LAURA ANNE GERMAN
The Dynamics of *Terra Preta*: An Integrated Study of Human-Environmental Interaction in a Nutrient-Poor Amazonian Ecosystem
(Under the Direction of TED L. GRAGSON)

This research explores human-environmental interactions in a nutrient-poor (oligotrophic) environment, the blackwater ecosystems of Amazonia. I focus in particular on the modifiability of ecosystem properties by traditional groups and the enhancement of subsistence options within these "anthropogenic" landscapes. The co-occurrence of naturally-occurring terra firme soils (Latosols) and Indian Black Earth, a more fertile anthrosol resulting from the semi-permanent settlement of Amerindian groups, provides a unique opportunity for analyzing: 1) the role of anthropogenic modifications of the environment in conditioning human adaptive processes, and 2) the plasticity of human-environmental interactions within nutrient-poor environments.

Two years of cognitive, behavioral and biophysical data collection among *caboclo* families farming both Indian Black Earth and non-anthropogenic Latosols provides the groundwork for the analysis. My inquiry into the role of the anthropogenic environment in conditioning human adaptive processes includes a characterization of the anthropogenic environment and an identification of distinctive adaptive processes resulting from environmental differences. To research the plasticity in human-environmental interaction, I analyzed the degree to which pedology and cultivation systems on Black Earth depart from the "referent" Latosol cultivation system (plasticity as practice and outcome), as well as the factors that constrain and enable this divergence (plasticity as theoretical construct). Both quantitative (soil sampling, botanical quadrants, time allocation studies, frame analysis) and qualitative (soil horizon descriptions, semi-structured interviews, participant observation) methods were employed.

Results show how anthropogenic modifications of the environment condition cognitive, behavioral and biophysical manifestations of adaptive process. This is true for ethnopedological domains, perceptions of productive opportunities and differences, cropping associations, nutrient management activities and fallow dynamics. Secondly, both the ecosystem and associated subsistence manifestations exhibit significant plasticity in distant blackwater environments. While soil fertility varies geographically, average values of exchangeable calcium, available phosphorus and Base Saturation are invariably the most plastic parameters and similar crops may be grown in Black Earth and non-anthropogenic soils in each setting. This suggests that divergent uses result from other, non-biophysical factors. Evidence that Black Earth becomes important as traditional diets change, exotic crops become available and market influences take hold suggest that important historical contingencies (technological, political-economic, cultural) underlie the plasticity of human-environmental interactions. Yet environmental constraints are also evident in the inability of contemporary groups to form Black Earth, in the constraints posed by an oligotrophic environment on intentional or fortuitous soil enhancement and in cultivation-induced soil degradation. The Structuration Model of Human Ecosystems was developed to explicate this ension between ecological praxis and ecosystem constraints in human ecosystems.

INDEX WORDS: Human ecology, *Caboclo,* Amazon, Indian Black Earth, *Terra Preta do Índio*, Rio Negro, Anthrosols, Blackwater ecosystems, Shifting agriculture

THE DYNAMICS OF *TERRA PRETA*:

AN INTEGRATED STUDY OF HUMAN-ENVIRONMENTAL INTERACTION

IN A NUTRIENT-POOR AMAZONIAN ECOSYSTEM

by

LAURA ANNE GERMAN

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LAURA ANNE GERMAN

Approved:

Major Professor: Dr. Ted L. Gragson

Committee: Dr. Ben Blount
Dr. Pete Brosius
Dr. Ron C. Carroll
Dr. Larry West
Dr. Frank Golley

Electronic Version Approved:

Gordhan L. Patel
Dean of the Graduate School
The University of Georgia
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For Mamá,

who taught me to fight for the things most dear,

and whose courage and tenacity

are exemplified in her most recent fight –

for life itself.

DEDICATION

For the families of the Negro, Urubú and Canoas Rivers, and for other friends and colleagues of Amazônia, for their friendship, patience and selfless assistance:

Qualquer trabalho intensivo . . . seja de rio ou de terra firme, destinado ao mercado ou para o consumo da família, feito com as mãos ou com a cabeça . . . precisa de conhecimento e dedicação. O trabalho de cada um de nós precisa de conhecimentos básicos e de empenho para poder se encaminhar. Contudo, para uma estrangeira poder entrar em um novo pais, em uma terra desconhecida, e levar para a frente um trabalho baseado só em livros e estórias, não é o suficiente o estudo, nem a dedicação ao trabalho. Mais importante ainda é a recepção das pessoas, a vontade desinteressada de compartilhar os conhecimentos e as experiências próprias com uma pessoa nova, a apertura das portas e cozinhas e quintais para fazer-a sentir "a vontade" e com barriga cheia, o esforço de fazer-a sentir entre família quando a sua família esteja longe. Para tudo isso, estou profundamente agradecida a todos vocês.

Através de dois anos nos quais eu tive a oportunidade de conviver com várias famílias e professionais da região, eu aprendí a respeitar a dedicação de cada um de vocês às suas professões, famílias e comunidades, e de apreciar o amplo conhecimento que faz possível que os seus trabalhos saiam para a frente. É o carácter da pessoa e o empenho no trabalho, e não a oportunidade de estudar em escolas ou colégios, que contribui à qualidade de trabalho e de vida. Eu tenho aprendido muito de cada um de vocês, não só sobre o seu trabalho, mas também sobre as suas vidas . . . e o resultado *tem sido o enriquecimento da minha própria vida. Reconheço que a minha contribuição tem sido limitada (em grande parte em função do imperativo teórico e acadêmico), e que estou levando comigo muito mais do que consegui deixar para as pessoas que tem me assistido. Essa contradição para mim tem sido o aspecto mais difícil desse duro e longe processo. Então de uma forma humilde, mas da forma mais sincera, eu gostaria de agradecer-lhes a cada um de vocês pelo tanto que tenham feito e agüentado para o único motivo de me ajudar. Por isso, estou eternamente grata, e em função disso estou dedicando o meu trabalho de doutorado a vocês.*

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Chapter I: INTRODUCTION

A. Description of the Research Problem

This research explores human-environmental interactions in a nutrient-poor (oligotrophic) environment, the blackwater ecosystems of Amazonia. I focus in particular on the modifiability of ecosystem properties by traditional groups and the enhancement of subsistence options within these "anthropogenic" landscapes. The co-occurrence of non-anthropogenic terra firme soils and Indian Black Earth (*Terra Preta do Índio*), a more fertile anthrosol resulting from the semi-permanent settlement of Amerindian groups, provides a unique opportunity for analyzing 1) the role of anthropogenic modifications of the environment in conditioning human adaptive processes, and 2) the plasticity of human-environmental interactions within nutrient-poor environments. Two years of ethnographic, behavioral and biophysical data collection among *caboclo* and indigenous families who farm both Black Earth and non-anthropogenic soils has provided the groundwork for a highly interdisciplinary analysis of human-environmental interaction. Caboclos are mixed descendants of Indians and Portuguese, and more recently Afro-Brazilian and other groups, whose traditional land-use practices reflect these indigenous influences. Research findings and theoretical interpretations allow for novel contributions to our understanding of human ecosystems through their emphasis on the dialectic between ecosystem constraints and human agency in the structuring of human environmental behavior.

The organization of my dissertation derives directly from my inquiry into human-environmental interaction in Amazonia. After initial chapters in which I describe the research problem, address the theoretical antecedents and describe the study site, I address myself fully to two areas of inquiry: human adaptation to anthropogenic environments, and plasticity of human-environmental interaction (Chapters VI and VII, respectively). In the final chapter I address the implications of these questions for our understanding of human ecosystems. I introduce a model called the Structuration of Human Ecosystems to explore the latitude of human agency and the factors – both cultural and ecological – that structure human-environmental interactions through time.

B. Contextualization and Justification

Many factors make this region particularly suited to the objectives of the proposed research: 1) a comprehensive anthropological tradition which has generated great insight into the processes underlying patterns of subsistence and settlement in the region, 2) the presence of nutrient-rich and easily identifiable anthropogenic environments in oligotrophic ecosystems allowing for the comparison of adaptive processes in both "natural" and "cultural" environments, and 3) the presence of culturally-similar caboclo communities with highly complex knowledge systems and resource management strategies (Moran 1989; Parker 1989).

This research generates the following novel contributions to our understanding of adaptive process in human ecosystems in general, and in the blackwater regions of Amazonia in particular:

1) It systematically explores ecosystem modification as a component of human agency in adaptive process for the Amazonian terra firme (see Anderson and Posey 1989;

Balée 1992, 1989). This builds on earlier approaches to human adaptation in Amazonia focusing on environmental limits (Meggers 1971; Gross 1975), social and technological buffering (Roosevelt 1980; Myers 1992; Denevan 1996), and political-economic mediating factors (Anderson and Ioris 1992; Schmink and Wood 1992).

2) It represents a diachronic approach to adaptive process, stressing not only the role of humans in modifying the environments to which they adapt, but also the changing technological, political-economic and cultural factors conditioning this adaptability.

3) It explores the plasticity of human-environmental interactions a blackwater ecosystem, highlighting the dialectic between environmental limits and ecological praxis in nutrient-poor (oligotrophic) environments.

C. The Rio Negro Cultural Area

The Rio Negro is particularly interesting for this research because:

1) It is one of the most ecologically and culturally "intact" regions in Amazonia, due in part to ecological conditions that have made intensive (non-traditional, or industrial) economic exploitation of resources in the historical era less attractive,

2) This relative preservation of culture and environment permits the study of traditional production systems on Black Earth (without the substrate modifications produced by chemical fertilizers, for example), and

3) The river's course presents a natural continuum, from the mouth to the headwaters, that permits the study of diverse human adaptive responses to similar environmental conditions (as a function of non-biophysical factors such as cultural differences, proximity to urban centers, accessibility to industrial agronomic inputs and other contingencies that influence material-ecological adaptations).

Certain aspects of the Negro region complicate a strongly materialist analysis of human adaptation, however, and warrant discussion here. First, the Negro has had a highly diverse ethnic composition in both historic and prehistoric times. The Upper Rio Negro region is one of the most culturally diverse areas of the world, with 18 ethnic groups occupying official indigenous territories alone (ISA 1996). This situation changes in the middle and lower Negro, as diverse non-indigenous influences (Portuguese, Afro-Brazilian, mestizo and more recently, Japanese) have strongly modified the ethnic composition. This spatial differentiation of ethnic and historical influences may be explained through historical processes that caused the exodus or complete genocide (either through appropriation of indigenous labor, or indirectly through the spread of disease) of indigenous groups near Manaus, a colonial center. This same process and intermarriage of Portuguese and indigenous groups account for the predominance of caboclos and detribalized (or "civilized," the popular term of reference for this region) Indians in the middle and lower reaches of the Negro River.

While the basin can be considered distinctive from geographic and ecological standpoints, caution should therefore be used in making generalizations about cultural manifestations. The few authors who have made such an attempt have either based their studies on a limited region (Chernela 1993), or made only the most general characterizations about culture and livelihood (Moran 1991; Ribeiro 1995).

Secondly, the increasingly centralized economic activity in the region both links groups along this main artery and catalyzes further differentiation in the cultural responses to these influences as a function of distance to market or other location-specific influences. While the region's economy is still largely extractivist, linking distant regions to centralized markets through the activity of merchants (Bunker 1985), the 1967 decision of the national government to make Manaus a free trade zone has only enhanced the influences of a globalizing economy (Schmink and Wood 1992). It is important to address the significance of these regional influences (rich cultural diversity, centralized market influences with differential impacts, etc.) to a strongly materialist research framework, in particular one that focuses on "traditional" adaptive strategies.

While Portuguese, Afro-Brazilian and other non-indigenous influences may defy our understandings of that which may be considered "traditional," most of these groups have a long, shared history of adaptation to the region throughout the historical era, and have assimilated many aspects of indigenous land-use practices (Parker 1989). Furthermore, even more recent immigrants (and traditional groups themselves that have altered their resource exploitation strategies as a function of contemporary political-economic influences) have been shown to rely on traditional land-use practices as a risk-avoidance strategy (Schmink and Wood 1992). While this may be explained through a materialist framework that views the environment as a determining factor (Meggers 1971), it has also been shown to reflect adaptive responses to the highly unstable boom-and-bust cycles of the extractive economy (Bunker 1985). The following common and lasting patterns of occupation and land use – widespread among ethnic groups, geographic regions and historical eras – indicate the influence of a common adaptive logic, independent of the ultimate motive:

- shifting cultivation as the predominant agricultural system, with home gardens and managed forest and fallow as subsidiary systems,
- bitter manioc as the predominant staple crop and source of calories,

- terrestrial and aquatic fauna as the primary source of protein, with the few exceptions resulting from the introduction of legumes in recent decades,
- the prevalence of extractive activities for both family consumption (hunting and gathering) and market (natural fibers, resins and medicinals), and
- the sole reliance on soils of the terra firme for agricultural production.

My use of the term "tradition" when referring to regional agricultural practices merits further attention. I use it first as a semantic label for cultivation practices that are widespread and understood as resulting from the strong coupling of ecosystem properties of the terra firme (i.e., of Latosols) with certain patterns of land use. These include a strong dependence on the burn for liberating nutrients for agriculture, the use of the fallow to restore system productivity (i.e., through the increase in aboveground biomass), and widespread cropping strategies in which bitter manioc predominates. While these aspects of regional agricultural systems ground my use of the term "traditional agriculture," certain aspects of agricultural production in the central research sites – in particular on Black Earth – depart from tradition. Some Black Earth farmers utilize agrochemicals to protect exotic crops and high-yielding varieties that are more susceptible to pests. My use of the term "traditional" when referring to the cultivation of Black Earth here takes on new meaning, as a descriptor for nutrient management practices (and materials) alone. While the use of non-traditional crops and pesticides defies "tradition" from an absolute standpoint, nutrient management techniques become the primary criteria for site selection in research that focuses on the role of the soil substrate in conditioning human adaptive strategies.

Both the commonalities and differences in regional culture and subsistence have been incorporated into the research framework and serve to strengthen the analysis. First, the practice of manioc-based shifting agriculture throughout central and comparative study sites gives a foundation for researching the departure of adaptive strategies from this system within anthropogenic environments and the contingencies that influence this divergence in adaptive processes. Patterns in the use of Black Earth environments that differentiate groups on the basis of technological, cultural or political-economic influences, on the other hand, assist in understanding how diverse factors articulate with the biophysical environment in conditioning adaptive process and the plasticity of adaptive process within anthropogenic ecosystems.

Chapter II: AMAZONIA: HISTORICAL-ECOLOGICAL CONTEXT

A. Ecosystems of Amazonia

The typology of Amazonian landscapes and riverine systems is perhaps best presented in the seminal work by Sioli (1984). He divides Amazonian ecosystems into three major categories: whitewater, clearwater and blackwater basins. This classification is based on limnology and on the characteristics of drainage basins that give rise to such divergent aquatic ecosystems. The whitewater ecosystems are those that drain from the Andes (the Amazon and Solimões – or upper Amazon, and its eastern tributaries), where soil erosion causes water to be highly turbid and inundated areas to be bathed annually with a rich layer of sediments. These floodplain environments, known locally as the *várzea*, are known to be the most fertile of the entire Basin for agriculture and to have sustained dense populations associated with complex chiefdom societies in the late prehistoric era (Roosevelt 1980). The risk associated with spatially- and temporally-variable patterns of flooding (Chibnik 1994), however, is likely to have caused these groups to depend on a complex association of subsistence strategies involving both floodplain and *terra firme* (non-inundated) environments (Denevan 1996).

Clearwater basins are those that drain the older geological formations of the Brazilian and Guiana shields to the south and north of the Amazon River, respectively (Sioli 1984). The largest of these are the Xingú and Tapajós Rivers, which drain into the Amazon downstream from the confluence of the Negro and Solimões (see Map II-1). Clearwater lacks the sediment found in the waters that drain the Andes, due to the highly-weathered state of the Brazilian and Guiana Shield formations. While these inundated environments are not particularly acid or limiting to agriculture, they lack the annual deposition of nutrients that provides a distinct advantage to cultivation in the várzea. Nevertheless, archaeological research by Heckenberger and colleagues (1999) demonstrates the existence of large, sedentary pre-contact populations in these environments.

Finally, blackwater environments are those that drain ecosystems on the extreme end of a gradient reflecting relative nutrient poverty or oligotrophy – the Campina or Caatinga ecosystems of the upper Negro and Uaupés regions. These environments are characterized by scrubby or open forest vegetation and by extremely weathered white sand soils called Podzols (Herrera 1985; Salgado Vieira and Oliveira Filho 1962). Podzols are sandy soils with distinctive spodic horizons where organic compounds accumulate. It is here that organic humic and fulvic acids leach into relatively stagnant bodies of surface and groundwater, leading to the characteristic dark and acid black water. This acidity, together with the lack of nutrient-rich sediment, causes the inundated islands and white sand beaches of the Rio Negro to be extremely acid and infertile, effectively restricting agriculture to the terra firme. Black Earth sites in the upper and lower Negro that I visited during field research attest to the presence of permanent Amerindian settlements in these environments. However, the location of the largest of these – the Açutuba site on the lower Negro studied by Heckenberger et al. (1999) – near whitewater environments and prehistoric settlements would suggest that these dense and lasting settlements may have been sustained by productive activities carried out beyond the immediate blackwater context.

This tripartite typology of Amazonian ecosystems has long been used by Amazonian scholars to explicate patterns of livelihood among traditional occupants of the region (Chernela 1993; Moran 1991; Roosevelt 1980). This interpretation has also been criticized, however, for simplifying environmental heterogeneity (for which greater variation exists) and the role of past human occupants in modifying these environments. According to Balée (1995), the várzea-terra firme dichotomy which divides the environment into two opposed zones ignores (pre) historic transformations taking place in both.

B. Prehistoric Amazonia

The tropical rainforest was once thought to be an ecological barrier to Paleoindians due to the scarcity of subsistence resources. Given the scarcity of terra firme resources for foragers, slash-and-burn agriculture was thought to be the subsistence base that permitted habitation of the region (Bailey et al. 1989; Headland 1987). There is mounting evidence, however, that the Amazon Basin was occupied by nomadic hunter-gatherers as early as the late Pleistocene (Roosevelt 1992; Roosevelt et al. 1996). Carbonized remains suggest that these early inhabitants had a broad-spectrum economy of human tropical forest and riverine foraging (Roosevelt et al. 1996). While fish were the most abundant fauna, other remains show a highly diversified diet including large land mammals, mollusks, rodents and amphibians. The high proportion of plant remains from species adapted to disturbance indicate some alteration of the forest from Paleoindian woodcutting and burning (Ibid).

Archaeological excavations indicate that the onset of root horticulture and ceramics occurred somewhere between 4000 and 2000 B.P. (Lathrap 1970; Roosevelt 1980), as evidenced by the prevalence of manioc griddles and pots in South American Formative horizons. Steward's (1948) description of these horticultural tropical forest cultures is perhaps the most well-known, yet is influenced by his comparative lens in which these groups are viewed along developmental lines and in contrast to the complex societies of the Cirbum-Caribbean and Andean regions. Although Steward did not attempt to explain the reasons behind these apparent differences, he did note that soil exhaustion on the terra firme required settlements to be moved every few years (Myers 1992; Steward 1949). In many ways, the phase during which these first horticulturalists emerged resembles the indigenous occupation known to recent historic times: semi-nomadic life, small and dispersed settlements, and diets based on root crops (in particular, bitter manioc) and the procurement of terrestrial and aquatic fauna (Roosevelt 1992).

It was originally assumed that the sparse settlements, simple agriculture and rudimentary social and political organization were adaptations to ecological conditions of the humid tropical forest (Meggers 1954), and were therefore common to the region at large. Yet Roosevelt (1992) states that this pattern of occupation essentially disappeared on the várzea of the principal Amazonian rivers during the first millenium B.C., with the advent of intensive cultivation of seed crops, population expansion and the development of complex societies (Roosevelt 1980). Lathrap (1968) also makes this distinction between the simple cultures of the interfluvial regions and the large and complex riverine cultures of Amazonia. Meggers (1971) responded by saying that while floodplain environments are richer in nutrients and aquatic protein, uncertainties posed by flooding and limitations to primary productivity in the more turbid whitewater provided few advantages over the terra firme.

Evidence that complex societies emerged in the floodplains prior to contact is increasing. The Omagua, occupants of the Solimões during late prehistoric and early historic times, are oft cited in ethnohistorical accounts in which their construction of underground silos to store maize and fish (Acuña 1859), maize and manioc-based agriculture spanning some 20 km of river banks (Vásquez de Espinosa 1948), dense population (Porro 1992) and trade with distant tribes of the upper Negro (Wright 1992) are described. Yet according to Myers (1992), the natural fertilization of floodplain required little in terms of organized labor – Marajó Island at the mouth of the Amazon being the exception, where people likely invested considerable amounts of labor to transfer muck from nutrient-rich swales in the absence of flooding (citing Brochado 1980). Earthenworks (causeways, etc.) are nevertheless documented for the middle Amazon (near Santarém) and from archaeological sites on the lower Negro and upper Xingú regions (Heckenberger et al. 1999; Palmatary 1960), a labor investment that is typical only of large, sedentary occupations. By the late prehistoric period the indigenous population along major rivers appears to have attained significant complexity and reached its demographic peak (Roosevelt 1992). This suggests that contemporary Amerindians are but geographically marginal remnants of the societies that lived on the várzea in late prehistoric times, prior to their dislocation and demographic decline that occurred through European contact.

The question remains as to the limitations of terra firme environments to the development of complex society. The limitations posed by low soil fertility, low density of edible plants and low biomass of terrestrial and aquatic fauna to the productive strategies of both hunter-gatherers and horticulturalists go unchallenged by this early generation of Amazonianists (Lathrap 1970; Meggers 1971; Roosevelt 1992). Recent archaeological evidence in blackwater and clearwater regions suggests the existence of large, permanent and complex settlements in a wider variety of environmental contexts (Heckenberger et al. 1999). In contrast to the floodplain societies studied by Roosevelt, however, the cultural complexity arising in these environments did not appear to stem from the cultivation of grain crops but from agricultural intensification in which bitter manioc continued to play a dominant role (Ibid). The location of the site on the lower Negro, where numerous archaeological sites from permanent occupations span the length of a canal connecting the Negro with the Solimões, suggests that important trade routes existed between populations inhabiting whitewater and blackwater environments. This leaves in doubt the level of cultural complexity reached by groups whose subsistence base was limited to blackwater environments.

