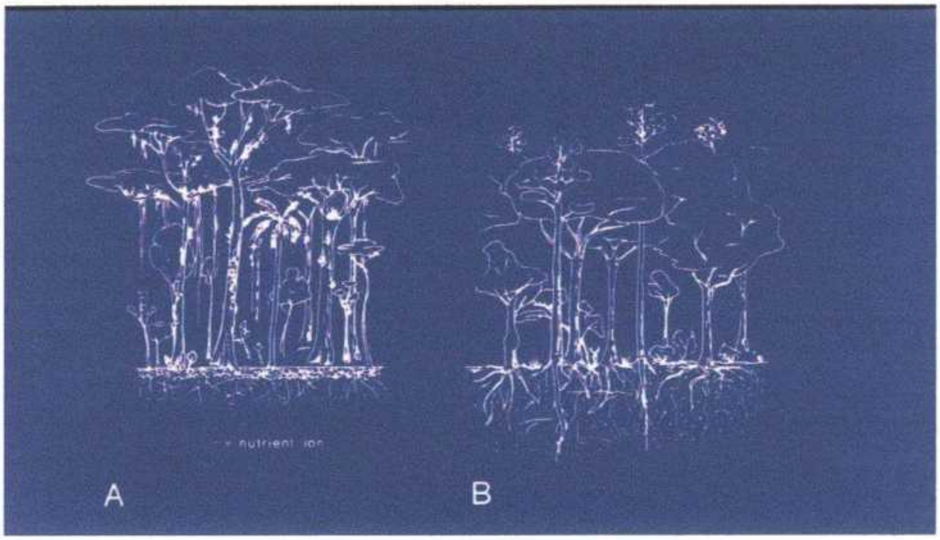
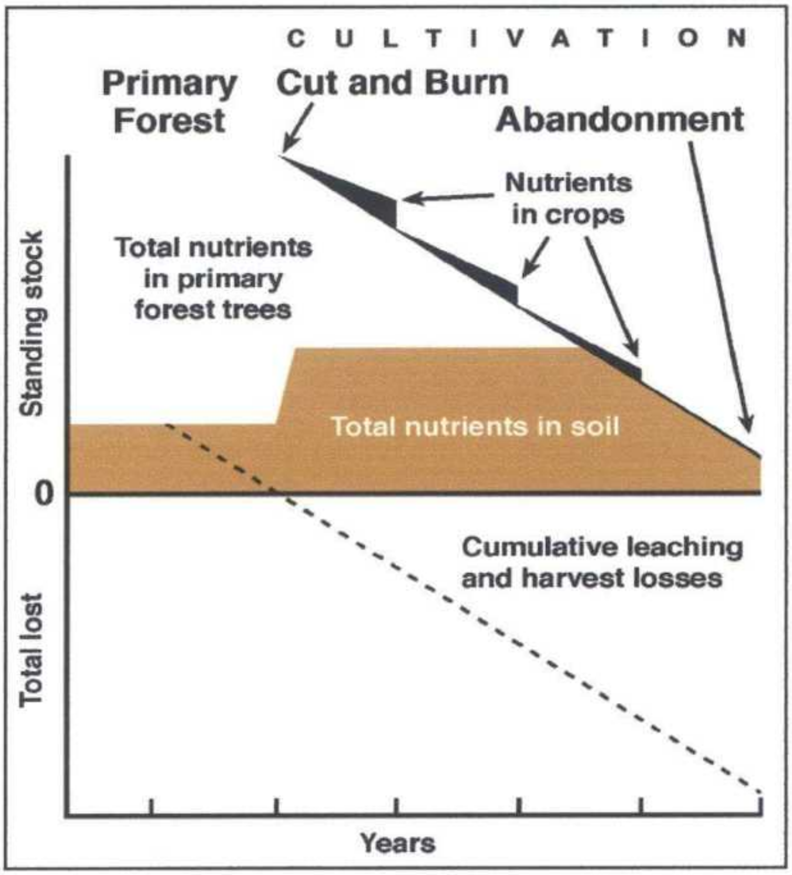
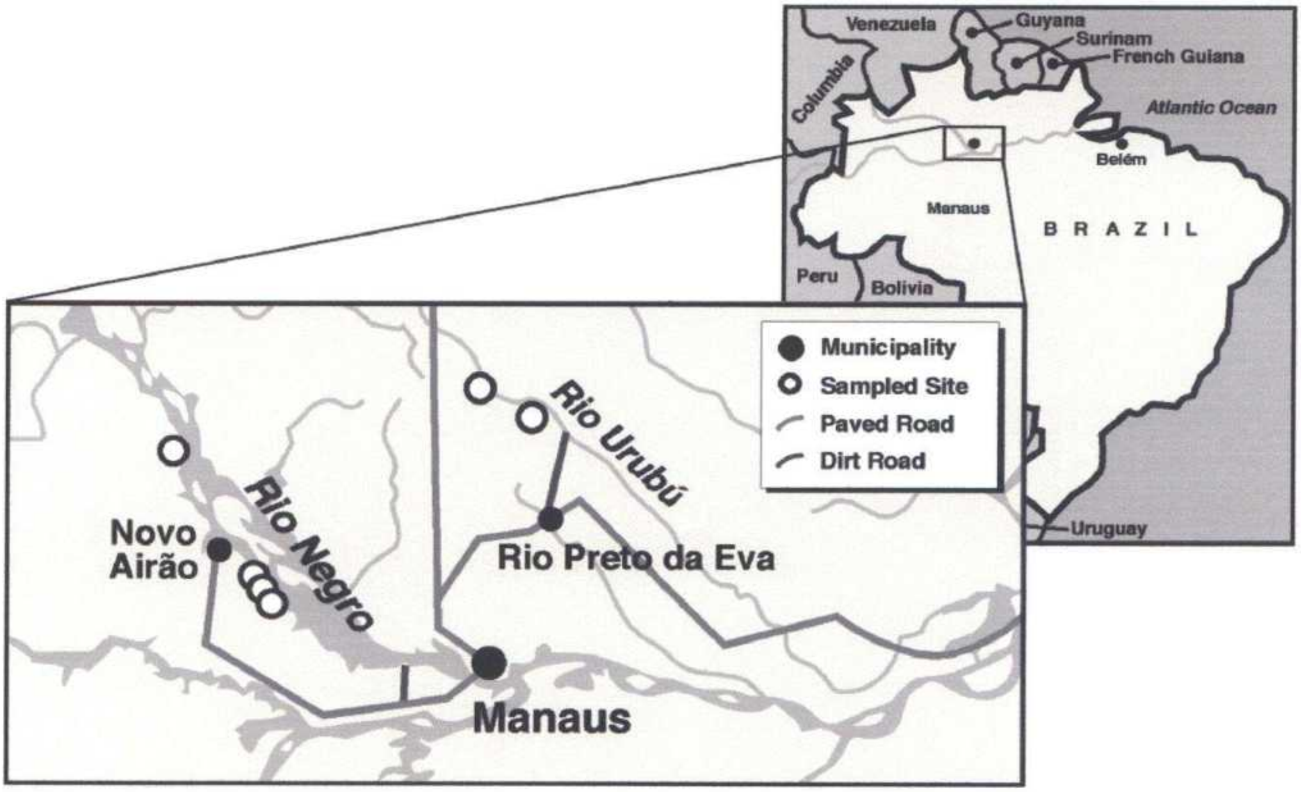