On the Rio Negro, the entire watershed, from the mouth to the headwaters, was territory of Arawak tribes (from the North Maipuré linguistic family). This occupation spanned 'the time when proto-Arawak expanded up the Rio Negro until European penetration in the 18th Century' (Wright 1992:253). This is confirmed by ethnohistoric accounts which indicate that Manao indians occupied much of the Rio Negro during early historic times (Ferreira Reis 1906; Porro 1987).

Other linguistic groups to occupy this blackwater region included Tukano and Maku linguistic families, which today occupy the upper reaches of the Negro and the Uaupés. Nimuendaju (1955) suggested that the culture of this northwestern Amazonian region was formed through three strata: 1) the oldest, diverse ethnicities of semi-nomadic hunters and gatherers (Maku, Uaicá and Xiriana), 2) populations of more advanced cultures at the beginning of the Christian era (Arawak and Tukano), and 3) the most recent, "hybrid cultures" arising out of European contact with these native groups. While the oral tradition of contemporary Arawak groups suggests an autoctonous origin, Tukano oral tradition attests to their migration from other regions of Amazonia[1] (Wright 1992). The research by Reichel-Dolmatoff (1985) suggests that when the Desana (a Tukano group) entered the region, they encountered other sedentary horticulturalists (a group of Baniwa, from the Arawak linguistic family) and nomadic hunter-gatherers (Maku) in the region. Each of these accounts suggests that groups from the Arawak linguistic family already inhabited the region when the Tukano arrived.

Certain patterns of complex social organization today characterize the Arawak and Tukano groups of the upper Negro region, including a system of social organization in which sibs are organized according to a hierarchy of ritualized roles and associated with certain territories and resources (Chernela 1993). Given that these cultural patterns are not shared by Tukano groups of Western Amazonia (in their supposed regions of origin), it is likely that the ritual complex and system of social organization were assimilated by the Tukano from the Arawak (Wright 1992). The first ethnohistorical accounts about the Arawak (such as the Manao) indicate similar patterns of complex socio-political organization (Ibid; Ferreira Reis 1906; Porro 1992). Tukano accounts that suggest sedentary horticultural activity among these groups are also curious for a region in which the predominance of Podzols limits Latosol distributions and also agricultural productivity (Klinge 1967; Salgado Vieira 1988; Salgado Vieira and Salgado Filho 1962). Arawak groups inhabiting the lower Negro, where Latosols predominate, would

[1] This migration most likely occurred from the Napo, Putumayo and Aguarico rivers in Western Amazonia where there are still Tukano speakers (Siona, Secoya).

certainly have been capable of sedentary occupation based on horticulture, fishing (as suggested by the predominant location of archaeological sites on river bluffs) and other subsidiary activities.

The lower Negro is today dotted by countless Indian Black Earth sites of various sizes. Black Earth is an anthrosol resulting from high-intensity nutrient deposition and burning which could only have resulted from semi-permanent settlement (Heckenberger et al. 1999; Woods and McCann 1998), in which a critical threshold level of culturally-induced biotic activity and soil nutrient retention status catalyzes a new “black earth dynamic” (McCann et al. 2001; Pabst 1996). This critical threshold appears to underlie the permanence of Black Earth in the absence of ongoing cultural amendments, and to be surpassed by contemporary small-scale caboclo and indigenous groups only in very isolated pockets[2]. Heckenberger (1999) observed that groups today appear to produce no extensive Black Earth deposits even after some 50 continuous years of occupation. This evidence indicates that the tropical forest pattern of occupation is not responsible for the formation of these anthrosols. These anthropogenic environments are more likely an artifact of the more sedentary, complex societies inhabiting the Negro during late prehistoric and early historic periods. Initial occupation dates associated with modified soil strata in sites on the lower Negro span a period between 6850 B.P. (on what ultimately became the largest and structurally most elaborate site) and 400 B.P. (in a community called Terra Preta, where research was carried out). According to Heckenberger et al. (1999), most of the smaller sites in this region were occupied no earlier than 1125 B.P.

2 I observed two such deposits no larger than 1 to 3 meters in diameter, in areas coincident with past residences or manioc griddles.

C. The Historical Era

The first European explorers arrived on the coast of Brazil in 1496. During the first century of occupation, the Portuguese, Dutch, French and English attempted to control the territories of contemporary Brazil. The English and Dutch colonies established on the lower Amazon by the early 1600's were later driven out by the Portuguese, who dominated the colonial process for the next four centuries (Williamson 1923).

According to the historian Victor Leonardi (1996), mercantilism always served as the mechanism under which indigenous occupants were subjugated. International financial capital was always predominant in driving colonialism in the Amazon region, yet resource exploitation began through private enterprises which were only incorporated under the Portuguese Crown in the 18th century (Ibid). Colonial efforts were first oriented toward ranching, sugar production, mining and the extraction of dye from hardwoods for the European textile industry, activities which spread along the coast and throughout southern territories. Exploitation of these products was "rented" to private entities, called *capitanias*. By the time these capitanias were incorporated into the Crown, coastal groups had been decimated due to the introduction of European disease and direct enslavement of indians as agricultural, extractive and household laborers. "Death and (often ephemeral) economic growth are siamese twins since the beginning of our history. Population and depopulation as well" (Leonardi 1996:50).

According to Leonardi, indigenous labor was also indispensable for "advancing the process of Portuguese penetration into the forest, toward the West, South and North, through the Tapajos, Madeira, Negro, Branco and Javari Rivers" (1996:82). In contrast to coastal regions, colonization within Amazonia was driven by the lure of exotic products of the tropical forest, including *drogas do sertão* (aromatic and medicinal products from the hinterlands), rubber, non-elastic resins, fibre, dyes and tannins, foodstuffs and oils. Gold and indigenous labor itself were further incentives for reaching far into the Amazon Basin. Each of these activities was connected to particular forms of occupation and subjugation, contributing to a complex social and cultural mosaic within the region (Ibid).

It was during this early period of occupation and economic exploitation that the Amazonian caboclo emerged as a distinctive social group in the lower Amazon. The term caboclo was originally used in reference to descendents of acculturated Indians who worked in the extraction of drogas do sertão during the 18th century, and ultimately, to individuals of mixed indigenous and Portuguese ancestry (Parker 1989). However, the mobility of the rural Amazonian population and the influx of groups from outside the region throughout the late colonial and post-colonial periods, in response to both the "rescue missions" of the *sertanistas* (early explorers of the hinterlands) and the booms in the extractive economy, has led to the incorporation of an evermore diverse cultural mosaic to the "caboclo" term of reference. Caboclos and indians alike played critical roles in the economy that took root from the early colonial period, serving as "the pillars of economic life structured around extractivism in the hinterlands of Amazonia" (Leonardi 1996:75).

The enslavement of indians, who were sold in Belém to feed the agricultural, industrial and domestic labor force, was the most lucrative of all the activities that drove sertanistas into the hinterlands. However, it proved also to be most difficult. Enslavement was permitted by law under conditions of "just war" (when attacking colonists or enslaved by another tribe), yet these sertanistas reduced as many indians as they found to slavery (Ferreira Reis 1906). While many indians along major rivers never reached enslavement, dying first from diseases brought by colonists and missionaries, the violent tactics of these sertanistas caused others to fiercely resist capture.

This was also true on the Rio Negro. According to Ferreira Reis, "It was difficult . . . the occupation of the Rio Negro. The famous Manaus dominated nearly the entire valley" (1906:93). While the commerce of indigenous slaves had reached the upper Negro and Uaupés regions long before (in the decades 1730 and 1760, respectively) (Wright 1992), the Manaus indians began to unite at the beginning of the 18th century to resist subjugation, forming the "largest Amerindian confederation of Amazonia" (Ferreira Reis 1906:94). In 1727, the famous leader of the Manao, Ajuricaba, led hundreds of Amerindian warriors to destroy all villages of Portuguese and allied Amerindians along the Branco, in which "nearly all the indigenous nations of the Negro participated" (Ibid:95). This ability of Rio Negro settlements along the Negro to organize politically and accounts suggesting intermarriage between the Manao, Tucano and Baré (Ibid) each suggest that far-reaching political and social ties characterized this region throughout the early historic period.

The arrival of Jesuits in the region produced the first obstacles to the operations of the sertanistas by reporting their abuses to the Crown (Ferreira Reis 1906). They disputed with the sertanistas, the former wanting indigenous loyalties and the latter indigenous labor (Leonardi 1996). Missionaries set up in villages where they found indians or relocated them, founding missions between the late 1500's and the 1850's that gave origin to many of the villages and cities of 20th century Amazonia (Ferreira Reis

1906). The first mission was established in the lower Negro in 1657, at the mouth of a tributary of the Negro called the Tarumã. The diverse religious orders competing to missionize the region were organized by the Portuguese Crown in a letter of 1694, which gave the Carmelitas dominion over the Rio Negro and the Mercenaries the Rio Urubú. According to an account by Ferreira Reis, the Carmelitas had the most success missionizing of any religious order, effectively occupying the lower Negro by the first half of the 18th century and:

> Creating nearly all the settlements of the rio Negro...and among the natives of the Waupés. By knowing how to triumph, over the [rudes] customs of those primitive people, inspiring their trust, defending them from the voracity with which the sertanistas presented themselves . . . Manaus, Barés, . . . gave in, bit by bit. . . . The carmelitas achieved, in this way, better results than the military expeditions, marked in bloodshed. They introduced them, methodically, triumphing over the natural indisposition of the native, to agricultural work. They disciplined the man of the jungles, taking away his nomadic habits (1906:74-75).

Despite this evidence that indigenous populations were decimated both demographically and culturally, Leonardi (1996) claims that in relation to other regions throughout the Americas, the decentralization of cultural practices assisted in the maintenance of a certain degree of self-sufficiency in the economic life of each tribe or village. This relative independence of the more remote ethnic groups meant that the conquest of lands was not concluded by iberian groups and their representatives, but is rather an ongoing process guided by the dominant Brazilian classes. "In the 19th century (1822), the Brazilian nation ceases to be a Portuguese colony to become, herself, colonialist in relation to the autoctonous tribes, whose lands were invaded and taken, by force, through classical colonialist methods" (Leonardi 1996:41).

The appropriation of indigenous labor for economic expansion remained important into the 19th and 20th centuries despite the role played by the Carmelitas in defending these groups from sertanistas (ibid). While African slaves began to replace indigenous labor on the coastal areas, indigenous labor predominated in Amazonia throughout the historical period. Yet a system of debt peonage controlled by *regatões* (traders) became increasingly important, slowly replacing the direct enslavement of these groups. This system was first organized for the extraction of timber and *copaíba* oil, yet slowly incorporated a broad number of products from agricultural and extractive activities (fibers, fauna, manioc derivatives and other local products). As practiced throughout the region in recent years, highly desired industrialized products (coffee, liquor, sugar) are loaned at a highly inflated price and paid later in kind, yet at vastly deflated prices. This indebts individuals to a specific regatão, and makes paying off the debt nearly impossible.

Native groups were further decimated through brutal clashes with Brazilians who migrated to the region in several waves. The first of these was in response to the rubber boom that peaked between 1890 and 1911 in response to the discovery of the vulcanization process in France, and provoked a threefold increase in the population of the northern region in this twenty-year period alone (ibid). This was due primarily to the immense northeastern immigration from the states of Maranhão, Ceará, Paraíba, Pernambuco, Rio grande do Norte and Alagoas, in response to severe population pressure and periods of extreme drought (Wood and Wilson 1984). The penetration of immigrants into the forest occurred through a system of exploitation that kept them subjugated to the *seringalistas* (rubber barons) and large traders of Manaus and Belém . . . who in turn were associated to the British exporters and to international financial capital (Leonardi 1996). Innumberable armed conflicts broke out between these northeastern rubber-tappers and indigenous groups of the most remote tributaries, putting an end to the relative autonomy of some native tribes that were able to survive the relative economic stagnation of earlier periods and decimating others within a few years (Ibid). When the rubber boom came to an end, many of these families from northeastern regions became integrated into caboclo society.

It is interesting to note that while both caboclos and indigenous groups alike played a critical role in the extractivist economy throughout the colonial period, indigenous groups share a pre-colonial history independent from these mercantilist influences. Caboclos, on the other hand, emerge as a distinctive (albeit diverse) cultural entity *through* this process. While knowledge of more traditional and autoctonous land-use strategies plays an important role for these families regarding risk-avoidance and food security, the high mobility of many caboclo families within the region itself is indicative of their ongoing linkages to the market economy. This is evidenced in family histories in which the search for more lucrative economic endeavors is often a driving force behind a family's geographic mobility.

The economic thrust brought on by the rubber boom was followed by a long period of stagnation, a result of the greater productivity of Asian rubber plantations that emerged at the beginning of 20th century. In the regions of most difficult access, this reversal of Western expansion made possible the physical survival and the preservation of certain autonomy of a few remaining tribes. This economic stagnation ended in 1960 with an initiative by the military government to open up growth poles in the most remote regions of Amazonia, in an effort to effect increased political control in these regions (Schmink and Wood 1992). The opening of a series of highways into remote forested regions and rapid penetration of financial capital from Brazilian companies involved in ranching and mining brought the next wave of immigrants to the region. Interethnic conflict decimated many remaining indigenous groups, with earnings and individual motives of the newly-arrived immigrants driving history beyond legislative controls, making social history more difficult for the native inhabitants than the already difficult colonial objectives (Leonardi 1996).

The most notable example of this conflict and "internal colonialism" (ibid) of the 1970's and 80's concerns the Waimiri-Atroari, one of last remaining tribes of the Central Amazon. The territory of these groups once spanned a vast area that extended far east and south of their now-official territory (see Map IV-1), and occupying the upper Urubú and Uatumã rivers. Yet a series of massacres of these Indians occurred, the first by the Brazilian military, and subsequent ones in the mid-20th century by hunters and ranchers, in which several hundred Indians were killed each time. The construction of BR-174 highway through their territory in the 1970's further increased incidences of violence with dominant Brazilian classes, with the final blow suffered during the flooding of large expanses of their territory when the Balbina hydroelectric dam was built in 1988.

One last governmental decision merits mention here, due to its influence on modes of agricultural production in the vicinity of Manaus. In 1967, the Brazilian government declared Manaus a *zona franca* (free trade zone) to end the long period of economic stagnation left from the decline of the rubber boom, through the creation of a "development pole" for the region (Despres 1991). This initiative stimulated industrial, commercial and agricultural activities around Manaus, stimulating rapid population growth through immigration[3]. The consumption of increased amounts of traditional foods and of non-traditional produce by this population has provided strong political-economic incentives for the cultivation of these crops in the hinterlands. These incentives are most notable in the area immediately surrounding Manaus, where the cultivation of exotic, nutrient-demanding crops is made viable by intensive inputs of chemical fertilizers. However, they also affect more remote groups who increase the production of traditional staple foods (from agriculture, hunting and fishing) for sale in these centralized markets.

D. The Contemporary Setting: Tracing Biophysical and Cultural Linkages between Distinct Occupations

The Rio Negro

The ethnic composition along the Rio Negro today varies a great deal from the mouth to the headwaters, in large part a result of geographical differences in the colonization process. On the lower and middle Negro, caboclo communities and homesteads are the norm. Closer to Manaus, these settlements are interspersed with small cattle ranches, often with absentee owners. The upper Negro and Uaupés region, on the other hand, is occupied by indigenous communities: the Baré (from the Arawak linguistic family) occupy the main channel of the Negro above Santa Isabel, while Tukano groups (Desana, Tariana) occupy the main channel of the Uaupés above São Gabriel da Cachoeira. Baniwa (an Arawak group), Makú, Yanomami and others occupy the main tributaries of these primary rivers.

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[3] The zona franca was largely responsible for the sharp rise in population observed in Manaus from the early part of the century (50,000 in 1902) to the mid 1980's (nearly a million people) (Despres 1991).

With the exception of semi-urban environments surrounding the municipal centers on the Rio Negro, the population is sparsely distributed along the primary channels of the Negro and its tributaries. While most individuals live in homesteads limited to the nuclear family on the lower and middle Negro, aggregation into small communities is becoming increasingly common as the government has extended social services (education, electricity) into these more remote regions. The orientation of settlements toward the main channel of the Negro and its larger tributaries has not changed as a result of this transition, although the orientation of settlement on high bluffs (Denevan 1996) has lessened as some families nucleate around these village centers. Settlements in the upper Negro region are similarly concentrated, yet more "traditional" cultural practices (language, communal swiddens, etc.) in this region suggest that this pattern of settlement may have a longer history than in the lower Negro.

As evidenced by the distribution of Black Earth, there is a great deal of overlap between contemporary and historical patterns of sedentary occupation. Local residents suggest that this is due to the proximity of main river channels, the extent of contiguous terra firme and aesthetic considerations rather than any finer discriminations concerning resource quality. As such, this overlap suggests that similar criteria governed site selection throughout time and that the presence of Black Earth on the contemporary landscape plays a limited role in this occupation process.

Black Earth sites in the lower Negro region are separated from one another by distances of ½ to several kilometers, and are generally limited in size (from <1 to 5 ha). While the spatial heterogeneity of anthrosols on some Black Earth sites suggests some dispersion of human activity among past occupants, the central area generally has higher concentrations of Ca and P, suggesting that spatial variations resulted from nucleated settlement surrounded by an area of semi-intensive agriculture (McCann et al. 2000). Given that nuclear families occupying single sites for long periods in the contemporary era fail to produce any significant Black Earth deposits (Heckenberger et al. 1999), it is likely that settlements of the past had much higher population densities. In the communities of Terra Preta and Marajá on the lower Negro, Black Earth sites are owned by a single family or split down the middle by no more than three adjacent families, while other families occupy the landforms connecting these sites (where Latosols predominate). The sparse patterns of contemporary occupation relative to prehistoric and early historic occupants are corroborated through estimations of population density in pre-contact Amazonia (Denevan 1976). This may be less true for the settlements surrounding Barcelos, where the absence of significant Black Earth deposits suggests low-density settlement throughout the region's past.

As would be expected from these changes in settlement patterns from earlier times, contemporary land use is also likely to depart from early usages. First, recent pedological and archaeological evidence suggests that the semi-permanent settlements leading to the formation of Black Earth in non-floodplain environments were made viable by some sort of intensive agriculture on the terra firme (Heckenberger et al. 1999; McCann et al. 2000). On the region's Latosols, contemporary farmers practice swidden agriculture alone, with a strong emphasis on bitter manioc (with small numbers of other crops in more fertile areas, such as banana, yams and sweet potato). The only intensification that has occurred results from the decreasing availability of mature forest near older settlements, which has caused some families (38% of informants) to begin clearing their own fallow for agriculture rather than walk longer distances to their swiddens. Results of this "intensification" are lower rather than enhanced yields. As such, contemporary use of Latosols might be considered more similar to Steward's (1948) tropical forest cultures than to those groups whose settlement led to the formation of Black Earth.

On Black Earth, the limited extent of modified soil has left entire sites covered in young fallow vegetation, forcing farmers to clear swiddens from their own fallowed landscapes. However, no intensification has occurred in these sites either; rather, soil fertility is maintained primarily through fallow management. Early occupants of these Black Earth sites are likely to have practiced more intensive cultivation practices that included mulching and burning (McCann et al. 2000), intensifying agriculture in the areas surrounding the settlements where Black Earth deposits are most significant. The only resemblance to this practice occurs today in two Black Earth sites subject to intensive, market-oriented agriculture. In these sites, the sole use of chemical fertilizers and the permanent removal of forest cover has led to site degradation, and farmers have begun to experiment with compost to restore soil organic matter and improve soil structure. The high returns from certain crops on these sites, however, are likely to be the critical factor that provides sufficient incentive for labor-intensive composting, which is here carried out by hired labor. It is unknown whether the deeper Black Earth deposits were ever utilized for agriculture in the prehistoric era.

The Rio Urubú

Given that sites on the Urubú River were incorporated as primary research sites along with sites on the lower Negro, it is important to discuss the differences between landscapes and occupation patterns between these two environments. The rural population on the Urubú is less dense than on the lower Negro, due to the absence of government services upstream from EMBRAPA. As such, settlements are limited to small homesteads where nuclear families engage in complex subsistence strategies for sale and household consumption. While the relative importance of each and the combination of diverse productive activities is similar to the lower Negro, the lower population density on the Urubú has helped to maintain populations of terrestrial game and to make hunting a viable component of integrated livelihood strategies.

Black Earth sites on the Urubú are spaced approximately 15-20 minutes (<1 km) apart along the Urubú, a river whose waterways meander back and forth in an oxbow fashion to form alternate areas of terra firme on opposite banks. Most of these bluffs (generally, the highest) have small Black Earth deposits of one to six hectares, presumably an artifact of the Waimiri-Atroari (Karib speakers) who lived here prior to the flooding of the Balbina Dam (Leonardi 1996). This limited amount of terra firme creates a situation that differs from the Negro in terms of the relative availability of anthropogenic and non-anthropogenic soils, and the amount of deforestation associated with contemporary occupation. As local caboclos selected their current areas of residence again on the basis of the proximity to water, extent of terra firme and aesthetic concerns, they almost invariably inhabited areas of Black Earth. The higher fertility of these soils permits a quickening of the fallow period, leading to reduced deforestation. However, while Black Earth swiddens are generally the oldest, each family also cultivates non-anthropogenic soils in other environments to expand their net productive possibilities in diverse settings.

Similar changes in land use on these areas of past Amerindian settlement are likely to characterize these sites as those on the lower Negro. The similar size of Black Earth deposits and patterns of pedological variability suggest that these were also permanent sites of residence supported by intensified agricultural practices. Fallowing practices are again the most common method for restoring soil fertility in Black Earth swiddens among contemporary farmers.

Chapter III: STATEMENT OF THE RESEARCH PROBLEM

A. Adaptation to Anthropogenic Environments (Hypothesis 1)

The first question guiding this research is whether the distinctive pedological and/or ecological dynamics associated with Black Earth condition unique patterns of subsistence and settlement. In other words, do humans adapt to biophysical conditions altered by both former settlement and by the ecological processes which result from this human-environmental interaction, or does "nature" alone condition this adaptation? In Chapter V, these questions are tested on the basis of the following hypothesis:

Hypothesis 1: *The unique pedological properties of Black Earth condition distinctive adaptive strategies on the blackwater terra firme.*

Prior assumptions regarding the immutability of ecological conditions and the limitations to subsistence imposed by *terra firme*[4] ecosystems tend to slight the possible roles of human behavior and ecosystem modification (i.e., improved fertility of Black Earth) in subsistence. The fact that both Indians and caboclos today recognize the soil as especially valuable for agriculture and favor Black Earth sites for farming and garden plots (Smith 1980) supports the untested hypothesis that qualitatively distinct adaptive processes characterize these sites.

[4] The more geologically stable, nutrient-poor of the two primary ecological zonations discussed in the literature – *terra firme* and *várzea* (the more fertile and dynamic floodplain) (Meggers 1971; Moran 1993).

B. Plasticity of Human-Environmental Interactions (Hypothesis 2)

The second question guiding this research may be stated as follows: How plastic are human-environmental interactions in blackwater, terra firme ecosystems? In other words, are the properties of the shifting agricultural system of Amazonia in fact determined by the ecological properties of the terra firme, or mutable through transformations of the ecosystem and through highly flexible adaptive strategies? In Chapter VI, these questions are tested on the basis of the following hypothesis:

Hypothesis 2: *The traditional shifting agricultural system of the Amazonian terra firme is plastic, conditioned not by absolute environmental limits but by the interaction between particular cultural and environmental processes.*

I define "plasticity" as the range of potential cultural expressions in an ecological context, conditioned not by absolute environmental limits but by the interaction between particular cultural and environmental processes. These expressions themselves, as well as the conditions and constraints articulating the interaction between particular cultural and environmental processes, are assumed to be mutable. Many of the theoretical models employed to explain cultural adaptation in Amazonia share implicit assumptions about this plasticity, namely that the more nutrient-impoverished the environment, the more constricted this plasticity in human-environmental expression. This approach privileges the environment at the expense of culture or synergistic interactions between the two in determining the outcome of this expression. A goal of this research is to identify quantitative and qualitative expressions of this plasticity, and to contribute to our understanding of cultural developments in the history of Amazonia.

C. Theoretical Antecedents

Human Adaptation

This research, through its grounding in the literature on the human ecology of Amazonia, rests on a basic understanding of human adaptability. A brief introduction to the assumptions used when referring to human adaptive processes becomes necessary.

While adaptive processes for any species include behavioral and physiological-morphological manifestations, behavioral adaptations among humans play a greater role in fine-tuning their interactions with their environment at short and intermediate time scales (Moran 1990). This emphasis on behavior rests both on our scales of reference (historical rather than evolutionary), and the greater flexibility of behavioral responses to environmental conditions and changes – responses that outweigh physiological-morphological influences in relative and absolute terms. For research that addresses anthropogenic modifications of the environment and the specific adaptations that occur in response to these modifications, and that focuses on the Amazon region – where human presence has only been indisputably confirmed for the past 11,000 years – the emphasis on behavior over other adaptive manifestations is warranted (Moran 1982).

In speaking of behavioral adaptations, it is important to recognize the links between cognition and the outward manifestations of cognitive processes in practice. While direct, deterministic links often fail to characterize the relationship between knowledge, intent and behavior (Quinn 1990), each of these manifestations must be studied in attempting to understand the process of knowledge acquisition, storage and use, and ultimately outward behavioral manifestations, in an environmental context. For more novel environments (with respect to their spatial predominance or more recent emergence on Amazonian landscapes), routine and implicit subsistence behaviors may play a lesser role than an active processing of environmental stimuli, relative to evolutionarily-predominant ecological and subsistence phenomena. If this distinction should prove relevant for Black Earth in relation to subsistence on more predominant agricultural soils, one would expect to see distinctions in cognitive phenomena, including levels of differentiation in soil classifications, informant agreement or knowledge verbalizability, and motivations. Each of these aspects of cognition highlight interesting aspects of the adaptive process, and must be studied in conjunction with purely behavioral manifestations of adaptive process.

Human Ecology of Amazonia

This research is rooted in a long trajectory of ecological interpretations relating to cultural development in the nutrient-stressed ecosystems of Amazonia. In this tradition, the adaptation concept has been successfully employed to tease out nuances associated with material culture and cultural evolution in the region. Steward (1948) catalyzed this materialist approach in his *Handbook of South American Indians*, where he suggests strong relationships between culture and environment for the groups he calls the Tropical Forest Tribes. Later scholars took this environmental determinism to the extreme, stressing an immutable environment to which humans must adapt. They cited the quantity and quality of agricultural land (Lathrap 1970; Meggers 1971; Sanchez et.al 1982; Smith 1980), protein scarcity (Chagnon and Hames 1979; Gross 1975), and physiographic features (Eden et al. 1984) as factors limiting human occupation and cultural development in the region.

Notions that the environment is a uniform and immutable context setting upper limits on human adaptive potential often resulted in theoretical models which more strictly inscribed the realm of possibilities for human settlement. Mounting evidence for greater internal differentiation and flexibility in cultural achievement led common understandings of the relationship between culture and environment in Amazonia to evolve. The "upper limits" to cultural development came to be defined not only by the environment, but by the technologies or cultural elements available to exploit that environment (Denevan 1992; Roosevelt 1980). This literature provided a more flexible view of "upper limits," many of these models continuing to rely on a model of the environment which in and of itself excluded cultural process (static from the standpoint of human modification).

The focus on uniform cultural and environmental process in these earlier models led to the dissection of Amazonian ecosystems into simplistic dichotomies (várzea/terra firme), to an overemphasis on the population as the relevant unit of analysis, and to a de-emphasis on the plasticity of human-ecosystem interaction. The lack of internal differentiation of these categories led to reified notions of the terminology framing our interpretations of the environment and human adaptability (i.e., culture, ecosystem, carrying capacity). Outcomes included deterministic explanatory frameworks, generalizations about the levels of social or environmental parameters that provoke human response, and assumptions about environmental "limits" based on isolated and idealized ecological units.

More recent approaches to the human ecology and cultural development of the Amazon Basin stress the importance of human agency in subsistence and adaptive strategies, and the fact that adaptation takes place in environments imbued with both "natural" and "cultural" elements. These novel approaches result in part from advances in our knowledge of the region, and in part as reactions to the negative attitudes that earlier models reinforced regarding past cultural achievements in Amazonia (Denevan 1966). The greater flexibility attributed to human-environmental interaction within these new approaches is evident in descriptions of social and environmental buffering (Hecht and Posey 1989; Myers 1992), patch modification (Hecht and Posey 1989; Posey 1982; Stocks 1983), "artifactual resources" (Balée 1992), and complexity in cultivation and resource procurement strategies (Anderson et al. 1995; Balée 1989; Clay 1988; Denevan 1996; Denevan and Padoch 1987; Gragson 1993; Hecht and Posey 1989). These views, in turn, have led to a concomitant view of greater ecosystem plasticity. Under these new frameworks, highly integrative and dynamic human adaptive strategies become the norm.

One more recent trend in Amazonian research merits mention here, in particular regarding the nuances this literature highlights in the motives influencing adaptive process on Black Earth. In recent decades, a great deal of literature has stemmed from this recognition that centralized markets exert strong influences on subsistence practices, even in remote regions (Anderson and Ioris 1995; Ozorio de Almeida 1992; Rudel and Horowitz 1993). Despite the tendency to think of the economic activities of traditional Amerindian groups as localized, apolitical, and tightly coupled to local environmental conditions (Gross 1975; Rappaport 1974), there is increasing evidence that political-economic influences among even the most isolated groups were critical causal variables in subsistence behavior (Chernela 1993; Whitehead 1993). An understanding of how political-economic influences condition decision-making processes of contemporary farmers will be critical in tracing causal linkages between environment parameters (i.e., soil fertility), human adaptive behavior, and the plasticity of this behavior.

Many of these same trends parallel interpretations of Black Earth, and lessons learned from these models ground the questions motivating the research. Grounding the analysis in contemporary theory on the human ecology of Amazonia holds important implications for our understanding of Black Earth, its role in adaptive process and generalized notions of plasticity in human-environmental interactions. These include: 1) the greater emphasis on human knowledge, agency and ingenuity in developing complex resource management strategies, 2) evidence for mutual causality in cultural and ecological process, 3) the recognition of the "culture" in assumedly pristine landscapes, and 4) the role of historical contingencies (political-economics, etc.) in conditioning human adaptive process. The research approaches adaptive process in a way that reflects its complexity, and its conditioning by multifaceted biophysical (both "natural" and "cultural" elements and interactions) and historical (technology, political-economics, etc.) conditions.

Human Ecology of Blackwater Ecosystems

The unique biophysical properties of blackwater regions are known to influence the productivity of human ecosystems and human adaptability in a number of ways. First, the acidic and oligotrophic conditions of aquatic ecosystems are known to limit primary productivity, and therefore the biomass of aquatic food webs. Therefore, while aquatic fauna are extremely diverse (Goulding et al. 1988), the total harvestable biomass is known to be more limited than in nutrient-rich whitewater environments. Second, these same aquatic conditions cause inundated landforms to be unfit for agriculture, as they are bathed annually by acid, nutrient-poor waters. As such, agriculture is limited primarily to terra firme environments. While most of the terra firme is known to pose chemical limitations to agriculture due to very weathered soil horizons (see below), the *campina* and *caatinga* environments that predominate in the upper Negro region are of the most extreme environments in terms of their nutrient impoverishment or oligotrophy (Salgado Vieira and Oliveira Filho 1962). These properties are seen by locals as strong limitations to agricultural productivity, as evidenced in their preference for Latosols over Podzols in the selection of swidden sites. An early generation of anthropologists posited direct linkages between these properties and human adaptability.

Blackwater Ecosystems

Pedology

While great variability in soils exists within both temperate and tropical regions, effectively obscuring any attempt to classify soils by their location on the globe, common environmental forcing functions tend to produce similar outcomes in soils and pedology. While it is easy to identify the direction of influence of forcing functions specific to the region (such as climate or parent material), it is often difficult to identify clear examples in the field due to the complexity of factors influencing soil development and genesis (Jenny 1941). It is useful to employ a model of soil genesis to understand how these forces influence soil formation, how they have led to soil chemical and morphological characteristics of the Amazonian terra firme, and the degree to which anthropogenic soils depart from these "natural" soil-forming processes.

The best known soil genetic model is perhaps that devised by Jenny (ibid), who identified five state factors that influence soil genesis: climate, organisms/vegetation, relief, parent material and time. Later models have done a better job in focusing on the dynamic influences of these state factors and their effects on soil development (Simonson

1959; Buol 1980). According to Simonson, there are two primary steps to soil genesis: the accumulation of parent material, and horizon differentiation. The latter includes four processes: 1) additions of organic and mineral materials to the soil as solids, liquids and gases, 2) losses of these from the soil, 3) translocations of materials from one point to another within the soil, and 4) transformation of mineral and organic substances within the soil (ibid). These events may take place simultaneously, either mutually reinforcing or contradicting each other (Rode 1962; Simonson 1959), and contribute to a downward "growth" or horizonation of soils.

Simonson's model is perhaps most useful in understanding the range of processes leading to soil development. However, to understand the influences of climate on soil genesis within the study region and the degree to which anthropogenic influences may counteract these climatic forcing functions, it is useful to look to the role of energy in soil development. Soils may be seen as thermodynamic systems (Runge 1973), within which this tension between contradictory processes – between "natural" and "cultural" influences, for example – is fundamental to the resulting pedological configuration of any soil.

In an idealized, closed system, entropy (disorder) tends to increase spontaneously until reaching a state of equilibrium where randomization is maximized (Obert 1963). Soils, however, are open systems subject to inputs of energy from without, namely solar energy and gravity. These inputs reverse the tendency for randomization, favoring the development of neatly ordered soil horizons through an increase in biological and chemical reaction rates and the downward movement of materials (Buol et al. 1980). Horizonation is favored by the upward movement of nutrients by plants (causing a redeposition of material on the soil surface), the gravitational pull of water and materials downward, highly stable parent materials (allowing for time to exert its effect on horizon development), and climate (high temperature or rainfall), among other factors. It is tempered, however, by processes favoring haploidization (i.e., inhibit horizon development or cause the mixing of horizons) (ibid). Haploidization is caused by soil fauna (horizon mixing), relief and erosion (erasing the effects of downward-moving horizonation processes), and climate (periods of low temperature or rainfall).

In the highly-weathered soils of the Amazonian terra firme, well-developed soil profiles resulting from long periods of weathering and pedogenesis are common. This is due to both climatic forcing functions (high temperature and rainfall) and the stability of terra firme landforms. The latter limits erosion or destruction of the pedogenic record, and causes the release of new minerals from the parent material to occur deep in the soil pedon, making these unavailable to crops. The resulting soil exhibits very deep B horizons, advanced mineralization (low-charged 2:1 clays), low cation exchange capacity, and a highly leached soil horizon that is acidic, nutrient-poor and high in exchangeable aluminum.

The predominant soils on the Amazonian terra firme are Red-Yellow Latosols (by the Brazilian classification system), which correspond to the Ultisols and Oxisols soil orders of the USDA. While Latosols are also predominant in the Central Amazon region, there is a great deal of textural heterogeneity in the epipedon of these soils that corresponds to the landforms where these are found. On flat plateaus and steep slopes, the epipedon has a high clay content similar to buried horizons, while on lightly sloping terrain the epipedon tends to be more sandy and distinctive. The distinction between

Podzólicos and Latosols in the Brazilian system, and between Ultisols and Oxisols in the USDA system, is based on the presence or absence of this textural differentiation throughout the pedon, respectively. From a soil fertility standpoint, however, these soils may be considered similar. In the Upper Rio Negro and Uaupés, on the other hand, Latosols are interspersed with abundant Podzols – soils with distinctive physical *and* chemical properties. This class of soils corresponds to Spodosols in the USDA system, and is characterized by very sandy soil profiles, extremely low fertility and dark spodic horizons resulting from the accumulation of organic matter. While bitter manioc and pineapple may be grown on these Podzols, Latosols are preferred both for increased yields and the broader range of crops that may be grown in these soils.

Indian Black Earth (Terra Preta[5]*).* Indian Black Earth (Black Earth, or *Terra Preta*) is an anthrosol that resulted from the dense or semi-permanent settlement of Amerindians on terra firme bluffs, in the várzea and in interfluvial regions of the Amazon Basin. The *World Reference Base for Soil Resources* defines anthrosols as "soils that have been so transformed by anthropedogenic processes that the original soil is no longer recognizable or survives only as a buried soil" (Spaargaren 1994). This definition has led these soils to be classified as sub-classes of the predominant background soils. The Brazilian soil classification system calls Black Earth Humic Anthropogenic Latosols, a sub-class of the Red-Yellow Latosols that predominate in the region (Salgado Vieira 1988). While the occurrence of an anthropic Black Earth horizon over buried Latosol horizons would support this classification, it obscures pedogenic processes that would

[5] The common name for Indian Black Earth is *Terra Preta*, or "Black Soil". While these terms are interchangeable, I use "Black Earth" as the standard term of reference unless referring to direct utterances of informants (for example, with cognitive data).

cause these two soils to be treated quite differently. Although Spaargaren (1994) suggests an alternative classification of anthrosols based on specific anthropedogenic processes, what is important here is to understand the conditions – both cultural and environmental – that gave origin to these soils.

The question of origins of Indian Black Earth has been a subject of debate in the Amazonian literature. While early theoretical interpretations privileged natural over cultural formation processes, including lake sedimentation, volcanic ash deposition and topographic influences (Smith 1980), recent evidence strongly supports cultural origins (Denevan 1996; Eden et al. 1984; Sombroeck 1966). Clear conclusions are obscured, however, by the difficulty in deciphering an archaeological context generated through the reoccupation of preferred settlement areas (selected because of a high *natural* fertility) from an anthrosol (soil modifications produced by human activity). Intermittent settlement makes the very question of ultimate causality an obscure one. It is nevertheless essential to identify the chemical enhancement of Black Earth as a cultural artifact, given the fundamental assumption of this research: the anthropogenic origins of Black Earth.

Amazonian scholars were once in general agreement that Black Earth sites are nothing more than middens – simple by-products of semi-permanent or intermittent habitation of preferred landforms and the successive accumulation of organic waste and ash (Denevan 1996). This theory is based on the presence of ceramics and lithic debris throughout the soil horizon, chemical signatures commonly associated with human habitation (namely, high Ca and P), and similarities in the texture and subsoil properties of Black Earth and surrounding soils (McCann 1999; Smith 1980). The presence of artifacts throughout the nutrient-rich epipedon suggests cultural origins because humans are shown to be present throughout the period of soil formation. Secondly, it is well known that archaeological sites have high levels of total phosphorous (Eidt 1977). When these levels extend well beyond phosphorous stocks in natural ecosystems, particularly in the absence of natural deposits of this element, anthropogenic influences can easily be determined. Among the elements present in soil, phosphorous is the most stable of these, particularly in the presence of calcium carbonate and iron and aluminum oxides that tend to bind to phosphorus, forming stable (insoluble) complexes (van Raij 1991). While most nutrients deposited in human settlements are slowly leached out of the soil horizon under natural weathering processes, phosphorous tends to be fixed in the soil horizon. The high values of phosphorus in Black Earth sites are perhaps the best indication that these soils are anthropogenic (Eidt 1977).

Recent investigations on Black Earth have clarified many aspects of the debate on origins, and discredit the midden model (McCann et al. 2000; Zech et al.1990). In the research by McCann and colleagues (2000), all Black Earth samples fell into two clearly distinct categories that they call Terra Preta and *Terra Mulata*, following Sombroek (1966). While the former exhibited the classic indicators of human habitation – abundant potsherds and high concentrations of P and Ca – the latter did not. This dark grayish brown soil was found surrounding smaller, darker zones of Terra Preta. This pattern of distribution and laboratory analyses in which lower levels of Ca and P and higher levels of organic carbon were found in Terra Mulata suggest that these soils resulted from long-term soil management practices associated with intensive agriculture.

According to this theory, mulching and burning practices contributed charcoal and ash to the soil, increasing soil pH, suppressing Al activity and increasing microbiological activity (McCann et al. 2000). Increased activity of soil biota would in turn add organic decomposition products to the soil matrix (as identified in Black Earth by Glaser 1999), further enhancing cation exchange capacity and fertility. As such, Terra Mulata formation would result from secondary pedogenic processes for which cultural additions are but a catalyst. The properties of the prototypical Terra Preta, on the other hand, suggest that household waste deposition and intensive burning were both instrumental in the formation of these soils. Yet these authors suggest that even these soils should not be viewed as middens, due to the combined influence of nutrient-rich debris, fire (pyrolitic by-products) and microbial activity in the formation and persistence of these soils. It is therefore suggested that fire is the most important contributory factor in the origin of both of these soils (Woods et al. 2000). The factors that are most likely to account for their persistence in the absence of ongoing cultural amendments are its high biological activity and high nutrient retention capacity (McCann et al. 2000).

While Woods et al. (2000) suggest that Black Earth formation spans the history of crop production and settled habitation in Amazonia, it is evident from the absence of Black Earth deposits in contemporary Amerindian and caboclo settlements (Heckenberger et al. 1999) that the low intensity of associated anthropedogenic processes is insufficient for Black Earth formation. Itinerancy, low-density settlement and swidden agriculture are apparently *not* the patterns of settlement and land use that led to these lasting soil modifications.

The suggestion that Black Earth forms and even attains the capacity to self-perpetuate under some threshold level of biotic activity and soil nutrient retention status (McCann et al. 2000) would suggest that a great deal of human effort (intentional or otherwise) is involved in building nutrient-rich soils in this environment. While estimations of Amerindian population density are found in the earlier literature on Black Earth environments (Smith 1980), greater caution is used among Black Earth researchers today as the complexities of historical extrapolation in these environments is acknowledged (Heckenberger et al. 1999; Woods and McCann 1999). Important qualitative understandings may be derived, however, from relative figures on site size. In a study by Smith (1980), the average size of interfluvial sites is said to be 0.3-5 Ha, while those along major rivers average 21.2 Ha. The largest site, of 80 ha, was found on a terra firme bluff of the lower Solimões where access to rich floodplain environments may have potentialized a greater density and duration of settlement. For the Negro, this average size for sites on terra firme bluffs abutting active river channels is inflated; most sites I observed in the field were no larger than 6-8 Ha in size. The largest site on the Negro is that of Açutuba, where habitation areas span a full 30 ha and surrounding use zones an additional 20 Ha or more (Heckenberger et al. 1999). Black Earth has been identified throughout Amazonia in a great variety of environmental contexts, including várzea, terra firme bluffs and in upland settings of blackwater, clearwater and whitewater rivers. The size and distribution of sites in a particular environmental zone, however, is unknown (Woods et al. 2000). What is evident from the simple occurrence of Black Earth is that these Amerindian settlements were either more dense or more lasting than current patterns of occupation of the terra firme, suggesting that a qualitative change in traditional patterns of settlement and agricultural production came about during the historical period.

For an inquiry into adaptive processes in anthropogenic environments, it is sufficient to establish that Black Earth is anthropogenic to determine how lasting anthropogenic modifications of the environment potentialize distinctive adaptative processes. To address the question of plasticity in human-environmental interaction as a function of anthropogenic soil modifications, however, it is necessary to have a more fundamental understanding of the limitations to soil enhancement or anthropogenic eutrophication. The soil genetic models of Jenny, Simonson and others (Buol et al. 1980; Jenny 1941; Simonson 1959) are helpful for this purpose.

Anthropogenic formation processes may be easily incorporated into Simonson's model, where horizon differentiation includes additions of organic and mineral materials, as well as translocations and transformations of these materials within the soil. While material additions are directly anthropogenic in Terra Preta, their movement and transformation within the soil are secondary processes that are only catalyzed by anthropic additions (Woods and McCann 1999).

The energy model is a bit more difficult to reconcile with anthropogenic soil-forming processes, yet perhaps more important to the question of plasticity in human-environmental interactions is providing a conceptual model to improve our understanding of the limitations to anthropogenic soil modification. For Black Earth, an alternate developmental trajectory is taken under similar climatic forcing functions, and is maintained spontaneously after direct anthropogenic influences cease (Woods and McCann 1999). This may be explained by the greater influence of anthropogenic influences and non-climatic state factors in soil formation, including both direct (i.e., human waste) and indirect (increased faunal activity as stimulated by these inputs) influences. Yet to what degree is the role of human activity within pedogenic processes limited, and to what degree does this simply rest on intentional behaviors to enhance soil fertility?