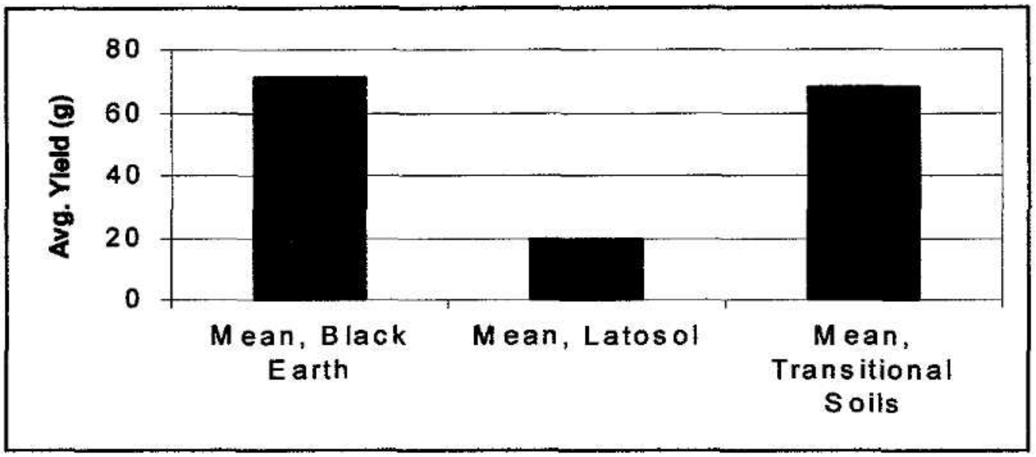
**Figure 2.** Standing Stocks of Nutrients as a Function of Time in a Slash and Burn Plot in the Amazon Basin (above Abscissa) and Cumulative Nutrient Losses from the Soil (below Abscissa). From Jordan 1989.