While horizonation may be catalyzed through cultural processes (unintentionally through modifications in settlement patterns, or through intentional inputs of materials), secondary influences (both horizonation and haploidization) are likely unintentional. Fortuitous results of human-induced nutrient additions include melanization of the soil matrix through culturally-stimulated biotic activity on the one hand (stimulating horizonation), and the incorporation of organic nutrients down through the soil horizon through weathering on the other (leading to synergistic soil chemical effects, and haploidization). These processes are tempered, however, by other weathering influences that favor horizonation and by agricultural practices that lead to the mining of nutrients from the epipedon and its differentiation from buried horizons.

While absolute limitations to purposive soil eutrophication certainly exist (as a function of this tension between these processes that cause nutrient maintenance and loss), limitations to the enhancing effects of soil modification in agriculture must be understood in terms specific to this frame of reference. For example, while melanization and synergistic chemical effects (resulting from an elevated pH, for example) of anthropic soil-building effectively maintain soil nutrient stocks, soil weathering processes exert differential effects on distinct soil nutrients. In terms of horizonation, these influences cause certain stable nutrients to be maintained in the rooting zone (i.e., phosphorus) and others to be slowly lost. Vegetation of course plays a critical role in keeping soil nutrients within the system, yet crops only accelerate losses. A balance must be reached between system gains and losses for any natural or anthropogenic (i.e., agricultural) ecosystem to be maintained. This dynamic should in theory effectively constrain the modifiability of soils, and ultimately in the productive activities carried out in these modified environments.

Nutrient Dynamics and Human Subsistence

The impoverishment of the rooting zone and of subsurface horizons that provide the bulk of nutrients for sustained agricultural practices in many temperate regions poses certain limitations to terra firme agriculture. Amazon scholars emphasize the inherent difficulty in continuously cultivating the acid, infertile soils of the humid tropics (Jordan 1989), in particular the region's predominant Oxisols and Ultisols (75% of the Basin, Sanchez et al. 1982). The primary chemical limitations to agriculture include low phosphorus (Ibid; Smith 1980), limited calcium and potassium (Jordan 1985a, 1985b), aluminum toxicity (Jordan 1985b; Sanchez et al. 1982), low pH (Jordan 1985a, 1985b), and rapid decomposition of organic matter (Meggers 1971).

The almost sole reliance of traditional terra firme agriculture on the liberation of nutrients from standing biomass reflects this impoverished pedon. With a highly impoverished rooting zone in terra firme soils (Jordan 1985b), the burning of plant biomass is considered by local farmers to be essential to crop productivity, 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 stocks at diverse stages in the swidden agricultural cycle have been characterized by Jordan (1989). His diagram of nutrient stocks in the system (soil, standing biomass, etc.) throughout the production cycle provides insight into the soil chemical dynamics influencing farmer decisions (Figure III-1).

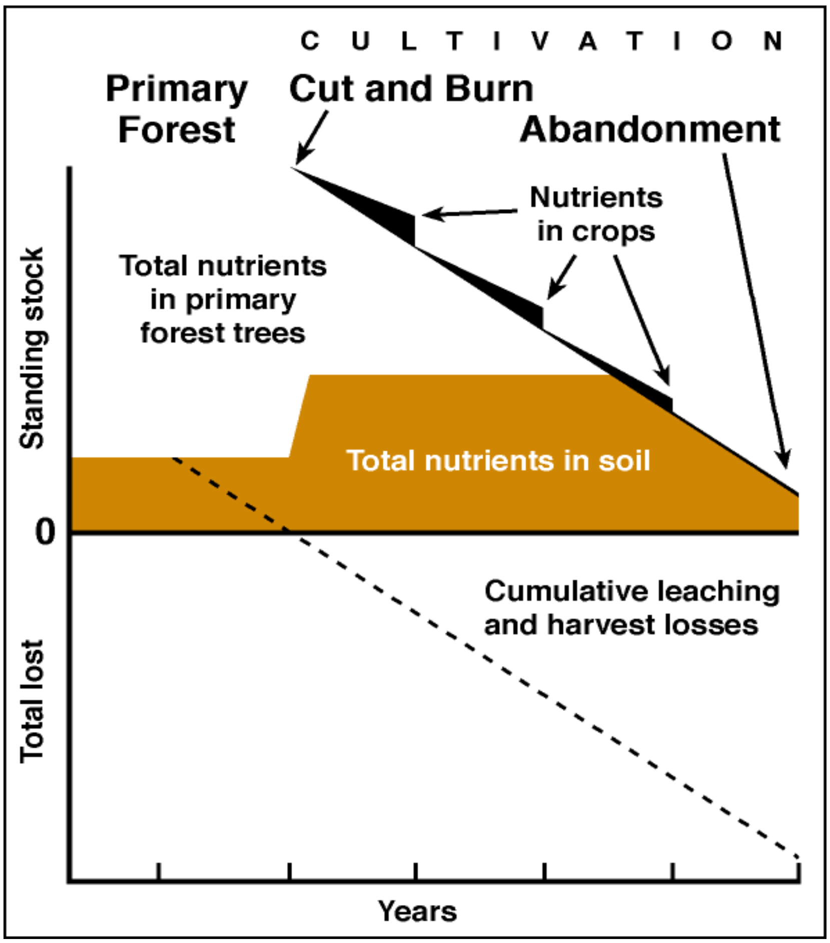


Figure III-1. Standing Stocks of Nutrients As a Function of Time in a Slash and Burn Plot in the Amazon Basin and Cumulative Nutrient Losses from the Soil. From Jordan 1989.

While this diagram is only a gross representation of soil nutrient stocks (undifferentiated by nutrient), it indicates that farmers abandon their swiddens above pre-burn levels. However, Jordan equates swidden abandonment with the binding (unavailability) of phosphorus in the soil, which would in effect resemble an adaptive response to an impoverished soil pedon (from the perspective of the availability of nutrients to crops and humans) (Ibid). Furthermore, the decline in mineral nutrient levels in time observed for tropical swiddens (Jordan 1989; Scott 1978) is accompanied by a rapid decline in crop yields (Peters and Neuenschwander 1988).

Indian Black Earth is an anomaly from the standpoint of the Amazonian terra firme. Anthropic soil-forming processes have increased the total amount of nutrients in the epipedon and improved the nutrient dynamics influencing nutrient retention within the rooting zone and nutrient availability to crops. According to Pabst (1991), the humic structure of soil organic matter in Black Earth is six times more stable than that of Latosols. Smith (1980), Falesi (1972) and Kern (1988) give evidence that extractable P, exchangeable Ca and K, and pH are each significantly higher on Black Earth, providing evidence for greater soil nutrient stocks and, by extension, agricultural productivity. Furthermore, other soil properties that influence the availability of nutrients to plants and the ability of soils to retain nutrients that would otherwise be lost through natural weathering processes (exchangeable aluminum, Base Saturation, Cation Exchange Capacity) are more favorable on Black Earth (Ibid). These chemical signatures contradict expectations for terra firme soils.

Given the tight coupling between ecosystem properties and traditional agricultural practices that has been attributed to terra firme environments, these modifications of the soil substrate should have profound implications for agriculture. Furthermore, the plasticity of human-environmental interactions should be enhanced as a result of the potential de-coupling of human adaptive processes and ecosystem properties. Some anecdotal evidence exists to indicate that Indians and caboclos alike prefer to plant more nutrient-demanding crops in Black Earth (Balée 1992; Carneiro 1983; Frikel 1959; Smith 1980). Despite the striking contrast between the limiting factors documented for cultivation and settlement in the Amazonian terra firme on the one hand and Black Earth chemistry and use on the other, no systematic studies have been carried out to demonstrate how these novel ecosystem properties *influence* or are *influenced by* patterns of human subsistence and settlement.

The Research Questions

Question 1: Human Adaptation to Anthropogenic Environments

Within human ecological scholarship, a more systematic effort to incorporate the complexity inherent in human adaptive strategy is needed. On a material level, it is important to incorporate recent historical ecological research that demonstrates the importance of human agency not only in adapting to absolute properties of the environment, but in modifying the environment itself – and also in adjusting adaptive processes to this novel context. Should we find evidence to confirm the hypothesis that distinctive adaptive processes characterize anthropogenic Black Earth environments, we will have a better understanding of this human-environmental dialectic in the most constraining of environments. Our understandings of human ecology and adaptability, as well as our interpretations of cultural developments in Amazonia, may be modified accordingly.

Question 2: Plasticity of Human-Environmental Interaction

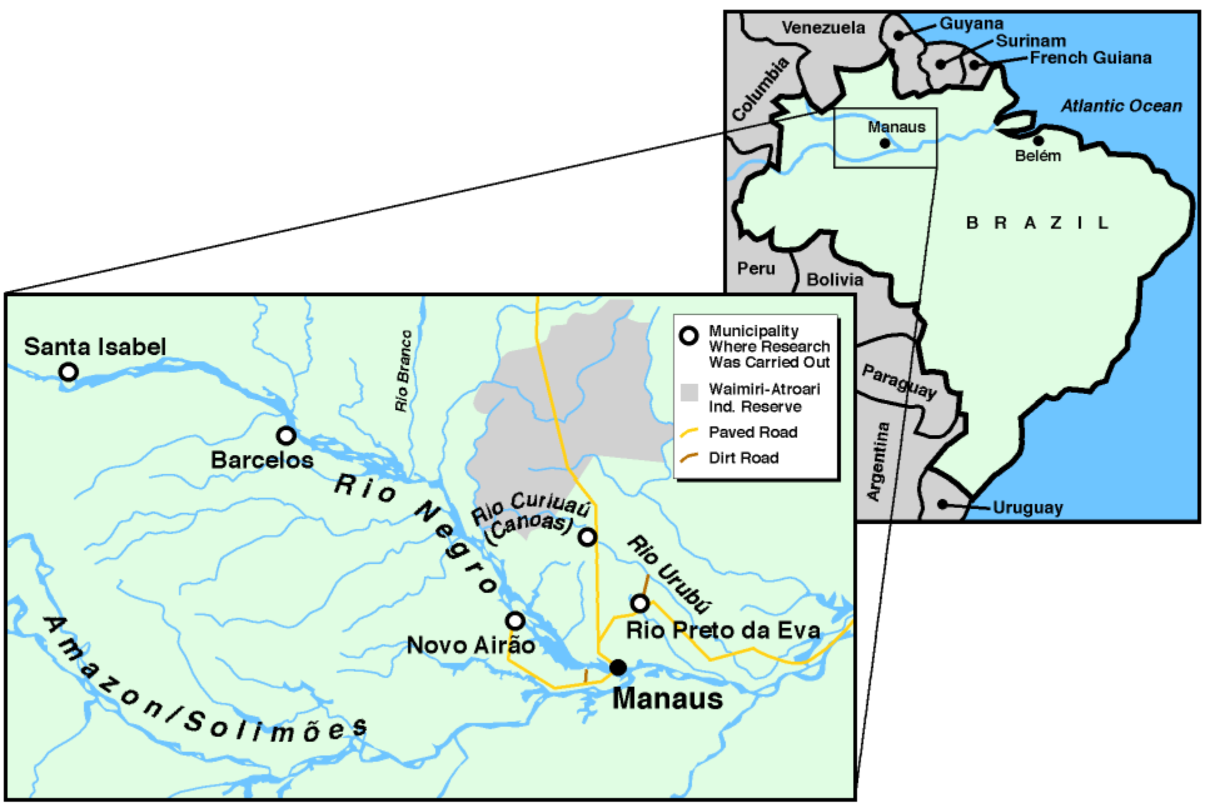
Within the debate over environmental limitations to agriculture in Amazonia, the obvious question with respect to nutrient-enhanced Black Earth is whether these soils were intentionally modified to expand livelihood opportunities in previously impoverished landscapes, as suggested by Herrera et al. (1992) and Mora et al. (1991). This was the precise question I had in mind when framing my dissertation research. If the soil substrate on Amazonian terra firme is in fact highly weathered and poor in nutrients, and if pockets of nutrient-rich anthropogenic soil defy all ecological expectation for the region (Herrera 1985; Jordan 1985b), then these soils are likely to have been modified intentionally and utilized to enhance the resource base upon which native inhabitants depended. This would in theory influence human adaptive processes in regions of Amazonia where pockets of Black Earth dot the landscape, and enhance the plasticity of the traditional swidden agricultural system – in essence de-coupling human populations from known environmental constraints.

The degree of this human-environmental de-coupling grounds the second research hypothesis, that the traditional shifting agricultural system of the Amazonian terra firme is plastic, conditioned by both the “natural” environment, and by the environmental vestiges of past human-environmental interaction. This research also permits the analysis of historical contingencies (technology, political-economics, etc.) that play a role in constraining or potentializing more diverse adaptive processes and the cultural responses to anthropogenic environments.

Chapter IV: FIELD RESEARCH

A. Geographical Setting

Several Amazonian blackwater regions were selected due to their high degree of oligotrophy, following the premise held by some scholars that the plasticity of human-environmental expression is constrained in direct proportion to levels of oligotrophy (Moran 1990): the Rio Negro (the largest blackwater region in the world) and smaller blackwater rivers of the Central Amazon (Rio Canoas, Rio Urubú) (see Map IV-1).



Map IV-1. Blackwater Regions Researched: Negro, Urubú and Canoas Rivers

Equally important, these regions have numerous Indian Black Earth sites dotting the landscape. Swidden agriculture, practiced by caboclo families in these two environments, provides a unique opportunity for comparing adaptive processes in "natural" and "cultured" environments. Furthermore, the analysis of caboclo settlement and subsistence in an environment which is at once impoverished and enhanced from the standpoint of human settlement provides an ideal context in which to analyze the plasticity of human-environmental interaction. Results of this research contribute to the broader debate on the role of nutrient-impoverished ecosystems in constraining the realm of possible alternatives for cultural adaptation in the region (Moran 1991).

The Rio Negro

One city and four primary municipal centers occupy the length of the Rio Negro: Manaus at the mouth, Novo Airão on the lower Negro, Barcelos on the middle Negro, Santa Isabel on the upper Negro and São Gabriel da Cachoeira on the upper Negro near confluence with the Uaupés. Manaus is a large commercial and industrial center, and the nexus of commercial transactions between the hinterlands and the national and international economies. The economy in each of the smaller municipalities differs as a function of the degree to which each is linked to the urban markets of Manaus and beyond. In Novo Airão and Barcelos, significant ties to outside markets make the urban economy in these environments more viable. In Novo Airão the economy is driven by boat construction, and to a lesser degree fishing, while in Barcelos the extraction of plant fibers and the ornamental fish industry predominate. While São Gabriel seems to have a more vibrant economy as a result of a mission school and military base, the economy of urban Santa Isabel appears to be very stagnant. A greater number of individuals settle in these municipal centers than can be sustained, causing most families to maintain strong ties to rural homesteads where they derive their sustenance.

The only road linking any of these municipal centers to Manaus and beyond is the paved road linking Novo Airão to Manaus, causing riverine transportation to predominate. While this makes travel slow (five to seven days between Santa Isabel and Manaus; eight hours from Novo Airão), most rural inhabitants travel by boat even when road travel is possible to facilitate the transport of goods to and from market. Other than this alternative mode of travel, the construction of this paved road linking Novo Airão to Manaus has had little effect on the communities of the lower Negro where research was carried out. This is because the only secondary roads linking up with the Negro proper are far downstream from the research site and provide no public transportation for rural residents.

Settlement patterns on the lower Negro are limited to individual homesteads and small communities of up to 40 families. Local residents travel between two and four hours by motorized canoe to Novo Airão to conduct business transactions. Production in excess of what municipal markets can absorb in Novo Airão may be taken by *recreo* (ferry) to Manaus – an option that is seldom used in practice but nevertheless provides a sense of security for local families.

The Rio Urubú

The sites researched on the Urubú are located between one and two hours upstream from the nearest road by motorized canoe. Local residents must travel by canoe, and an additional hour by dirt road to the municipality of Rio Preto da Eva to reach the closest market. This two- to three-hour trajectory to municipal markets is similar to the two- to four-hour trip that residents of the lower Negro must make to Novo Airão, although road transportation on the Urubú must be coordinated with regular trips by EMBRAPA (a governmental research institute with an oil plantation on the Urubú). Local residents seldom target the markets of Manaus to sell produce due to the difficulty of transporting large quantities of produce by bus from Rio Preto.

Rio Canoas and Rio Preto

The Canoas region is accessed by roadways that extend north of Manaus (the asphalted BR 174 that passes through the municipality of Presidente Figuereido), and on to the headwaters of the Canoas via dirt roads. While public transportation between Presidente Figuereido and Manaus is frequent, transportation along these dirt roads is difficult and the final portion of this road to the port on the upper Canoas has no public transportation. The Rio Preto runs through the municipality of Rio Preto da Eva, east of Manaus some 100 km along the paved state road AM-010. Black Earth sites along the Rio Preto fall within the municipal center, and are therefore much more accessible to municipal markets and to Manaus.

While the Canoas region abuts the Waimiri-Atroari Indigenous Reserve and has been occupied for centuries, the region was first settled by caboclo colonists some 20 years ago. A more recent *ramal* (road extension) was added on in 1996 under an INCRA colonization scheme to settle colonists and extend Institute of Colonization and Agrarian Reform's (INCRA) original area of influence (along the original roadway).

B. Phase One Research: Intensive Research on Adaptive Strategies in Lower Negro and Urubú Sites

Socio-Cultural Setting

Ethnic Composition

To provide a straightforward description of the ethnic composition of the lower Negro and Urubú regions is a difficult if not impossible task. In general, rural residents of the Central Amazon are considered caboclos, yet their complex genealogy includes indigenous, Portuguese, Afro-Brazilian, Japanese and other influences and is a direct result of the dynamic history of Amazonia. The mobility of the rural Amazonian population in response to changing economic opportunities and the influx of groups from outside the region throughout the late colonial and post-colonial periods has contributed to a much more complex cultural and ethnic mosaic than ever before. Important waves of immigrants from other countries and regions of Brazil have also had a profound influence on the meaning of "caboclo". Perhaps the most significant of these was from the northeast of Brazil and from Japan, the latter immigrating in response to an agreement between Japanese and Brazilian governments to naturalize Japanese citizens during World War II. Many of these more recent immigrants are also considered "caboclos" by locals and outsiders alike, contributing to a more generalized use of the term among *ribeirinhos* (river-dwellers) as a term of collective identity. This term is often used as well by indigenous groups as a term of self-reference, perhaps in defiance of the negative associations that have stigmatized indigenous identities throughout the historical era.

This ethnic complexity is evident among residents of the lower Negro and Urubú regions, which makes an analysis of common adaptive strategies and/or their treatment as a single population somewhat suspect. A review of family life histories, however, sheds light on many commonalities within both family demographics and subsistence. All research participants grew up in the region: along the Branco, Solimões, Tapajós and Negro rivers. Many of their parents are direct immigrants from other regions outside of Amazonia (predominantly Ceará); in other instances their fathers came to the region alone and married caboclo or Amerindian women from the region. The pull to Amazonia was invariably economic: to work as rubber-tappers (*seringalistas*) or miners (*garimpeiros*). The caboclos collaborating in research were therefore the children of either first-generation immigrants, or of a recent immigrant with a resident caboclo or Amerindian.

The similarities among collaborators derive more from individual life histories, however, than those of their families. Individuals spent significant amounts of time travelling the region far and wide with their parents, following short-lived economic opportunities. The most significant of these was work as rubber-tappers in *seringais* that were transient due to limited natural supplies of rubber. As one man describes the work of his father, "his business was to go after the money." These periods of travel provided indirect exposure to native forms of subsistence; members of the family also opened swiddens to supplement income from rubber tapping. Each family also passed through periods in which manioc cultivation was the main form of sustenance. Perhaps most importantly, collaborators have lived in current areas of residence for anywhere from eight years to their entire lives (more than 50 years) and have developed complex subsistence strategies based on both prior life experiences and experimentation.

Something that differentiates the experience of some individuals from that of others is a family or individual history of Black Earth cultivation. Knowledge of Black Earth cultivation is neither generalized nor distributed among collaborators in a clear pattern. Many individuals whose farming was limited to Latosols during my field research have family histories of farming Black Earth. Others who farmed Black Earth during the year of observation have little experience doing so, and confronted difficulty in the management of exotic crops. It was clear, however, that those who have the most success farming Black Earth had a prior history of cultivating Black Earth either with their families or cultivating exotic species during temporary work on large-scale farms of the region.

Kinship

Due to these complex histories of movement and resettlement, families in the region have few kinship ties. There are two obvious exceptions, however, to this general pattern. First, many of the collaborators moved frequently as young men in search of employment opportunities, similar to their parents. However, once finding wives, many settled and engaged in more sedentary lifestyles. As such, kinship ties are generally matrilineal. The second exception involves the marriage of their children to neighbor's children, thereby binding two unrelated families in ties of kinship. In these instances, a significant amount of sharing occurs through which each family acquires access to a greater range of products than that stemming from subsistence activities of the nuclear family alone. When observed in the field, this sharing generally extended beyond that which occurred between friends and neighbors; it is doubtful, however, if it contributes significantly to family sustenance.

Belief Systems

It is difficult to give a succinct account of local belief systems given both the complexity of the subject and the lack of systematic research in the study region. There are some realms, however, in which symbolic understandings intersect with material-ecological behavior. It is important to state up front, however, that what might be called "findings" are both preliminary and interpretive rather than comprehensive and synthetic. It represents an attempt to intuit an overarching ideology from linguistic and symbolic understandings that overlap within multiple realms of thought and behavior; it is not a simple recording of a belief system expressed as such by local informants.

While most individuals profess Christian affiliations (Catholic, Presbyterian and Evangelist), belief in supernatural beings is widespread and remains ingrained in local folklore. It is difficult to assess the extent to which each mystical-symbolic tradition influences subsistence behavior. While most accounts of beings that inhabit inland forests and waterways seem to be divorced from material concerns, others appear to have direct repercussions on livelihood. Most of these, however, relate to hunting and fishing, as indicated by the following tales of local residents:

> If I were to get game to eat, well alright. But hunt to sell, I don't agree. . . . There was this man who made a living from game. Until one day, a jaguar appeared without a pelt, covered only in flesh. Later on, another appeared in the same way. Until the man died from "craziness." – Lúcia

> The elderly used to say there was a church carved into stone. They say if you enter the church you'll find *pirarucú*[6] and manatee. If you try to grab them, you become possessed. – Dalva

> One day a man was fishing, and spotted a *pirarucú*. As he made the motions to harpoon this giant fish, dolphins jumped out of the water to block his aim. Angry, the fisherman vowed to return the following day and harpoon the

[6] Arapaima gigas – renowned in the region for its large size and ability to swallow humans whole.