**Map 1.** Research Sites on the Negro and Urubú Rivers



Graph 1. Maize (Zea mays) Yields As a Function of Soil Type



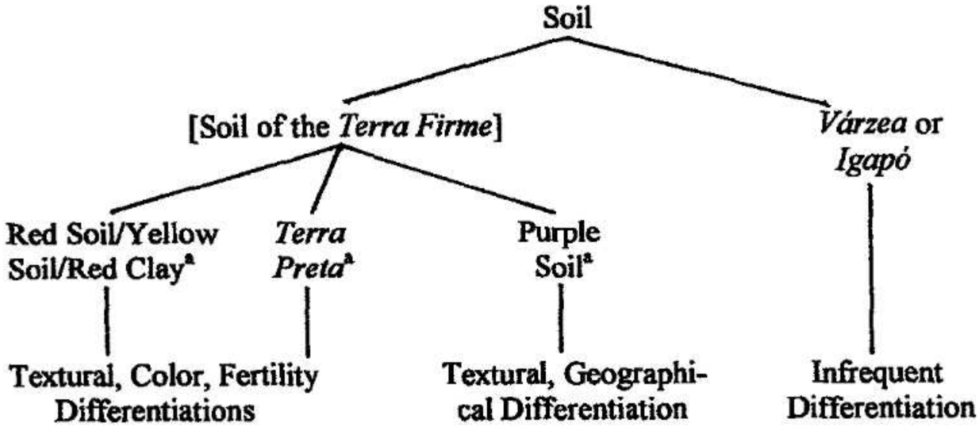


**Figure 3.** Commonalities among Soil Classifications along the Middle Urubú

[a] Folk generic taxa.

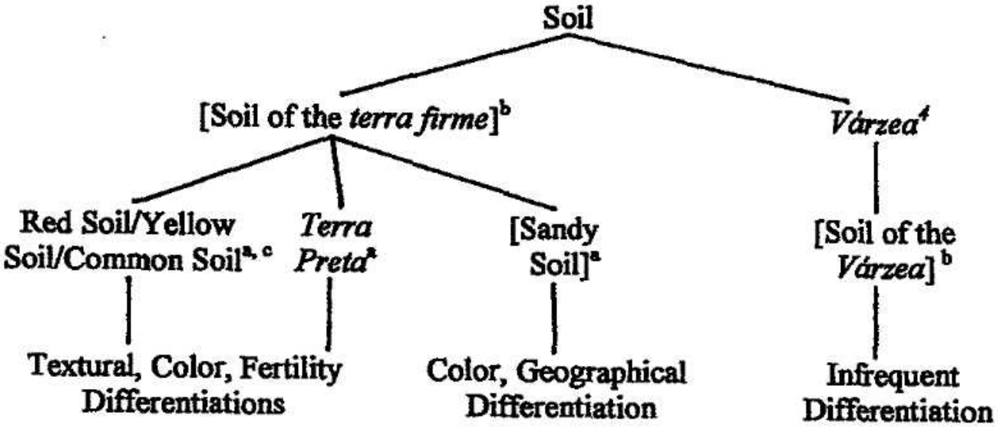


**Figure 4.** Commonalities among Soil Classifications on the Lower Negro

[a] Refers to the most salient, or 'folk generic' (Berlin 1992), taxa.

[b] Bracketed terms represent optional or covert categories.

[c] A variation of this classification system is to substitute Red Clay/Yellow Clay for these taxa, and in contrast to Sandy Soil.