> dolphins themselves. The following day, the same event occurred while he was fishing *pirarucú*, and instead of getting the fish he sunk his harpoon into a dolphin. A family of dolphin then frightened him into letting loose of the harpoon. Upon returning home across the river, a large boat with "gringos" – red men – stopped and invited the fisherman on board. They asked him to close his eyes, and the next thing he knew he woke up in the *encanto* [the enchanted underwater world]. He was brought to this room to see the coronel, who sat in a throne with a harpoon in his back. If he were successful in removing it, he could return to his life; otherwise, he would stay forever in the encanto. When the coronel improved, they told him, "If you ever harpoon again, you will never return from the encanto." He next woke on his doorstep. – Waldecir

In very general terms, it is not uncommon to hear individuals express their ideas involving what in secular terms might be called environmental limitations. The following statements by local residents attest to a diversity of ideas regarding the boundedness of material life:

> You know how it is, life with life. When you work with things that have life, they aren't always going to produce. Things with life have their time. – Lúcia

> Cattle are like sweet pepper. You plant one pepper plant, and you will see that she produces well. Now, you plant 20 pepper plants and you see that disease appears. Cattle the same way. You can raise [one animal], but with three animals you begin to have problems. – Pelado

> This is why it [my swidden cleared from fallow vegetation] has disease, because where it was "brute" forest, there was no disease. – Luzia

These common-sense understandings of natural limits to productivity contrast with commentaries stemming from Christian belief systems. In response to governmental policies to conserve critical resources, many individuals have observed the recuperation of flora and fauna that were once at risk. In contrast, one women very involved with the Evangelist church (in the lower Negro) stated the following with respect to environmental limits and dietary taboos:

> Doesn't the Bible say that animals are under the dominion of man? – Dolores

> What God left for us doesn't run out, no. The population continues increasing, but food goes on increasing as well. – Dolores

While these beliefs are central to research that looks into environmental plasticity, it is difficult to trace origins *or* consensus in these belief systems. The obvious exception is the Christian concept of dominion, yet the more salient beliefs are those acknowledging limitations rather than boundlessness of material life. These beliefs appear to stem from secular understandings based on learned experience and others from shared symbolic understandings rooted in often-told stories and myths about the supernatural.

Similar to other Amerindian traditions, symbolic understandings seem to break down into two realms that roughly correspond to culture/nature and culture/supernature dichotomies (Descola 1994; Viveiros de Castro 1992). This dichotomy may be observed in concepts of beauty, in understandings of the nature of other beings (human and non-human), and in processes of domesticating plants and ecosystems.

Local residents differ from conservationist-minded outsiders in their understandings of beauty. For them, the tamed or domesticated is beautiful. The common practice of sweeping the litter or *lixo* (lit. "garbage") from fruit gardens and areas of residence is one indication of this. As one long-time resident of the lower Negro states, "When we arrived there was only forest and now [the community] is *no limpo* (clean/cleared); now it is better." Ironically, plant residues and weeds are the more prototypical *lixo*, whereas urban or domesticated garbage (plastic, tin) are less worrisome and are left strewn about. This concept of beauty is also seen in the domesticated landscape. One long-time farmer spoke with pride about her role in converting the landscape through swidden agriculture.

The one tract of mature forest that remained as she looked towards the landholdings of upstream residents was a source of displeasure for her. "So I said to him," she says, in reference to her neighbor, "'take down this mata [forest], then it will look pretty.'"

Understandings of other beings have a similar dichotomy: "The parrot has feelings," states one local resident, "creatures of the forest don't have this affection, no." The parrot somehow occupies an intermediate status between the wild and tame. Distinctive understandings and behaviors seem to govern each realm. When commenting on which land mammals are fit to hunt, for example, one informant commented that it isn't right to kill sloths or primates "because they are very tame," and therefore in some way part of the cultural realm. This contrasts a great deal with treatment of indigenous peoples, who are strongly scorned for cultural behaviors that penetrate too far into the world of the untamed: "The *Índio* is like jaguar. He never completely civilizes. He easily turns on you." This use of the term "civilized" is widespread, and reflects an appropriation of colonial attitudes towards the "savage" or untamed. Calling somebody *Índio* is the worst of insults, as reflected in this woman's criticism of her sister, "Savage *Índia* . . . illiterate, all of her life spent there, without leaving [getting out to learn and see things]."

The nature/culture distinction is also evident in understandings of the domesticating processes of plants and ecosystems. A strong *linguistic* dichotomy exists between domesticates and invasives, independent of the continuum that exists in the degree of domestication of diverse species and in the behaviors towards them (i.e., how to classify and manage utilitarian species or semi-domesticates when they colonize a swidden). The word "plant" (*planta*) refers only to domesticates, while the remainder are cloaked as *mato* (roughly "weed", understood as useless and untamed). A common response to questions about whether any given plant is useful ("*É planta*?"), for example, is, "No, that is *mato mesmo*, wild." A similar linguistic dichotomy is applied to soil that has been domesticated through the burn, as evidenced in the contrast set *crua*/*queimada* (raw/burnt). This domestication of soils is considered temporary, however, as indicated by the justification for letting a swidden go to fallow: "It's because the manioc tubers won't grow anymore. The soil is very raw."

While the culture/supernature dichotomy does characterize local distinctions between phenomena that lend themselves to secular explication from those that defy such understandings, the supernatural penetrates both natural and cultural realms. As such, culture/nature and "nature" (secular)/supernature (symbolic) dichotomies are by no means isomorphic. On the one hand, creatures of the forest that are considered a threat to humans are called *feras* (roughly, "wild beast"), and ascribed distinctive properties from the human realm: "Jaguars will attack people . . . it's not because of hunger, no, it's because they are *feras*." Countless mythical beings are known to inhabit the forest and waterways, while secular/"natural" beings are also ascribed mythical powers (jaguar, freshwater dolphin). These understandings penetrate everyday experience in the form of fear for phenomena that defy simple secular understandings (i.e., the otherworldly). Both the natural world and the supernatural are seen as somehow above humans and beyond their control, paralleling earlier observations on environmental limitations. Yet supernatural powers also penetrate the cultural realm, as evidenced in the abundance of an herb (*peão roxo*) known to protect families from the "strong" or evil eye (*olhar forte*) near sites of residence. In response to poor crop performance, one man claimed it was because a pregnant woman (known to have a particularly strong *olhar*) entered his swidden, saying, "I have it proven." Where humans fail to exert control over nature, supernatural understandings are often employed as means for explanation.

These symbolic understandings influence agricultural practices in a number of ways. First, domestication of the natural is considered fundamental to swidden productivity, as evident in the widespread use of the burn and timely weeding. Contrary to the conventional swidden model characterized by high structural and biological complexity (Conklin 1954), neatly-ordered, rectangular swiddens with few weeds are favored esthetically. Second, these understandings come into play in interpretations of the novel properties of anthropogenic Black Earth. The existence of a *naturally* burnt soil is an irony, given that prior to cultivation (domestication) soil is known to be raw and untamed. While local residents acknowledge this burnt status, they tend to maintain that soils are a product of nature alone. This is evidenced in the reluctance to acknowledge anthropogenic origins despite much evidence to the contrary (its burnt status, presence of artifacts and domesticated species, etc.). "If man could make soil," they state, "we would all be doing it." The *Índio*, seen as somehow inferior, could not possibly achieve such a feat, equivalent of "civilizing" nature itself. They explain this, rather, as the tendency for Indians to recognize and inhabit fertile soils when they encountered them. Finally, limitations to production are understood as a state that has somehow reverted to the natural or to the supernatural. Supernatural understandings are readily employed to explain crop failure, for example. Given the higher incidence in fitosanitary problems with the exotic crops grown on Black Earth, these understandings are often called upon to explain phenomena that defy secular explanation within these anthropogenic environments.

Political-Economic Setting

Traditional residents of the lower Negro and Urubú regions have followed worldwide trends in responding to influences of economic globalization (Anderson and Ioris 1992; Bunker 1985; Rudel and Horowitz 1993). These influences are evident in economic strategies aimed at urban centers rather than local gifting and exchange, and in the development of subsistence strategies that effectively combine both subsistence and market orientations. Each family engages in complex subsistence strategies in which diverse activities are effectively combined to satisfy consumptive needs while providing limited income for the purchase of basic industrial products: sugar, coffee, salt, cooking oil and, occasionally, beans, rice, pasta and flour.

While hunting, extractivism and animal husbandry (with the exception of cattle) are largely subsistence-only activities, fishing and agriculture may be carried out for subsistence and/or market, and full market orientations are found with carpentry, logging and cattle. Furthermore, while each family combines diverse subsistence and market-oriented productive activities to balance the respective benefits of each, the particular way in which each family combines livelihood strategies is highly variable.

Despite this variability in combined subsistence strategies, the lower Negro and Urubú regions share many similarities regarding the role of political-economic influences in adaptive behavior. Residents of each region have the option of selling their produce in a variety of settings: among neighboring families who engage in other productive activities, in municipal markets (where demand for rural produce is nevertheless limited), and in Manaus, where a fully urbanized population has posed strong challenges to regional food self-sufficiency and created a high demand for traditional and modern foodstuffs.

Access to local, municipal and urban markets is similar for field sites on the Urubú and lower Negro. First, the presence of groups within each region that dedicate themselves fully to non-agricultural income-generating activities has catalyzed local demand for agricultural produce. On the Urubú, employees of EMBRAPA's nearby oil palm plantation fulfill this role, while on the Negro a similar demand is generated by families who dedicate themselves to carpentry. Second, the nearby municipal markets of Novo Airão (on the lower Negro) and Rio Preto da Eva (near the Rio Urubú) have limited demand for agricultural products yet are connected to Manaus via inland roadways. As mentioned before, families on the Negro travel by river to Manaus and Novo Airão, while on the Urubú they must travel both by river and dirt road to urban markets. The road portion of the Urubú trip is free of charge, however, due to the assistance that EMBRAPA gives to local residents during regular trips to transport workers and materials. Despite these differences, the accessibility of each of these regions to municipal markets and Manaus is similar in terms of labor and capital investments. These similarities justify the uniform treatment of these regions with respect to the role of external political-economic factors, enhancing their comparability in an analysis of adaptation to specific ecological conditions.

While the costs and benefits of targeting each market reflect location-specific demands for diverse products and must be assessed accordingly, nearby municipal markets are utilized most frequently in both regions to sell agricultural produce. Prices in Manaus are invariably higher; however, the costs of transport often do not warrant the effort. The one exception involves the production of exotic vegetable crops on Black Earth, for which local demand is limited. While most farmers continued to target municipal markets despite this limitation, one full-time Black Earth farmer frequented both markets. The decision rested on frequent calculations of the costs and benefits of each, including relative sale prices, transport costs and the size of the harvest.

Additional political-economic influences on the adaptive strategies of local residents include institutional policies that regulate land use. The most salient of these are those of *Instituto Brasileiro de Meio Ambiente e Recursos Naturais Renováveis* (IBAMA), formerly SEMA, that regulates certain hunting, logging and agricultural activities. These policies should be classified into two categories: those policies that target specific protected areas, and those that are more widespread and generalized.

Policies targeting specific areas are of more concern here, given their potential to differentiate adaptive strategies between research sites. The Anavilhanas Ecological Reserve spans the area of study on the lower Negro, for example, an influence that is absent from the Urubú. In the Anavilhanas archipelago, the felling of timber for sale or agricultural production is forbidden, while fishing and hunting are allowed solely for subsistence purposes. These restrictions are actually beneficial to the analysis of adaptive processes within blackwater ecosystems. Soils on the archipelago's countless islands are known by local residents to be the most productive naturally-forming soils of the region, given the yearly influx of sediment-rich waters from the Rio Branco, a whitewater river that joins with the Negro above the study region (see Map IV-2). However, it is evident from visual inspection of this satellite image that this influence is limited in the lower Negro region, where the color of blackwater is similar to that of other blackwater regions with no such whitewater "contamination." Nevertheless, the elimination of this confounding influence of a distinctive ecosystem is beneficial, and creates a sort of natural experiment that effectively isolates the influence of whitewater ecosystems on blackwater agriculture. As a result, in both the lower Negro and Urubú regions, cultivation is restricted to the nutrient-poor terra firme. Flooded forests along the Urubú River and the right margin of the lower Negro are all seen as unfertile for agriculture and left intact.

Map IV-2. The Influence of Whitewater in Relation to Research Sites, Lower Negro River

One final instance in which institutional policies influence adaptive strategies involves land tenure. In each region, the *Instituto Nacional de Colonização e Reforma Agrária* (INCRA) acts as the official state agency to regulate land tenure. Residents are encouraged to register (*cadastrar*) their claims to land acquired through simple occupation (*posse*). This effectively stakes out rights to utilize specific areas of terra firme and protects land occupants from intrusion. It also individualizes land ownership at the level of the nuclear family, effectively precluding communal forms of ownership, occupation and use. It was evident from family histories that this form of occupation is older than INCRA itself (established in the 1960's), and communal production has been limited to labor exchange as far back as people can remember. The most significant way in which these policies modify adaptive processes involves the possession of lands that have ownership yet no current occupation (*terras devolutas*). Occupants are required by law to demonstrate current usage of occupied lands to maintain rights of possession; as such, absentee owners often encourage landless families to occupy and farm their lands. These families are reluctant to make long-term investments in this land, for fear of reaping no benefits from their labor. This is most evident, however, in houseyard gardens (where perennial fruit trees are grown), use areas that were only peripheral to this research.

One final political-economic influence on land tenure deserves mention. SUFRAMA, an institution created by the military government in 1967 to encourage intensive agriculture and industry in the vicinity of Manaus (Schmink and Wood 1992), presides over land tenure decisions along the western (right) margin of the Urubú River. This program failed to catalyze intensive agriculture and industry in the region due to short-sighted and unrealistic goals for land use and productivity (Ibid), and has therefore failed to pose any real risks to local residents of the Urubú. Nevertheless, local residents hold some reservations due to the fact that rights of possession remain obscure. As such, collaborating families have made efforts to secure lands on the eastern margin of the Urubú by registering these properties in the names of female heads of household, leaving the rights to original properties to be negotiated in the names of male residents. The impact of these decisions on subsistence behavior has been to incorporate additional, generally non-anthropogenic, soils into the subsistence strategies of each family.

Caboclo Subsistence

To understand the adaptive strategies utilized in anthropogenic and "natural" terra firme environments, each farming system must be seen as part of a broader subsistence system in which individuals balance the constraints and opportunities of alternative economic activities and seek to maximize benefits while decreasing risk. As such, the agricultural system, defined by Krantz (1974) as "the entire complex of development, management, and allocation of resources as well as decisions and activities which, within an operational farm unit or a combination of such units, results in agricultural production, and the processing and marketing of the products," expands outwards to encompass the entire subsistence system. While giving analytical primacy to the agricultural system may fail to reflect real subsistence priorities of caboclo families of the lower Negro and Urubú regions, it is useful for research questions that select, a priori, agricultural adaptations as the primary area of inquiry.

While no assumptions are made about the primacy of agricultural activities in the minds of informants, nor about the directionality of causal relations, this approach sees the interaction between system components (agriculture, fishing, etc.) as fundamental to the resulting patterns of labor and resource allocation in each. The definition proposed by Norman (1979:3) for farming systems – "the pattern of resources and processes of resource use in a farming unit" – is perhaps better suited to encompass these system-wide relations. For Norman, patterns of resources include natural resources, human resources (knowledge systems, labor), and capital, as well as what he terms "incipient products" or system output (for consumption or sale), while the process of resource use refers to the physical and biological processes or sub-systems that underlie farming operations. Defined broadly, both the patterns and process of resource use have system-wide articulations with other subsistence systems, as evidenced in the division of limited amounts of household labor among distinctive productive activities, or the choice between allocating land to agriculture and to hunting and gathering activities.

In the lower Negro region, patterns of resource use reflect household-level decisions to engage in one or more of the following activities: agriculture (traditional manioc swiddens, or Black Earth cultivation), fishing, hunting, animal husbandry, extractivism (of natural fibers, timber, fruits and medicinals), carpentry and to a limited extent, day labor. Alternative productive activities on the Urubú are similar; however, there is no such tradition of canoe-building and opportunities for earning day wages are almost unheard of. A brief introduction to each of these economic activities and to their relation to agricultural production is helpful for understanding system-wide interactions and farmer decision-making associated with the spatial and temporal distribution of critical resources.

Traditional Swidden Agriculture on Latosols

The division of swidden agricultural tasks into diverse steps is useful for heuristic purposes, and roughly corresponds with real stages in labor and resource allocation for shifting cultivation systems worldwide (Peters and Neuenschwander 1988).

Site Selection. Field sites may be selected from primary forest (*mata bruta*), mature secondary forest (*capoeira velha*) or more recent fallow (*capoeira nova*, or simply *capoeira*), although a minimum fallow age of ten years is seen as necessary for restoring a minimum level of system fertility. While primary forest is preferred due to the opportunity for deriving higher net yields, the ability to re-plant several times and reduced problems with weeds (see also Ruddle 1974), farmers perceive an allopathic effect between decomposing roots and crops when the burn is insufficient to mineralize the belowground biomass. At the other extreme (younger fallow), significant yields are sustained for only two cropping periods (a cultivation time of two to three years), and labor inputs are higher due to residual invasives. Mature secondary forest generally presents optimal conditions for cultivation, a pattern that has also been documented in other tropical regions (Conklin 1957).

Site selection based on optimal properties of the forest to be cleared is limited, however, by increased sedentism in recent decades and other important criteria for site selection. Impacts of sedentism are still limited for the target population, however, in which 64% of families continued to clear from primary forest (generally the newer arrivals to a chosen swidden area). Other criteria entering site selection include relatively flat terrain, soil quality, tenure arrangements and distance from residence areas. Given that soil differences are primarily textural and that each textural class is preferred for different reasons (the crops that grow better there), the strongest constraints appear to be land tenure and distance from areas of residence. The latter is particularly acute with long-term residents, where the labor associated with farming at a distance generally warrants the higher labor inputs associated with weeding younger fallows (at closer distances). Ultimately, while site selection criteria are largely shared between families, there are distinctive trade-offs faced by each as a result of residence history, particular biophysical characteristics of the site and household labor constraints.

Land Clearing and Preparation. Clearing implements and strategies are classified according to targeted vegetation. Local residents distinguish between two activities, the *roça* (slashing) and the *derruba* (felling). Felling is limited to primary forest and mature secondary forest, where trees are considered too large to cut with a machete. Slashing is carried out in these same areas prior to the *derruba* to clear understory vegetation, and is the only clearing method employed in areas of younger fallow. While machetes are universally used for slashing, felling is generally done with a chainsaw. The few families who can't afford to purchase or rent a chainsaw continue to fell with metal axes.

Slashed vegetation and felled trees are left undisturbed to dry before burning. To my knowledge, no burning enhancement activities are carried out such as those documented for New Guinea (Clarke 1971; Norman 1979) other than effective timing with rains. Timing is of utmost importance to the success of the burn in tropical swiddens (Peters and Neuenschwander 1988), and is expressed as such by caboclo farmers of the study region. The imperative of a dry-season burn also places significant constraints on labor during the dry season, which extends from approximately June to November. While this seems like a large window of time, mature forest requires approximately a month to slash and fell and two months of drying time to ensure an effective burn. Furthermore, locals recognize the importance of planting soon after the burn and prior to heavy rains to avoid nutrient losses through leaching. This places further temporal constraints on site preparation.

Traditional systems vary in the importance placed on the burn. In some regions, thoroughness of the burn is regulated to suit the intended crop (Clarke 1971; Peters and Neuenschwander 1988). In the study region, however, an effective burn is seen by local residents as essential to swidden productivity indiscriminate of crop selections (see also Smole 1976). According to Peters and Neuenschwander (1988), the most important effects of the burn on highly acid soils is an increase in exchangeable cations and pH, although phosphorous inputs are also likely to be critical for these ecosystems where it is known to be a limiting factor. These chemical changes are seen as critical to site productivity for tropical swidden farmers, as indicated by the more limited changes in fertility that stem from changes in soil humus and cation exchange capacity when burns are substituted with litter additions (Nye and Greenland 1960).

The importance placed on the burn by local residents is perhaps best demonstrated by the semantic distinction between raw (*cru*) and burned (*queimada*) soils. *Terra crua* is seen as infertile, capable of producing nothing. The use of this terminology as a descriptor for (the state of) soils also demonstrates that the critical distinction is not the addition of ash, but the burning of the soil itself. Ash is understood as fertile, but a fully burnt soil is nevertheless considered a necessity independent of ash additions. The discrepancy may extend beyond fertility per se and reflect the perceived antagonism between decomposing roots and slash on the one hand, and tuber development on the other.

The effectiveness of the burn is measured primarily in terms of the ease of mobility within a swidden (i.e., the elimination of physical obstructions) and the burning of belowground biomass which again enhances tuber development. The practice of re-burning leftover slash from the first burning event is common to many tropical swidden systems (Peters and Neuenschwander 1988) and also to those of the study region. While aimed at "cleaning" the field, the piling up and firing of slash creates isolated patches of nutrient-rich soil (*covas*) that are targeted for more nutrient-demanding crops. The widespread nature of this practice is indicated by its uniform semantic-linguistic coding as *coivara*, meaning the practice of re-burning slash in isolated pockets. The generalized usage of the coivara is telling for soil fertility, given that groups who do not consider a complete burn essential for crop yields usually eliminate this step altogether (Peters and Neuenschwander 1988).

Planting and Weeding. Farmers of the central study region plant on flat terrain rather than mounding and ridging. Mounding is limiting to yams. While multiple benefits of mounding are cited in the literature (Norman 1979), Latosol farmers tend to mound to concentrate nutrient-rich topsoil and to enhance soil aeration. This practice helps to surpass critical fertility thresholds for targeted crops, while the latter facilitates the growth of tubers (Ibid). Hoes are used both for mounding and for planting bitter manioc through minimal tillage, where isolated pockets of soil are aerated prior to planting. Seasonality in Latosol swiddens is limited to the site preparation phase in which the timing of the burn is critical, and to planting (for which manioc and a few other crops are generally planted "with the moon"). The new moon is seen as favoring vegetative growth and tuber development.

Unlike the classic model of swidden agriculture in which fields are known as having high structural and biological diversity (Conklin 1957), Latosol swiddens are limited to a few crops. With the exception of edible invasives and fruit gardens, cropping nearly always limited to bitter and sweet manioc, yams, sweet potato and banana. Manioc is by far the most abundant of these. This corresponds with the tendency for root crops to predominate as staples in tropical rainforest swiddens (Peters and Neuenschwander 1988; Ramakrishnan 1992), and for manioc to predominate in those of lowland South America (Brochado 1977). During the first year, manioc is planted throughout the swidden, while banana, yams and sweet potato are planted in isolated pockets of higher fertility. During subsequent years only bitter manioc is replanted, yet due to the extended yields of banana these plants are also maintained throughout subsequent plantings of manioc and often into the fallow stage. This decrease in the range of crops planted in a single field from early to late stages of the cropping phase is common in tropical swiddens, and reflects the narrowing options imposed by a deteriorating environment (Norman 1979; Ruthenberg 1980). It also suppports the determinist argument of Meggers (1971), in that monoculture under shifting cultivation is known to be more common with increasing environmental limitations (temperature, seasonality, fertility) (Ibid). These conditions presumably restrict the range of cultivable crops.

Farmers tend to exploit the full range of microenvironments within a swidden, in addition to intentionally creating them through the coivara. Examples include the use of burnt logs (downed or standing) to plant yam, banana and in one swidden, ginger. This practice is widespread in tropical shifting agricultural systems (Hecht and Posey 1989; Norman 1979).

Manioc is harvested anywhere from 8 months to 1 ½ years after planting. Crop residues and weeds are either left on the soil or burnt to enhance the following year's yield. When the field is to be left to fallow, weeding generally ceases prior to harvest and the swidden resembles a field gone to fallow despite the manioc crop that remains. When the area is harvested, the slash is left rather than burnt, a further indication of swidden abandonment.

Harvest and Post-Harvest. Contrary to other swidden agricultural systems in which yields steadily decrease after the first year (Andraea 1980; Peters and Neuenschwander 1988), farmers on the lower Negro claim that yields often dramatically increase during the second year of planting. This is particularly true in swiddens cleared from primary forest, in which the decomposing root mat and belowground biomass "heat up" the soil during year one, making it unfavorable to crops. This may be due to the negative influences of decomposition on crop growth, perhaps resulting from nitrogen depletion that may ensue from high C:N ratios in the decomposing roots and slash (see Magdoff 1992).

With the exception of bitter manioc, all of the harvest on Latosol swiddens is destined for household consumption. It is rare, however, to find a family that produces manioc strictly for household consumption. For most families, approximately half of the manioc flour produced on-farm is destined for market or local sale, while families that rely on Latosol swiddens for their primary source of income sell close to 80% of the total harvest. Local sale of manioc flour has become more common in recent decades due to an increase in the numbers of individuals who dedicate themselves to alternative economic activities on the lower Negro (i.e., carpentry) and to the proximity of wage-earning families at the EMBRAPA research station downstream from Rio Urubú sites.

While other foods are consumed directly or through simple cooking procedures, bitter manioc is understood as toxic in its unprocessed form. It is therefore subject to labor-intensive post-harvest processing to derive edible products (manioc flour, *beijú*, manioc starch or *goma*, tapioca, *pé de moleque*, etc.) (Grace 1977; Holleman and Aten 1956). Families of two to six individuals spend approximately five days harvesting, peeling, grinding, draining, sieving and roasting manioc flour to derive anywhere from two to five 75-pound bags of flour. These are sold for Rs. 17 to 35 each (U.S. $10 to $20.60). Other products are consumed at home, with the possible exception of manioc starch or *goma* which is sold at Rs. 0.60/kilo (U.S. $ 0.52).

Site Recovery/Fallow. Unlike some other swiddens documented for lowland South America (Denevan and Padoch 1987), there is a distinctive point at which swiddens are abandoned in the central study region. Succession is not managed nor are useful species planted after the harvesting of annuals, as has been documented for other systems (Balée and Gély 1989; Bartlett 1955, 1956; Irvine 1989). The use of fallows is limited to soil regeneration, the harvest of weed-resistant crops that were planted during the cropping stage (primarily banana and manioc) and useful, fire-resistant species. The last originate in the forest prior to felling, survive the repetitive burning associated with swidden cultivation and produce during the fallow stage.

Successional pathways are known to be influenced by decisions made at each stage of swidden evolution (Peters and Neuenschwander 1988). The lack of quantitative botanical studies requires that I focus solely on a few clear patterns that emerge from qualitative observations. As is true for the succession of tropical fallow communities in general, trees tend to replace shrubs, lianas increase in abundance and herbaceous species decrease upon swidden abandonment (Harris 1971). There are many exceptions, however, during early stages of the cropping cycle. The umbrella tree (Cecropia spp.) is generally the first to colonize new swiddens and does so in abundance; other common early colonizers include shoots sprouted from the stumps of woody plants (trees and lianas felled during swidden clearing) that generally survive the full planting cycle. Rapid regeneration of these trees is made possible from well-established root systems (Peters and Neuenschwander 1988). An important anthropogenic influence on successional communities on Latosols is the persistence of fire-resistant palms, which are left in the swidden during clearing and thrive with fires of medium to low intensity. The most resistant of these, and therefore the most abundant, is *tucumã* (Astrocaryum spp.).

Farming Systems on Indian Black Earth

Black Earth cultivation systems in many ways resemble traditional shifting agriculture on naturally-forming Latosols. System fertility is maintained through the burn, swiddens are cropped for a period that corresponds to both growth cycles and minimum fertility thresholds of preferred crops, and fallows are left to regenerate through unmanaged successional processes. There are, however, many generalized management differences that provide a background to the analyses that follow. I have again treated these differences according to distinct stages in swidden evolution.

Site Selection. Local residents identify Black Earth first by the properties of vegetational communities that occupy these sites: the smaller average girth of mature trees, the greater abundance of exotic species and/or the higher proportion of native semi-domesticates. Local residents attest to this higher abundance of useful species for any abandoned settlement, however, independent of soil type. Nevertheless, they claim that certain useful species are restricted to abandoned Black Earth sites or found in much higher abundance there (see Table IV-2). The most salient of these, as mentioned by nearly all informants in the central study region, is *caiaué*. This species, a relative of the African oil palm, produces an edible oil and is absent in the forests surrounding researched Black Earth sites.

Table IV-1. Forest Species Common to Black Earth Sites, As Identified by Local Residents

Classification	**Common name** (Portuguese)	**Common name** (English)	**Scientific name**
Exotic Domesticates found on Black Earth	*Manga*	Mango	Mangifera indica
Native Semi-Domesticates Found in Higher Abundance on Black Earth	*Açaí* *Bacaba* *Tucumã*	Açai palm - Star nut palm	Euterpe oleracea Oenocarpus distichus Astrocaryum spp.
Black Earth Indicator Species[a]	*Caiaué* *Limorana* *Taperebá* *Camu-camu*	Oil palm Arrow cane Hogplum -	Elaeis oleifera Gynerium sagittatum Spondias mombim Myrciaria dubia

[a] Exotic plants that are claimed to occur solely on Black Earth.

Locals recognize that no primary forest exists on Black Earth. They derive this understanding from similarities between plant communities on Black Earth and other old fallow sites rather than by an understanding of the anthropogenic origins of Black Earth. For this and other reasons, a distinct classification system exists for the vegetational communities in which swiddens may be cleared on Black Earth: mature forest (*capoeira* *de Índio*, or Indian's fallow), new fallow (*capoeira nova*) or scrub vegetation (*mato*). "Capoeira" nova generally refers to areas that were cleared in recent history, while "mato" refers to weedy vegetation that has not quite gone to fallow, aged anywhere from a few months to a year or more. It is not yet considered capoeira (fallow), and generally results from only a temporary lapse in weeding and cultivation. While capoeira de Índio and capoeira nova are preferred due to higher fertility indices, mato is often cleared due to the limited labor investment required for planting. A minimum of two years of fallow is considered necessary to restore soil fertility after the soil tires.

Given the limited spatial extent of Black Earth, the additional criteria influencing site selection on Latosols (terrain, soil quality, tenure arrangements and distance from residence) are less critical to site selection on Black Earth. The terrain is almost always flat and close to sites of residence, presumably because Black Earth was formed from settlements that were (and continue to be) located on preferred landforms. Ownership considerations are important inasmuch as they determine a family's access to Black Earth; they do not influence site selection between alternative Black Earth sites. I found only one exception to this general rule, in which one Urubú couple legalized their occupation (*posse*) of two Black Earth sites by placing one name each on two separate deeds. While they have yet to farm the second site, they have high hopes for the second sight due to its higher clay content, which they associate with higher soil fertility.

Land Clearing and Preparation. Black Earth sites are generally fully cleared with a machete, with the exception of capoeira de Índio, where the girth of many trees is too large to fell with a machete. Unlike the practices common to Latosol farming, piles of slash are often created directly after clearing an area to achieve a more complete first burn. This practice is perhaps more a reflection of timing than fertility enhancement per se, given that clearing and burning an area of Black Earth in the "winter" or rainy season is common and the success of the burn often rests on a higher concentration of plant biomass. While informants agree that Black Earth sites burn better in the dry months, they also believe that unlike manioc farming on Latosols, this is not a necessity. As such, fewer constraints are felt in the timing of Black Earth site preparation. This is an important point, given that absolute constraints on the timing of Latosol site preparation would only increase labor shortages should the labor peaks of these two systems coincide. The economic incentives to cultivating vegetable crops in the rainy season when the floodplain is inundated make the benefits of this winter burn even greater.

Winter burns are nevertheless less effective. This common practice is therefore telling given the importance placed on the burn by Latosol farmers, and is perhaps most indicative of the heightened soil fertility on Black Earth. This observation is corroborated by the tendency of local residents to cognize Black Earth as *both* naturally-forming and burnt, something that would be seen as the ultimate contradiction for forested Latosols (understood as naturally-forming, yet raw and unfertile). In fact, when questioned on the status of Black Earth informants were reluctant to state the obvious (i.e., that it is burnt-looking)[7], which reflects what I believe to be a semantic contradiction. A soil under mature forest is thought of as raw despite prior usage, given that remnants of prior burns associated with swidden agriculture are transitory. A soil that maintains these qualities for years and even decades after abandonment when under forest vegetation fails to fit this cultural model.

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[7] Only 58% of informants answered "yes" regarding the burnt status of Black Earth, while 100% of informants answered a firm "no" to the burnt status of Latosols.

The burning of leftover slash from the first burning event (the coivara) is common only on Black Earth sites with a history of repeated cultivation, or during winter months when the swidden often remains cluttered after the first burn. I witnessed the planting of squash, West Indian gerkin and yams in the resulting *covas*. This practice is not as widespread on Black Earth as on Latosols, due to both the higher "inherent" fertility and to the lesser combustible biomass on Black Earth.

Planting and Weeding. Black Earth farmers also plant in the flat, yet those farmers with more experience planting vegetables for market create mounds and ridges for certain crops (in particular, cucumber, papaya, sweet pepper and tomato). Planting does not follow lunar cycles on Black Earth; planting times depend, rather, on labor and market considerations, and on the seasonality of the particular crop. While crops such as papaya are sensitive to drought, others such as peppers, red bean and watermelon become easily diseased during the rainy season.

Black Earth swiddens tend to be more diverse than Latosol swiddens; however, structural diversity is only attained with staple crops. When manioc is cropped it is generally intercropped with maize, particularly in the season immediately following the burn. These areas are often further intercropped with other crops such as squash and red bean. Areas that are dedicated to a vegetable cash crop are generally monocropped, most likely to facilitate the labor-intensive management requirements of these crops. This reduces the structural diversity of the swidden; however, throughout the Black Earth site there are generally several swiddens in cultivation at once, each with its own particular association of crops. This practice enhances both spatial and temporal aspects of swidden biodiversity.

Vegetable crops planted in the above manner include watermelon, West Indian gerkin, cucumber, tomato, sweet pepper and papaya (considered a vegetable, or *legume*, by locals). When bitter manioc is planted on Black Earth, planting techniques are similar; however, it is intercropped with maize and other crops until these are harvested. From this point until the manioc harvest, it will remain a monocrop. Each of these areas will generally be planted again only after a year or two of fallow, or (minimally) a few months of weed overgrowth. Subsequent plantings (after crop residues and low-lying mato is burned) may include any of a number of crops. This ability to plant nutrient-demanding crops again after only a short period of fallow or re-growth is an anomaly for the region, given the tendency for the range of crops to sharply diminish from early to late stages of the swidden. This would indicate that Black Earth has a higher natural fertility; however, this fertility is crop-specific. Banana, for example, is a crop that is never planted on Black Earth due to its failure to bear fruit.

The practice of exploiting microenvironments is less common on Black Earth, presumably due to the relatively good performance of crops throughout the swidden and the fact that less heterogeneity is created from fallow than mature forest. The high volume of weeds created in Black Earth swiddens, however, provides the possibility for creating such microenvironments by accumulating and burning this material. Yet few farmers exploit this opportunity, and if they do so it is generally experimental. One farmer accumulated weeds and crop residues in ridges, where he later planted watermelon.

After harvest, the swidden quickly “closes in” with weeds (*cerra*), causing farmers to prefer the clearing of adjacent land to maintaining those swiddens already in production. Yet this does not necessarily constitute abandonment. The threshold between cropping and abandonment is much more diffuse for this reason, given that mato can easily become fallow, or otherwise be re-cultivated prior to the establishment of a legitimate fallow. The only evidence that this distinction exists in the minds of local residents is a linguistic one, namely the distinction between "mato" and "capoeira". Management practices generally reflect a continuum rather than this clear distinction.

Harvest and Post-Harvest. Similar to other swidden agricultural systems (Andraea 1980; Peters and Neuenschwander 1988), yields on Black Earth decline throughout the cropping period of the swidden cycle. However, yield decline is perceived as being less abrupt than on Latosols. According to local residents, when soils "tire" on Black Earth they still produce, albeit meagerly, and quickly regain fertility through a short period of fallow. When yields decline on Latosols this drop in fertility is seen as absolute with respect to both yields and recuperation time.

Contrary to the patterns on Latosols, bitter manioc is singled out as the crop that is *least* destined for market. A smaller area is cropped on Black Earth due to the demands of alternative crops on farm labor, and vegetable crops bring higher prices in regional markets due to simple supply and demand. The latter is particularly true in Manaus, where demand is relatively high, regional production extremely low and importation costly. In local and municipal markets (the nearby town of Novo Airão on the lower Negro, and the EMBRAPA experiment station or the town of Rio Preto da Eva for the Urubú), demand is more limited and Black Earth farmers often feel the strain of local competition for limited market niches.

Site Recovery/Fallow. While the threshold between cultivation and abandonment on Black Earth is obscured by weed invasion, abandonment is generally more immediate once it occurs due to the relative absence of crops that withstand competition from aggressive invasives. Locals seldom return to a Black Earth fallow to collect residual crops, with the possible exception of papaya.

Secondary succession is more rapid in early stages of fallow, with herbaceous species and liana quickly (re-)colonizing the site. Local residents identify past indigenous settlements by the predominance of lianas, which also raises their curiosity about soil fertility. This observation supports documented evidence that liana forests are late successional in Amazonia (Balée 1989; Balée and Campbell 1990). Young fallow resembles an impenetrable thicket of scrub vegetation and woody species. Local residents observe, however, that successional processes slow down at a certain point relative to Latosols. Trees are much slower to gain in girth relative to Latosols, and the understory is slower to clear out (a characteristic of mature forest of the terra firme). A higher concentration of fire-resistant and useful species is found in old fallow on Black Earth, the most distinctive of which is *caiaué*, the native oil palm. This palm is not only resistant to fire, but also to the machete, and self-propagates in Black Earth fallow. Efforts to rid swiddens of this species, seldom utilized in recent years, are futile. Local residents also observe a higher predominance of lianas in Black Earth fallow. Cecropia spp. are much less abundant as an early successional species on Black Earth relative to Latosols.

Fishing and Hunting

While fishing and hunting are known to be both widespread and critical sources of dietary protein for traditional inhabitants of Amazonia, fishing is by far the most important source of protein among inhabitants of the lower Negro today. While fishing is also critical to subsistence on the Urubú, its importance is diminished by the greater abundance of game in this region. While local residents claim that predatory fishing operations (by commercial outfits on the Negro and EMBRAPA employees on the Urubú) have made significant impacts on fishing returns, they perceive terrestrial fauna to be much less resilient in the face of contemporary impacts. While hunting remains an activity of local residents and weekend visitors (from urban areas), increased population densities and the focused attention of hunters on larger mammals have contributed to massive declines in harvesting rates of these species (Emmons and Feer 1990).

Fishing is carried out year-round, as an income generator for some families yet more commonly for household consumption. Procurement strategies change, however, according to species-specific feeding behaviors and climate. A simple typology utilized by locals distinguishes bottom-feeders (*peixe liso* – lit. "smooth fish", or *feras*) from scaly fish (*peixe de escama*), and helps to understand the difference between class- and species-specific procurement strategies. At the peak of the rainy season the flooded forest becomes the preferred fishing ground for peixe de escama due to the tendency for these fish to seek out food and refuge in these settings. The importance of native fruits in fishing yields and of forest flooding for making these available to fish populations is well-established for blackwater ecosystems (Goulding et al. 1988). The common practice of fishing near trees in fruit and adapting fishing technology to those species known to feed there indicates an intimate understanding of this relationship among local residents (see Table IV-2).

Table IV-2. Local Understandings on the Associations between Flooded Forest and Fish Feeding Behavior

Fish Species (local name)	**Local Classific.** [b]	**Diet**	**Species of Fruit Eaten** (local names)
Cuyú cuyú	F, PL	Omnivores	*Jauarí*, *cajuarana*, *louro* (fruits that sink to the river bottom)
Dourada	F, PL	Omnivorous	Same
Filhote	F, PL	Omnivorous	Same
Jandiá	F, PL	Omnivorous	Same
Pacamá	F, PL	Omnivorous	Same
Pirarara	F, PL	Omnivorous	Same
Surubím	F, PL	Omnivorous	Same
Pirarucú	F, PE	Omnivorous	Same
Aracú	PE	Primarily herbivorous[a]	*Seringa*, *tacuarí*, *tucano patauá*
Branquinha	PE	Detritivorous	"eats mud"
Cará	PE	Omnivorous[a]	?
Curimatã	PE	Detritivorous	"eats mud"
Jaraquí	PE	Detritivorous	"eats mud"
Matrinxã	PE	Omnivorous[a]	Fruit, minnows
Pacú	PE	Primarily herbivorous[a]	*Taquarí*, *louro*, *molongó*, *araçá*, *cajuarana*
Pescada	PE	Carnivorous	None
Piranha	PE	Omnivorous ("all fruit, any fish") [a]	*Abacatirana*, *seringa*, *jauarí*, and all other edible fruits
Sardinha	PE	Herbivorous[a]	*Cajuarana*, *turimã*
Tambaquí	PE	Herbivorous[a]	*Seringa*, *louro*, *jauarí*, *cajuarana*, *camu-camu*
Tucunaré	PE	Carnivorous ("any type [of fish]")	-

[a] These species of fish also eat the bait most common to the region (earthworms, crickets).
[b] PL = *Peixe Liso*; PE = *Peixe de Escama*; F = *Fera*.

The practice of fishing for peixe liso with distinctive technology and class-specific bait also reflects these understandings. During the rainy season, these bottom-feeders are targeted with an *espinhel*, a long line with large hooks spaced about 5 m apart that is extended across the main channel of the river and checked periodically. This line is baited with fish whose meat is said to give off a specific smell and to attract fish whose sense of smell is said to drive its feeding behavior. Those species that eat earthworms and crickets are fished in the rainy season with a hook and line (*caniço*) within the flooded forest and near trees that are in fruit. Families that have acquired the technical know-how for knitting and repairing nets and making explosives also fish peixe de escama and schools of fish in the flooded forest and at the confluence of primary and secondary rivers (respectively) in the rainy season.

During the dry season, fishing in the flooded forest is replaced with fishing in main river channels (at rocks and fallen trees where fish seek refuge from carnivorous species) and in lakes created by the draining of islands and waterways. This is known as the season with most *fartura* (roughly, "abundance") due to the ease with which fish are caught when concentrated in limited volumes of water and trapped in seasonal lakes. A three-pronged spear (*zagaia*) is utilized at night to *faxear* (scan the river's edge with a flashlight) in shallow waters of the igapó and on the terra firme, the hook and line are utilized in rock outcroppings and near fallen trees and nets are placed at the mouth of secondary streams. Finally, the *linha cumprida* ("long line", with lure) is utilized to fish the prized peacock bass (*tucunaré*) and other carnivorous species attracted to colder, fast-running water on the upstream side of islands, and bottom-feeders that feed at the river's edge (including *surubím* and *pescada*).

While peaks in fishing activity do occur, they do not necessarily correspond with peaks in availability due to the strong seasonality in labor investment/return ratios. It is common, however, to see a peak in fishing activity in November when the returns from all procurement technologies are high, and an extreme lull in capture rates at the beginning of the rainy season when fish spread into newly-flooded ecological zones to avoid predation. The time dedicated to fishing must be balanced with that dedicated to agriculture throughout the year, given that the substitution of protein-rich grains for faunal protein in local diets is extremely limited for both Latosol and Black Earth farmers. In recent years, however, the purchase of red beans (Phaseolus vulgaris) from southern Brazil for local and regional consumption has increased dramatically, effectively obscuring these environmental constraints on local diet. This reduced dependence on faunal protein is nevertheless limited both by the strong cultural preference for fish and game over beans, and by the need to derive capital from other extractive activities for the purchase of alternative foodstuffs.