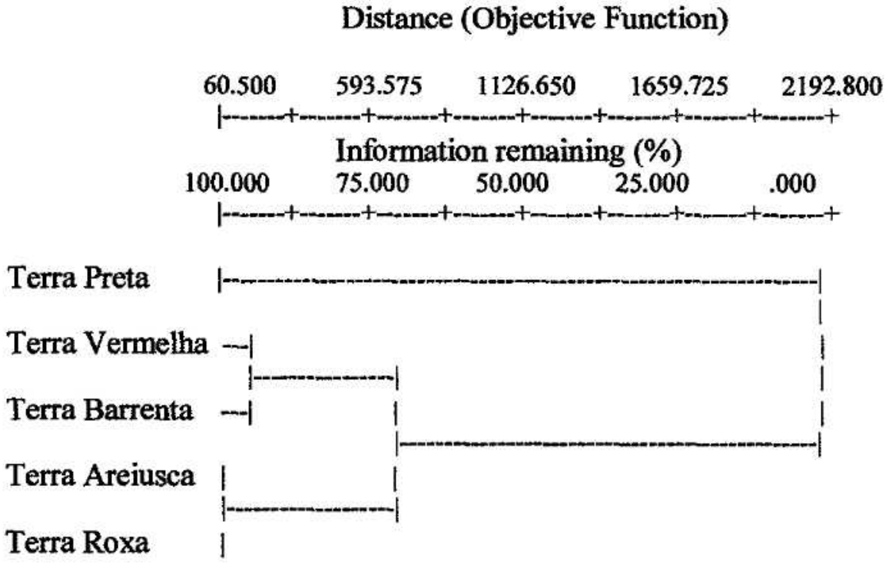
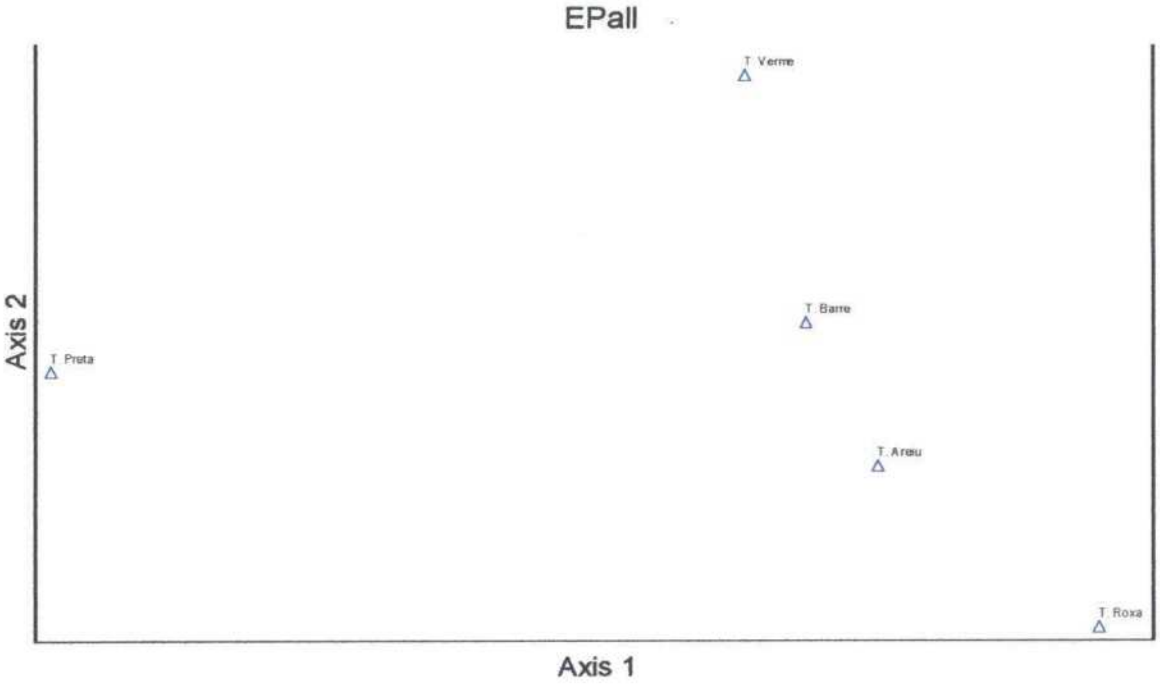
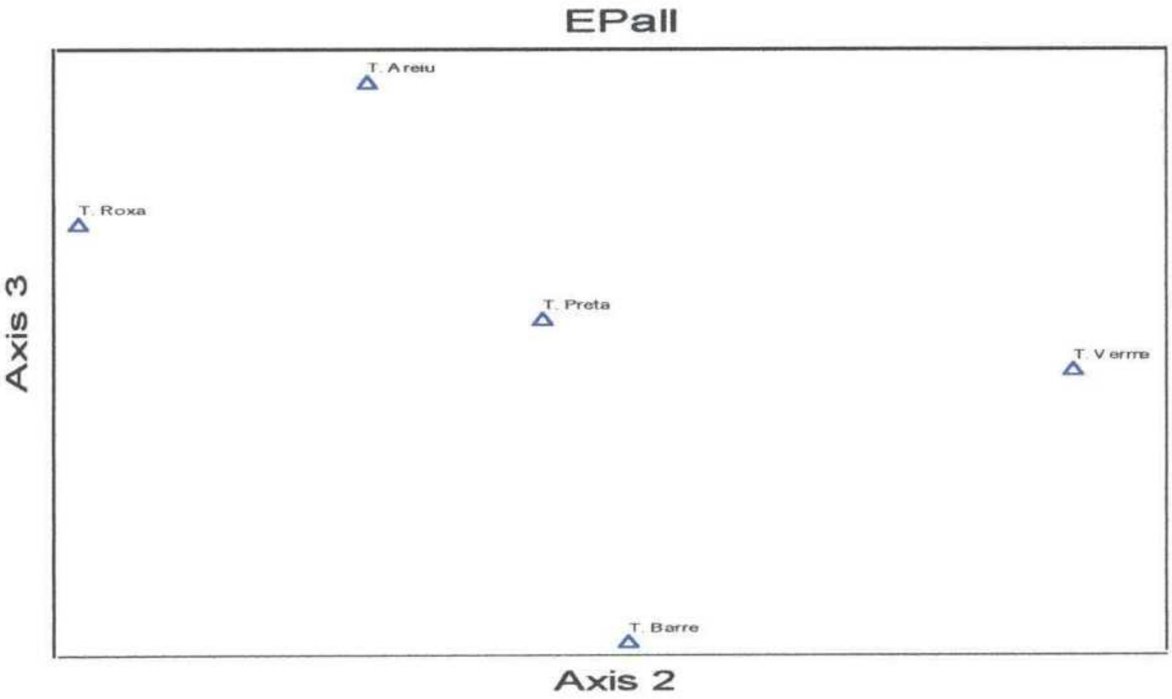