The most commonly hunted game along the Negro include paca (Agouti paca), agouti (Dasyprocta sp.), peccary (Tayassu pecari and T. tajacu), capybara (Hydrochaeris hydrochaeris) and an occasional primate, while on the Urubú they still kill tapir (Tapirus terrestris), armadillo (Dasypus sp.) and occasionally, brocket deer (Mazama sp.). The seasonality of hunting stems from seasonal patterns in the behavior of terrestrial mammals and in the resources upon which they depend. Two basic patterns may be observed throughout the region. First, when inland watering holes dry up in summer months, game must descend to the river's edge for water, a behavior that facilitates their capture. Hunters will search the river's edge at night with flashlights and kill game with shotguns. Labor allocated to hunting during this season therefore overlaps with nocturnal fishing episodes (the *faxia* being a term used interchangeably for each), facilitating protein capture.

The second important generalized and seasonal hunting behavior corresponds with the fruiting of native species that attract game. The most important of these corresponds to *buritizais* (thick stands of *burití* – Mauritia flexuosa) which fruit during the months of May and June, yet other important species include *uixí* (Endopleura uchi), star nut palm (Astrocaryum spp.) and *açaí* (Euterpe oleracea), which ripen together with burití, and *bacaba* (Oenocarpus distichus), which fruits from September to November. These peaks in fruiting activity cause a peak in hunting returns in May and June, when hunters practice *a espera* (the wait), hanging hammocks in these trees and waiting for game to come feast on fallen fruits. Hunters also practice the espera in active swiddens and old fallows, where hunting stands replace hammocks. Seasonal patterns in the last of these activities are less evident.

Many species of turtle – both terrestrial and aquatic – are caught in each region, including *irapuca*, *jabotí*, *tartaruga* and *tracajá*. Some species have been over-hunted on the lower Negro, however, and are now only captured on the Urubú (most notably the *cabeçudo*). While jabotí are found year-round in terra firme forests, the seasonality in turtle capture corresponds with reproductive behavior: turtles and their eggs are found during the dry season (approximately August to November) when favored nesting sites (beaches, swampy areas) emerge.

Animal Husbandry

No native fauna are grown in captivity, with the exception of mascots (primates and birds) and turtles that are found in the wild and raised until the need for meat or income arises. Exotic species that are frequently raised for household consumption include swine and poultry (chickens and ducks), while cattle are raised solely for market. The prevalence of each activity varies in cultural importance and by socioeconomic status. The raising of a few chickens is the most common of these activities, yet is by no means widespread. Cattle are extremely rare, and only raised by those families that accumulate enough wealth to afford the large capital inputs for pasture establishment, a labor-intensive activity. I observed only two families raising a small number of pigs for household consumption.

Cattle are the most valued culturally, given the status of the few ranchers in the area and perceptions that cattle are associated with wealth. Beef is also favored for consumption, perhaps due to high prices and its relative inaccessibility to local residents (due to a supply that is insufficient for regional demand). Poultry are less valued in cuisine, yet more common as a source of protein during times of scarcity. The limited availability of locally grown feed represents a limitation for most families. One Black Earth farmer has designed an entire production strategy around this demand, cultivating maize for local sale to families with poultry.

These linkages between animal husbandry and agricultural practices are important and influence decision-making practices within the agricultural system. Several of these associations deserve mention. The production of feed for livestock is limited to poultry and, to a limited extent, swine (i.e., crop residues). This association is stronger on Black Earth, given that manioc derivatives are reserved for human consumption. The one exception is the use of *crueira*, the coarse material that remains when manioc is passed through a sieve, to feed poultry.

The second association between livestock and agriculture involves farm labor. The caring for poultry and swine places few competing demands on household labor, given that feeding is carried out in the morning and evenings and seldom diverts labor from other activities for the growing of feed. Cattle differ a great deal from other livestock in the high initial demands they place on family labor and resources. While these demands sharply diminish with time, initial capital and labor inputs are too high for the majority of local residents. During my time in the field, only one farmer (of both Black Earth and Latosols) engaged in these activities, diverting significant amounts of labor and capital to this activity. Furthermore, there is only a limited seasonality to animal husbandry activities, effectively diminishing any competition between the labor allocated to livestock and agriculture that might influence the time allocated to distinctive agricultural activities (i.e., to Black Earth or to Latosols).

The final association that might be discussed with respect to the associations between livestock and agricultural activities involves draft power, fuel energy and nutrient additions (manure). Shifting agriculture on both Black Earth and Latosols fails to involve energy and nutrient functions characteristic of other annual cropping systems (Norman 1979).

Extractivism (natural fibers, fruits and medicinals)

Extractivism once played a central role in regional subsistence, and continues to be of great cultural importance in more remote regions. Population densities on the lower Negro have placed great demands on extractive resources and these activities have dropped in importance. Most families continue to benefit, however, from native fruit and medicinals, yet utilize these products primarily for household consumption. The one exception is the harvest of natural fibers (the lianas *cipó titica* and *cipó timbó açú*) for sale as unprocessed fiber or brooms (woven at home and sold in local towns).

Fruits extracted from mature forest include brazil nut (Bertholletia excelsa), *uixí* (Endopleura uchi), *bacaba* (Oenocarpus distichus), *pequiá* (Caryocar brasiliensis), açaí palm (Euterpe oleracea), *burití* (Mauritia flexuosa), wild cocoa (Theobroma cacao) and star nut palm (Astrocaryum spp.). Several fruits are also collected from the Anavilhanas archipelago of the lower Negro during fishing events (local names include *araçá*, *gogó de guariba*, *ingá marí-marí*, *ingá guariba*, a*biurana*, *bacurí* and *pitomba*). These fruits are highly seasonal and are generally collected during fishing, hunting or logging trips rather than as an isolated subsistence activity. As such, they place few constraints on farm labor or resources. Several medicinals are also extracted from the terra firme and flooded forest, many with the same name yet recognized as sub-species adapted to each environment (*arara tucupí*, *carapana-uba*, *cumarú*, s*ucuba*, *saracura-mirá*, *tucano patauá*). These lists are by no means complete, reflecting only the species with the most widespread usage.

The only extractive activity to place significant demands on labor is the harvest and processing of lianas. The economic benefits are limited (Rs. 1 or U.S. $ 0.87/broom) in relation to the long hours of labor invested in this activity, yet prices are stable and the importance of this activity is derived from its ability to bring in limited yet much-needed income. Further benefits are associated with the possibility of processing lianas at home, permitting people to work into the evening and weekends, and in any weather. This activity has no inherent seasonality; its practice appears to reflect purely economic goals and concerns.

Carpentry

In the lower Negro region a number of local residents have acquired the skills to construct canoes by hand, in response to large economic gains made by this activity in nearby towns. Most people regard this as one of the most promising activities for family sustenance, yet many lack the skills. Furthermore, increased production of canoes has nearly saturated urban markets and the selected harvest of hardwoods has created a scarcity of desirable species near sites of residence. As such, carpentry has become a strongly seasonal activity, practiced primarily in the rainy season when secondary streams are flooded and provide access to remote forests.

Logging

Selected harvest of timber is carried out not only for canoe construction, but also for sale in regional markets. On the lower Negro, selected hardwoods are sought out and harvested due to their market value. They are felled with a chainsaw, cut into boards, carried to the river's edge by hand and transported by canoe to sites of residence. The activity is extremely labor-intensive, yet attractive due to the potential for rapid economic returns. Small ferries are rented to haul the timber to Manaus or Novo Airão for sale. Favored trees (by local terminology) include *itaúba*, *louro* (of which four types are identified locally), *cedro*, *angelím*, *tintarana* and *cupiúba*. This activity tends to be seasonal due to the high labor costs of transporting timber by hand, and roughly corresponds with the flooding of secondary and tertiary streams in the rainy months. No such sale of timber occurs on the Urubú, presumably due the greater ease with which IBAMA controls these activities along inland roadways. It is not uncommon, however, for local residents of both the Negro and Urubú to cut stakes or fence posts for sale locally or in Manaus. These activities are sporadic, and undertaken according to informal contractual agreements of short duration. No patterns of seasonality were observed for this activity.

Day Labor

Permanent employment is unavailable to residents of the lower Negro and Urubú, with the exception of those Urubú residents who came to the region to work at EMBRAPA's experimental farm and who were excluded from this study. However, part-time work may be found with neighbors engaging in highly seasonal, labor-intensive activities such as swidden clearing or the processing of manioc flour. These services are generally paid in kind, and show no clear seasonal or functional relationship with agricultural activities.

C. Phase Two Research: Upper Negro, Rio Canoas, Açutuba and Rio Preto Sites

Santa Isabel do Rio Negro

In the region surrounding the municipality of Santa Isabel, the ethnic composition is very different from that of the lower Negro. Residents are primarily Baré, an indigenous group of the region with a language that has fallen into disuse as *lingua geral* gained importance in the region throughout the historical period. Lingua geral is an indigenous language that was widely used in prehistoric Amazonia, and therefore appropriated by the Portuguese as the first official language of the colony. While the Baré now speak lingua geral among themselves, most individuals also speak Portuguese.

The subsistence economy of the region is still strong, although bitter manioc is cultivated for both household use and market. The traditional fish-game-manioc diet is much more prevalent in this region than in the lower Negro, where access to industrial commodities (in particular, beans and rice) is greater. This was also evident in the large number of individuals involved in manioc processing during my brief visits to Santa Isabel communities. Traditional practices and technologies are also more prevalent in the region, as evidenced in the greater reliance on local basketry and devices for processing manioc (grinding boards, draining technology, etc.) and by the variety of food derivatives still produced.

Soils of the region are sandier than those of the lower Negro region, indicating the tendency for soils to fit more closely to the Podzolic soils common to the upper Negro region (Jordan 1989; Sombroek 1966). This textural pattern extends to Black Earth soils as well, as would be expected for anthrosols formed over the spatially-predominant soils. These Podzols tend to be less fertile than the Latosols of the lower Negro, as evidenced in the more restricted range of crops that are grown on these soils (in particular, bitter manioc, pineapple and cashew, three crops known to be well-adapted to impoverished soils).

Local soil classifications made it difficult to clearly identify Indian Black Earth from naturally-forming soils, given the tendency for some individuals to include both Black Earth and naturally-forming soils under the class *Iví Cuí* or *Praia* (lit. “sandy soil” or “beach”) and for others to lump Black Earth with darker naturally-forming soils. Subsequent laboratory analyses permitted the conclusive identification of anthropogenic soils for the region, however, allowing the comparative study to be carried out.

Black Earth was found on similar landforms as on the lower Negro, yet research was restricted to sites located on terra firme bluffs. While an exact determination of the spatial abundance of these soils would be difficult, sites tended to be more distant from one another, with no striking differences in their coloration, depth or artifact content.

Barcelos

The Barcelos region is more centrally-located, with a semi-urban setting more linked to the market economy. International sale of ornamental fish and the extraction of natural fibers are two important extractive industries that complement the subsistence economy. While traditional manioc cultivation is an important economic activity despite the poor drainage of the terra firme (which limits the availability of cultivable land), the cultivation of Black Earth is non-existent.

Laboratory analyses on the region's soils corroborated local statements about the absence of Black Earth in this section of the middle Negro. The only sample confirming the presence of Black Earth was collected from an isolated patch of very dark soil with the measurements of a manioc griddle, which provides good evidence for the formation processes of Black Earth yet fails to provide sufficient substance for a comparative study. As such, this region was excluded from the analysis of plasticity of human-environmental interactions in distant blackwater settings (Chapter VII).

It is important to note the correlation between the poor quality and limited spatial abundance of cultivable terra firme soils, and the absence of Black Earth. The failure of Black Earth to form was more likely a result of settlement patterns than biophysical differences, given that poor drainage characteristics would favor rather than hinder the preservation of higher fertility indices on these soils after abandonment. If early inhabitants of large and relatively dense settlements depended on traditional manioc cultivation, as suggested in the literature (Heckenberger et al. 1999), then poor drainage would prove to limit this settlement pattern through the limitations posed by these conditions on traditional root crop agriculture. Here we see an environmental limit on the modifiability of the environment, yet one that is manifested indirectly – through the limited ability of the surrounding environment to support the dense populations that would be needed to reach the biochemical thresholds at which Black Earth forms.

Rio Canoas

The Canoas is a very small river that locals describe as *pardo*, a color reflecting blackwater origins with significant inputs of sediment during heavy rains. The origins of this sediment in local (nutrient-poor) landforms and the failure of local farmers to practice swidden agriculture in inundated areas justify its treatment as a blackwater region.

While downstream residents practice more "traditional" land-use practices, impacts of the aforementioned government services (INCRA, agricultural extension) have been significant in the headwater region. First, the collaborative work of INCRA and IDAM (Institute of Amazonian Development) have influenced cultivation through State-run agricultural extension initiatives. While all research was carried out on the river proper, banana monocultures along access roads (catalyzed by the government through financial and technical incentives) influenced land-use decisions of riverine inhabitants. A truck arrives bi-weekly to transport bananas to market, paying farmers at the port for their produce. This both incentivates and facilitates banana cultivation.

Soils of the region are similar to those of the lower Negro, where non-anthropogenic soils are predominantly Latosols. These soils tend to have a higher clay content, however, which by widespread local opinion makes them more favorable for banana cultivation. Innate soil properties are particularly critical given the reluctance of local farmers to follow the advice of government extension agents to use heavy inputs of industrialized fertilizer. Many farmers favor swidden abandonment and the clearing of new tracts of forest over the use of chemical fertilizers to sustain the productive system. Bitter manioc is also cultivated for consumption by most of the region's residents.

Small patches of Black Earth may be found on more elevated landforms, and extend along the upper reaches of the Canoas until the river passes into the Waimiri-Atroari area some two to three hours downstream. Attitudes toward these soils differ greatly by household. Relative to other blackwater regions, these patches of Black Earth tend to be spatially abundant yet smaller in extent (from ¼ to 3 ha). Their depth and color differ little from Black Earth soils in other regions.

Intensively-Cultivated Sites near Manaus

To complement research carried out in more remote sites and among low-income farmers, a rapid assessment of the intensive production systems at Rio Preto and Açutuba farms was carried out. The use of chemical and organic fertilizers to maintain soil fertility, mechanized production and frequent trips to market to sell produce in farmer-owned trucks differentiate these sites from the other sites of this comparative study. Furthermore, owners and caretakers on each farm are immigrants from outside the Amazon region: the Odetas of Açutuba are a family of second-generation Japanese immigrants, while the owner and caretaker of the Rio Preto farm are immigrants from southern Brazil. The only large-scale, intensive farms in this study are those on Black Earth; assessments of the comparative advantage of Black Earth when subject to intensive agriculture are therefore descriptive, and rest entirely on emic understandings.

The size and properties of these sites differ a great deal from those of other regions. The Açutuba site, in particular, is the largest known site on the Rio Negro and spans some 50 ha (including the darker habitation and surrounding use areas). The Rio Preto site is somewhat smaller, yet is nevertheless large enough for mechanized agriculture (I would estimate less than 10 ha). The Black Earth epipedon in these central habitation areas tends to be deeper than on smaller sites, reaching some 80 cm. The cultivation potential on these sites should therefore be greater. More intensive nutrient extraction occurs despite the use of chemical fertilizers, however, due to the tendency for these farmers to eliminate the fallow system and to maximize the productivity of fruit and vegetable crops on these sites.

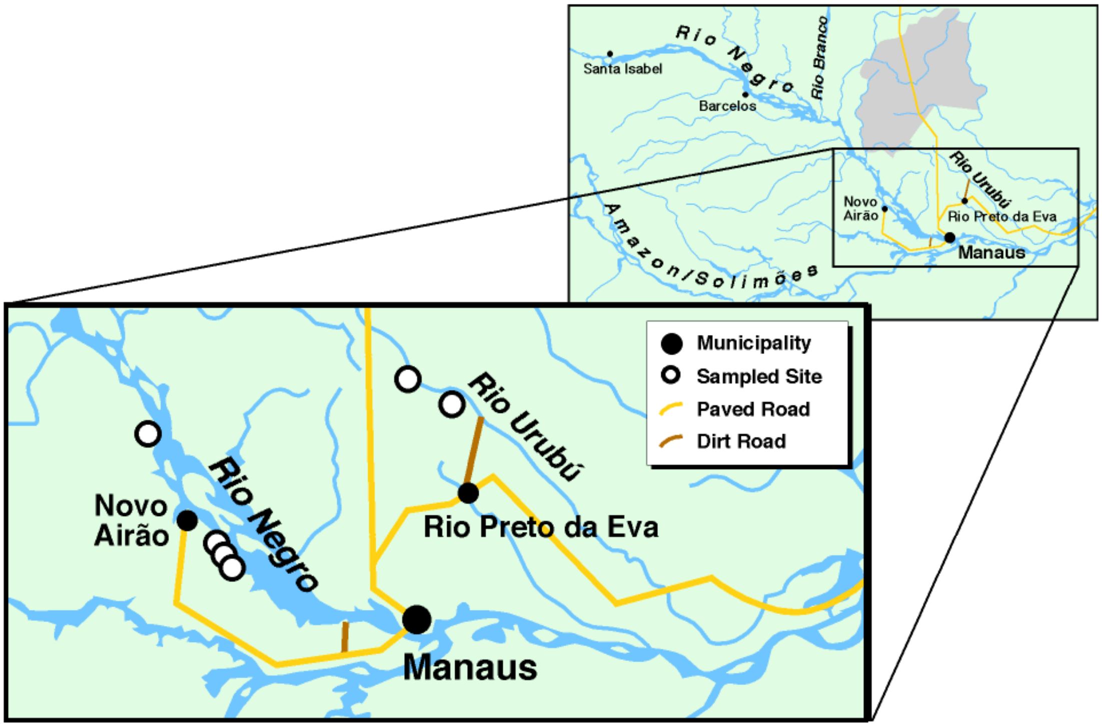
Chapter V: METHODOLOGY

A. Selection of Field Sites

Field research took place in several blackwater sites in the Brazilian Amazon, in traditional homesteads and communities of both caboclo and indigenous residents. I carried out research in two overlapping phases that roughly correspond to the distinct research objectives of Hypotheses 1 and 2. Comparative research frameworks were employed in each phase of research, yet differentiated according to these objectives.

Phase One research was a comparative, in-depth study of the adaptive strategies employed by caboclo families on Indian Black Earth and adjacent Latosols. I selected sites along two blackwater rivers in the Central Amazon, the lower Negro River and the middle Urubú River, to carry out research. These sites are illustrated in Map V-1.

During site selection, I carried out reconnaissance visits along 150 kilometers of the lower Rio Negro and Rio Jaú (a tributary of the Negro some 200 kms northwest of Manaus), as well as along some 30 miles of the middle Urubú. These areas were identified through conversations with researchers at EMBRAPA, and with the help of local guides prior to travel. Large sections of river were excluded for this phase of research where Black Earth was known to be uncommon, uninhabited or managed intensively (i.e., with chemical fertilizers). This resulted in three preliminary site selection criteria: the presence of Indian Black Earth, the importance of this soil 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 role of chemical fertilizers in: 1)



Map V-1. Phase One Research: Lower Negro and Middle Urubú Sites

altering the soil substrate that constitutes the anthropogenic environment under study, and 2) enhancing ecosystem plasticity with non-local materials, thereby obscuring the very questions under study – namely, ecosystem plasticity in nutrient-poor environments.

Next, within each site (lower Negro, middle Urubú) participant families needed to be identified. Four criteria governed this process: the family's dependence on local resources for livelihood, the role of agriculture as a primary economic activity, the comparative research framework and full consent. The first of these was more critical on the Urubú, where a number of families were eliminated from the comparative framework because they derived their income primarily from permanent positions of employment (at the EMBRAPA research station downstream from selected sites), rather than the use of natural resources. The second criteria is closely linked to the first for the Urubú, where employment caused many of these same families to dedicate little time to agriculture. Participant families were therefore chosen on the basis of their strong reliance on traditional productive activities. This is also true for the lower Negro; however, the absence of permanent sources of employment facilitated the selection process.

The third criteria, 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[1], the selection of Black Earth farmers fitting the minimal criteria (as stated above) was therefore exhaustive. The remaining collaborators therefore had to be 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 cultivation systems).

While on both the Urubú and the lower Negro soil selection occurs on the basis of both land tenure and biophysical parameters, only on the Urubú is the availability of Black Earth sufficient to allow each family to cultivate their soils of choice. The limited spatial extent of Black Earth resulted in a research framework based on both within-family (the adaptive strategies of single families cultivating both soils) and between-family (families cultivating one soil to the exclusion of the other) comparisons. It would be ideal if within-family comparisons could be employed throughout, so as to eliminate the messiness associated with "extraneous" variability (i.e., that derived from the

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[1] This individual was selected on the basis of his long-time use of Black Earth, and the saliency of this cultivation system in the mind of my field guide.

particularities of individual families rather than from distinctive environmental contexts). This was impossible, however, given the diversity inherent in local configurations of land occupation and use.

This selection process produced the following comparative research framework:

Table V-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

These cultivation practices are effectively integrated by each family with a complex array of complementary productive activities, including fishing, hunting, animal husbandry, canoe construction (carpentry) and the extraction of timber and non-timber forest products. Household strategies for combining diverse activities are highly variable and depend on a complex array of factors including available labor, differential access to natural resources, expertise in a given activity and other factors. This is evident in Table V-2, where I have classified the combined livelihood strategies utilized by each collaborator or family according to destination (market, subsistence, or combined).

Table V-2. The Integration of Diverse Economic Activities by Collaborator/Family: Subsistence (S), Market (M) and Combined (C) Orientations

	Collaborator											
Productive Activities	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Black Earth Agriculture	M	M	M	S					M	C	C	S
Latosol Agriculture	C	S		S	S	S	C	C			C	C
Fishing	S	C	S	M	S	S	S	S	S	S	C	S
Hunting	S	S			S	S	S		S	S	S	S
Logging		M			M	M					M	
Extractivism		S		S	S	S	S		S	S	S	S
Carpentry				M	M	M		M				
Animal Husbandry, Cattle	M											
Animal Husbandry, Other	C	S		S							C	

Phase One lasted a full year and a half, during which time all cognitive, behavioral and biophysical research was carried out (see below). A full year of observations in Latosol and Black Earth swiddens was designed to capture seasonal variations in behavioral and biophysical data.

Phase Two corresponds to a comparative study of Black Earth cultivation strategies in diverse blackwater environments. During this period, I employed a comparative framework to contrast the properties and use of Black Earth between distant blackwater sites. These satellite sites permit contextualization of research findings from Phase One research sites on the lower Negro and Urubú. This phase of research was designed to determine the plasticity of adaptive expressions within and between distant blackwater environments, and to identify diverse factors (environmental modifications, political-economics, technology, culture) that influence this plasticity.