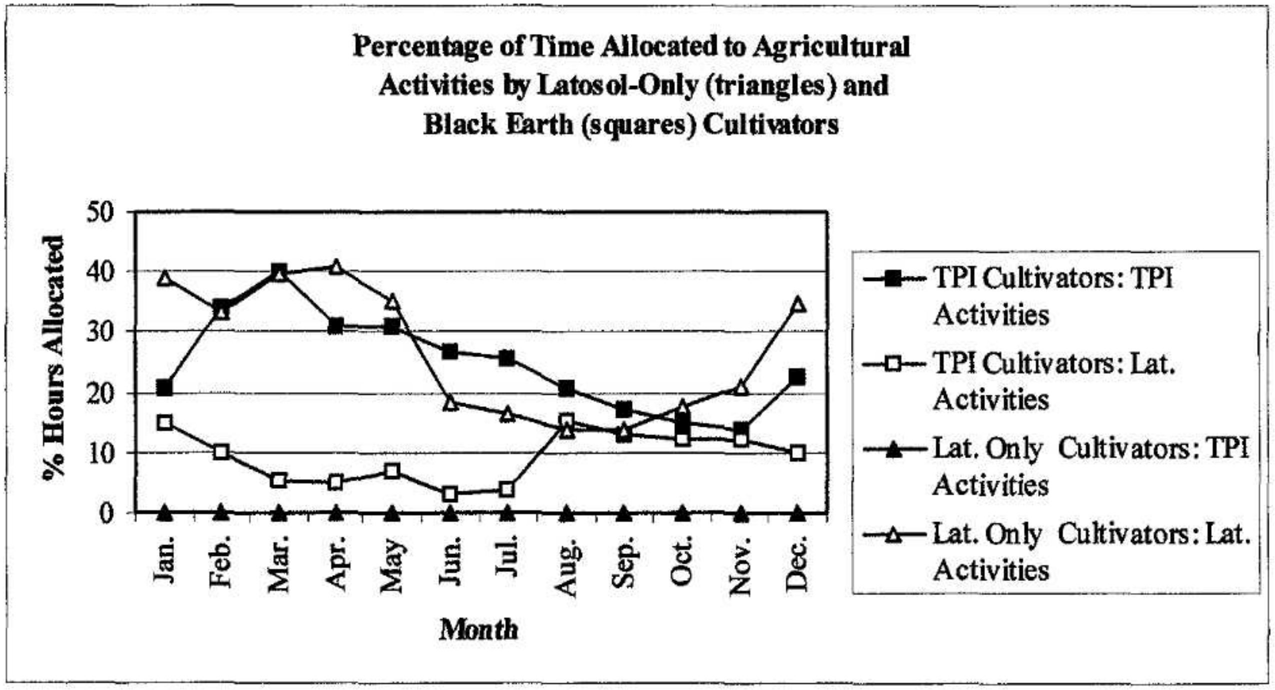
**Figure 5.** Perceptual Similarity of Soil Classes: Results of a Cluster Analysis of Ethnopedological Data



**Graph 2a.** Multidimensional Scaling of Soil Taxa: Axes 1 and 2



**Graph 2b.** Multidimensional Scaling of Soil Taxa: Axes 2 and 3



**Graph 3.** Percentage of Time Allocated to Agricultural Activities by Black Earth Farmers and Latosol-Only Cultivators