I selected several sites for Phase Two research: the middle and upper Regions of the Rio Negro, the Canoas River and two sites with road access to Manaus (Açutuba, Rio Preto da Eva) (see Map V-2). The first two were chosen to research variability in production practices along a trajectory that spans the lower and middle Negro, from Phase One (primary) research sites to the municipality of Santa Isabel (see red boxes in Map V-2). This trajectory covers a broad cultural and political-economic spectrum, as a function of both the increased distance from urban markets and the transition to fully indigenous ethnicity as one travels upstream. Along this trajectory, I selected two regions that are more comparable to sites of the lower Negro due to their proximity to municipal markets: the area surrounding the municipalities of Barcelos and Santa Isabel do Rio Negro. The influences of political-economic influences of Novo Airão in the lower Negro would therefore be offset by contrasting upstream sites similarly close to municipal centers. Within each municipality I sampled two 10-mile stretches exhaustively for Black Earth and associated use practices (see areas highlighted in boxes in Map V-2).

Map V-2. Phase Two Research: Rio Negro Trajectory with Regions of Exhaustive Sampling, and Satellite Sites – Canoas, Açutuba and Rio Preto Localities

Second, I selected several "satellite" regions on the basis of unique characteristics that might indicate how diverse factors influence adaptive behavior in Black Earth and non-anthropogenic environments. Along the upper Canoas river, for example, the presence of state-funded cooperative extension services and land reform projects (leading to the predominance of more recent immigrants) present unique political-economic, technical and socio-cultural influences. The Açutuba and Rio Preto localities, on the other hand, each have easy access to market via transamazon highways, and cultivation systems that may be classified as intensive (industrialized[2], mechanized and with full market orientations). Clear circles in Map V-2 show the location of these satellite sites.

B. Identification of Black Earth Sites

It was necessary to identify criteria for the identification of Black Earth sites in the field so that the above research framework could be established. For this purpose, I defined a "Black Earth site" as the full geographical range of direct human-environmental interaction in a given homestead (including 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). "Non-anthropogenic" sites were to be those exhibiting either qualitatively or quantitatively distinct properties for any of the aforementioned parameters, and recognized as such by local informants.

[2] I use the term "industrialized" to refer to high-input systems, where industrialized technology (fertilizers, machinery, pesticides) are central to system productivity.

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.

C. Data Collection Methods

Hypothesis 1: Adaptation to Anthropogenic Environments

Comparative Framework

The comparative framework discussed above permits identification of both quantitative and qualitative differences in human adaptation between "cultured" and "natural" environmental contexts (Black Earth and Latosol ecosystems, respectively). All data types are analyzed under this comparative rubric, as reflected in data collection procedures. Clear differences between cultivation strategies on Black Earth and Latosols, and between informant perceptions of these, are interpreted as proof that human adaptation incorporates adaptive responses to former anthropogenic influences on the environment, and to the ecological processes that result from these interactions.

Definition of the Anthropogenic Environment

To interpret adaptive responses to anthropogenic environments, it was necessary to begin by identifying and characterizing the anthropogenic environment. For this purpose, I first analyzed pedological differences between Black Earth and Latosols to confirm the anthropogenic origins of the former. For each horizon, I carried out soil profile descriptions to document the morphological properties of each pedon. I then sampled each horizon for subsequent chemical analysis.

The second step was to determine the background fertility of Black Earth and adjacent, non-anthropogenic soils. I did this first through a fertility experiment contrasting the growth and yield of corn (*Zea mays*), a nutrient-demanding crop, on distinct soils. These soils were taken from the swiddens of each participant family, to capture the variability in soil quality throughout Phase One research sites.

Finally, I took 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). I then analyzed these soils through standard laboratory analyses (see Appendix A), resulting in the pedochemical assessment of fertility differences between these soils. Analyses included total phosphorous, total carbon and exchangeable calcium, three indicators of anthropogenic Black Earth (Pabst 1991; Woods and McCann 1999).

Human Adaptative Responses to the Anthropogenic Environment

It was next necessary to identify distinctive adaptive responses to Black Earth and Latosols. I did this by identifying differences in the production system (nutrient dynamics, cultivation and fallow time, fertility management practices, cropping patterns) and in human cognition of each environment (properties, productive potential, crop-specific uses, etc.). I utilized both qualitative and quantitative methods for this purpose, as indicated below.

Cognitive Adaptations. Perceptions on the difference in adaptive strategies between Black Earth and non-anthropogenic environments were gathered through semi-structured interviews, frame interviews, elicitation of soil classification systems and rating exercises. While collaborators alluded to distinctive hunting and gathering activities in these two environments, research to compare adaptive processes focused solely on agricultural practices. This is because agriculture represents the most important subsistence activity on Black Earth sites in the study region, as observed in the field and confirmed through open-ended interviews. One could argue that agriculture is the sole subsistence activity carried out on these sites today, due to widespread removal of naturally-occurring vegetation for agriculture. The primary exception may be the practice of hunting in active and transitional swiddens.

• Semi-Structured Interviews. I began interviews with an open-ended question to target the most salient differences between Black Earth and Latosols. Collaborators were then asked to discuss properties of each soil class, as well as relative benefits of subsistence 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.

• Frame Interviews or Item-by-Feature Matrices. I generated systematic frame interviews from the above descriptor terms and used these to generate item-by-feature matrices with a total of 12 informants (one from each of 12 homesteads) (Andrade 1995). Multidimensional scaling and consensus analyses were then carried out on the basis of informant agreement on each descriptor term, resulting in statistical and graphic representations of the taxa *Terra Preta* and *Terra Comúm*.

• Elicitation of Soil Classification Systems. To elicit soil classification systems, I first used free listing (Bernard 1994) to elicit: 1) all soil classes, and 2) all of the members of each soil class. The questions, "What are the different types of soil that you know of?" and, "Are there any other types of soil?" were asked to elicit a complete list of items in the contrast set "terra" (soil). Further questioning then targeted the differentiation within soil classes, until classes could be differentiated no further. On the basis of responses, I inferred the structure of these classification systems (i.e., hierarchy), while attempting to reduce artifacts of the elicitation framework by asking additional questions for each taxon (for example, "Is [sub-class x] a type of [class X]?"). I then compared classification systems across informants and soil classes to determine: 1) levels of classification (folk generic, folk specific) of each soil class, 2) the tendency to further differentiate soil classes into folk specific taxa and 3) informant agreement (%) for each of these.

• Crop Performance Rating. I employed an exercise to elicit informant ratings on the performance of diverse crops on Black Earth and Latosols to complement behavioral data on actual cropping practices. For this procedure, I compiled a list of common crops from field observations, and of soil classes from the elicitation of common soil classes. 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). I first compiled these ratings across informants by taking simple averages, and then calculated Pearson's correlation coefficients to test the relative contribution of diverse incentives (crop performance, economic returns, etc.) to observed cropping practices[3].

Behavioral Adaptations. I utilized both behavioral and biophysical data to research behavioral adaptations to anthropogenic Black Earth, the former as a means to determine the seasonality of labor allocation, and the latter to decipher biophysical motivations and outcomes of behavior and to triangulate with other data types.

• Participant Observation. Frequent 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.

• Time Allocation Studies. The time allocated to distinct subsistence activities was recorded for each of the 12 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 for this purpose. Four literate assistants documented the activities of participant families when I was

[3] While averaging should be limited to integer data, results better capture aggregate perceptual discriminations among crop classes than the median. Further limitations may be found in the calculation of correlation coefficients based on these cognitive data. The imperfect isomorphism between the conceptual discriminations of crops and the classification of these differences (across individuals) represents a discrepancy inasmuch as these differences are treated as integers and used inferentially. Here they are used in a relative and interpretive sense, as a means to identify the relative influence of distinct independent variables (motives) on cropping behavior and to corroborate more qualitative data and field observations.

absent, and reviewed the data with me upon my return. Weekly values were extrapolated for the entire month and graphed to show seasonal changes.

• Ground Survey Measurements. I carried out ground surveys to measure plot size and orientation for each farm (active swiddens and fallow). The roughly rectangular shape of swiddens made this a straightforward task.

• Botanical Plots. I established three botanical plots of 25 square meters each in all active swiddens in January 1998 and monitored them throughout one full year (at three-month intervals). I established additional plots in swiddens cleared during the observation period. 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 1) plot, 2) swidden and 3) farm. I used these measures to differentiate cropping patterns by soil class and season, to identify discrepancies between crop performance ratings and actual cropping practices, and to decipher those factors that provide the greatest incentives for cropping (via Pearson's correlation coefficients).

• Fertility Assessment of Fallow Systems. I collected composite samples using the same method as that described above for identification of the anthropogenic environment (Anderson and Ingram 1993), yet 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.

Next, I classified these samples according to four stages of the production cycle: forested, burnt, cultivated and abandoned (fallowed). 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 the four-stage pedochemical characterization of each found in Table V-7.

Laboratory analyses targeted important indicators of soil fertility: pH, Cation Exchange Capacity (CEC), Base Saturation (BS), exchangeable cations (Ca^{++}, Mg^{+++}, Na^{+}, K^{+}), plant-available phosphorus (PO_3^{-}), total nitrogen, total carbon and exchangeable aluminum (Al^{+++}). See Appendix A for a description of laboratory assays.

- 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.

Hypothesis 2: Plasticity of Human-Environmental Interactions in Nutrient-Poor Ecosystems

Comparative Framework

I employed a comparative framework in two ways to address the question of plasticity in human-environmental interactions for blackwater ecosystems. First, large-scale comparisons were made on the basis of Phase Two research to examine spatial variability in adaptive responses to anthropogenic environments. Spatial dimensions of plasticity were first researched on the lower Negro-upper Negro trajectory, along which observations were made on the roles of tradition (i.e., more traditional modes of land use) and distance from centralized markets in conditioning the plasticity of adaptive processes. Subsequent comparisons with data collected from the Canoas River, Açutuba and Rio Preto localities permitted an assessment of the relative benefits of Black Earth when subject to government-mediated, centralized and intensive cultivation systems.

Second, I employed data from comparative research in central (Phase One) research sites to discern temporal dimensions of subsistence plasticity on the basis of historical contingencies. This was done by determining the factors that most motivate Black Earth cultivation today, and discussing how these factors themselves may have changed throughout history. I utilize results to ground our understandings of the spatial variation in adaptive responses to anthropogenic Black Earth environments.

Spatial Dimensions of Plasticity in Human Adaptation to Anthropogenic Environments

To identify how perception and use of Black Earth differs today in distant blackwater regions, I use data from Phase Two research sites. To research factors other than the biophysical environment conditioning adaptive process in these diverse blackwater environments, it was first necessary to determine that Black Earth is, in fact, a similar entity in these settings. Second, cognitive and behavioral differences in adaptive processes in each site were assessed to determine: 1) how plastic adaptive processes are on the terra firme, and in particular in modified Black Earth sites, and 2) those factors that structure adaptive process and the plasticity of human-environmental interactions in each region.

Pedological Assessments of Similarity in Black Earth Environments. To determine the similarity of Black Earth in distant blackwater regions, I first carried out pedological characterizations to compare Black Earth with naturally-occurring soils satellite sites and to identify commonalities in the environmental stimuli encountered by groups in each setting. Next, I interviewed local residents from each site to determine the *potential* uses of Black Earth environments. These data serve to confirm that similar uses of Black Earth are possible in distant blackwater settings, independent of the actual uses of these soils. These activities allowed me to distinguish between the role of environmental stimuli and other possible factors influencing variability in human response to these anthropogenic environments.

• Pedological Characterizations. For each satellite site, I analyzed soil profiles for each community or homestead. I utilized trenches and auger samples to sample soils on the basis of distinct soil horizons, to a depth of one meter. These samples were later subject to standard pedological assays: exchangeable cations, pH, Base Saturation, Effective Cation Exchange Capacity (ECEC), available phosphorus, total carbon and total nitrogen (Appendix A). I then analyzed the departure of a number of soil chemical parameters on Black Earth environments from those on non-anthropogenic soils, to determine how Black Earth diverges pedochemically from non-anthropogenic soils in each region. This allowed me to assess whether Black Earth can be treated as one and the same with respect to human adaptive processes. I devise several measures of divergence for this purpose, as described in Chapter VI.

• Semi-Structured Interviews. Preliminary interviews, carried out upon arrival to each site during Phase Two, targeted informant perceptions on the potential uses of Black

Earth and the crops that may be cultivated in Black Earth and non-anthropogenic soils of each region.

Plasticity in Cultural Response. To identify plastic cultural responses to these environmental modifications in comparative (Phase Two) research sites, I used both qualitative and quantitative data. Qualitative data include family histories and rapid assessments of cultural and economic articulation with urban centers. Quantitative data include botanical and cognitive indicators of divergence between Black Earth and "natural" ecosystems. Methods used include the following:

- Elicitation of Soil Classification Systems. I used local responses to free listing techniques to contrast informant perceptions on the relationship between soil classes in each region. The saliency of Black Earth in these classification systems was determined by: 1) the level of classification of Black Earth with respect to other taxa (i.e., % of individuals classifying the given taxon as a folk generic or folk specific), and 2) the relative degree of differentiation of Black Earth into sub-classes (in % of individuals differentiating into folk specifics) (see Appendix B). I then utilized these classifications to identify distinctions between the use of Black Earth on the one hand, and recognition of its distinctive properties on the other. Rather than serve as a direct indication of plasticity in human-environmental interaction, these data help tease out the foundations of plasticity (cognitive-perceptual vs. political-economic, for example) in Phase Two research sites.

- Documentation of Use Systems and Crops Present on Each Soil Class. I carried out a rapid assessment of use systems through preliminary interviews and field visits, as a means to contrast use systems in each region with those in the central (Phase One) field sites. I compiled a list of the crops cultivated in swiddens and houseyard gardens in each locale.

Temporal Dimensions of Plasticity in Human Adaptation to Anthropogenic Environments

This research utilizes the following data from Phase One sites as indicators of plasticity in human adaptive responses to Black Earth environments (plasticity in human-environmental interaction) throughout history:

• Crop Performance Assessments. I utilized informant ratings of the performance of distinct crops on Black Earth and Latosols in lower Negro and Urubú regions to assess the contribution of distinct crops to the *potential* plasticity of subsistence (i.e., cropping) in Black Earth environments. I then assessed the origins of each crop to determine whether those crops that grow best on Black Earth (i.e., those most capable of providing productive advantages on these soils) are native or exotic domesticates. This gives a temporal dimension to the plasticity of adaptive manifestations on Black Earth by intuiting when the productive advantages associated with characteristic "*Terra Preta* crops" would have come about.

• Crop Ratings. I contrasted informant ratings on the properties of diverse crops with crop performance ratings to assess the relative importance of diverse incentives (economic, crop performance or other) in conditioning cropping practices among contemporary farmers. I assessed the relative importance of biophysical (crop performance) and political-economic (economic characteristics of crops) incentives by calculating Pearson's correlation coefficients with actual cropping data on Black Earth. This allowed me to interpret the role of political-economic contingencies in the use of these anthrosols through time.

- Soil Chemical Data. I utilized soil chemical data to determine the impacts of contemporary groups on the fertility of Black Earth, and to identify historical factors within the environment itself that may condition its cultivability through time. The same method used for the sampling of pedological data (i.e., by soil horizon) was employed here; however, samples were taken at abandoned settlements for which histories of recent use were available. I analyzed samples for total phosphorus and divided them into groups based on the extent of recent agricultural usage. Results suggest how use influences the leaching of the most stable nutrient (P) and therefore, too, other more soluble or labile nutrients.

Chapter VI: THE ROLE OF ANTHROPOGENIC MODIFICATIONS OF THE ENVIRONMENT IN CONDITIONING HUMAN ADAPTIVE PROCESS

A. The Research Question

This chapter is dedicated to testing the first of two research hypotheses upon which this dissertation is based:

Hypothesis 1: *The unique pedological properties of Black Earth condition distinctive adaptive strategies on the blackwater terra firme.*

Both Black Earth and adjacent soils of the terra firme are recognized and utilized as resources among caboclo families of the lower Rio Negro for agriculture. As such, the differences in human adaptive processes between these two environments could be easily researched. Black Earth phenomena are here employed as a means to address broader questions about the nature of human adaptation – namely, whether human adaptation reflects innate properties of "pristine" environments or the biophysical conditions created through former anthropogenic influences on the environment and by the ecological processes which result from these interactions.

To test Hypothesis 1, it was first necessary to define the "anthropogenic environment" by identifying those properties of Black Earth that define its uniqueness in relation to adjacent, naturally-forming soils of the region.

B. Defining the Anthropogenic Environment

Soil Profile Descriptions

Descriptive characterizations of soil profiles (up to 1 meter) from sites on the lower Negro and Urubú regions help to distinguish the chemical and morphological properties of Black Earth from those of non-anthropogenic soils. Two sets of horizon pairs were selected to provide qualitative descriptions of Black Earth and Latosols (see Appendix D, Figures D-1 and D-2), and to identify probable differences in their formation. While these were selected from central research sites, they tend to reflect generalized differences in anthropic and naturally-forming soils in the region.

Several important patterns emerge from these horizon descriptions. First, the depth of the epipedon in these anthrosols is generally much greater than in adjacent Latosols. While epipedon depth tends to be obscured by the influences of cultivation (through the formation of an "artificial" pedogenic division at a depth reached by hoeing and planting practices), this depth difference supports the idea that Black Earth is anthropogenic. In addition to the direct creation of an anthropic epipedon through deposition, subsequent pedogenic processes (soil fauna activity, downward movement of water and materials, etc.) lead to a mixing of the soil horizons, and help to explain the deepening of the anthropic epipedon (Woods 1995; Woods and McCann 1999).

Secondly, color differences are evident in most soils, and serve as the most didactic visual indication of anthropogenic influences. These differences are most evident in the epipedon, decreasing with depth as Black Earth gives way to the underlying Latosol (see Figure D-1, where each B horizon is characterized by the same 7.5YR 5/8 by the Munsell Color Chart). Secondly, the color of the anthropic epipedon itself differs significantly, as evidenced in the contrasting colors of Pedons 1 and 3 (Appendix D). Finally, while the colors of the soil matrix do not differ abruptly between matched soil horizons, the spatial distributions of matrix and non-matrix colors and materials do. Greater color and material segregation occurs on Black Earth, in particular in the most superficial buried horizons composed of a mixture of matrix materials and Black Earth (leached in through more porous areas).

Black Earth horizons can generally be characterized by one of two possible sequences. While each anthrosol has a very dark A horizon and a relatively homogenous subsoil B horizon at the bottom of the measured profile (1 m) that differs little from non-anthropogenic subsoils, middle horizons may or may not be divided. In the first scenario, the singular middle horizon has distinctive colorations: a lighter color approximating that of the subadjacent horizon (the pre-anthropic state, or 7.5YR 6/8 for the Figure D-1 horizon), and a darker color resulting from leaching processes from the epipedon (here represented by colors 10YR 2/3 and 3/3). These darker colors variously coat peds and root linings, or color distinctive sections of the horizon down to the core of any structural elements (here, 10YR 4/3).

In the second scenario, a fourth horizon is present and is superadjacent to this “middle” (A/B or B/A) horizon. This horizon presents itself as a thoroughly mixed horizon, lighter in color than horizon A, and resulting from a sandier texture (permitting efficient mixing), deep tillage practices and/or soil fauna activity. It might be classified as an A2 or an AB horizon, depending on its divergence from horizon A characteristics and the presence of features similar to subadjacent horizons. These horizon sequences indicate anthropogenic origins due to the evidence for depositional events that differentiate the epipedon from buried horizons. Although this is common in floodplain environments, the location of Black Earth on high bluffs suggests that this deposition occurred through human influences.

Finally, textural and structural differences are generally observed between Black Earth and naturally-forming soils. The anthropic epipedon on Black Earth tends to be sandier and lack significant soil structure, with these differences diminishing with depth as subadjacent horizons of the anthrosol approximate those of naturally-forming soils. Pedons 3 and 4 (Appendix D) from the Urubú region exhibit more characteristic textural differences between Black Earth and Latosols: the Black Earth profile exhibits much less structural development and a higher sand content than its counterpart. The reasons for this are unknown; however, the mixing and trampling of soils in long-term settlements would cause structural changes, while the removal of vegetation might expose soils to climatic forces that could accelerate the leaching of clays and loss of soil organic matter.

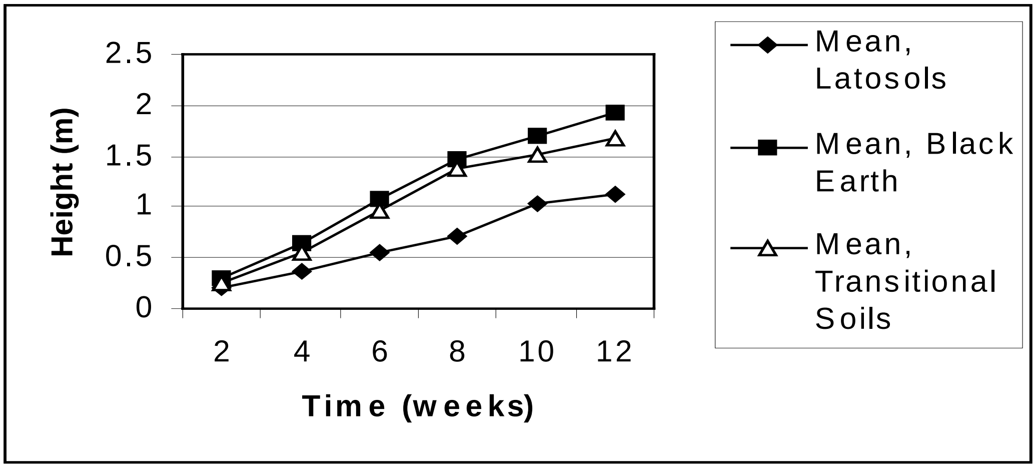
Finally, it is important to look at the chemical differences between Black Earth and Latosols that might further confirm the anthropogenic origins of the former. In Table D-1 (Appendix D), soil chemical indices have been averaged by horizon for Black Earth and Latosols. The most significant difference is in soil phosphorous, known to be a limiting nutrient in Amazonian ecosystems (due, in part, to its binding to iron and aluminum oxides). In Black Earth, however, phosphorous is nearly 20 times higher than in adjacent soils, a clear indication that these soils are anthropogenic (Eidt 1977).

Fertility Experiment

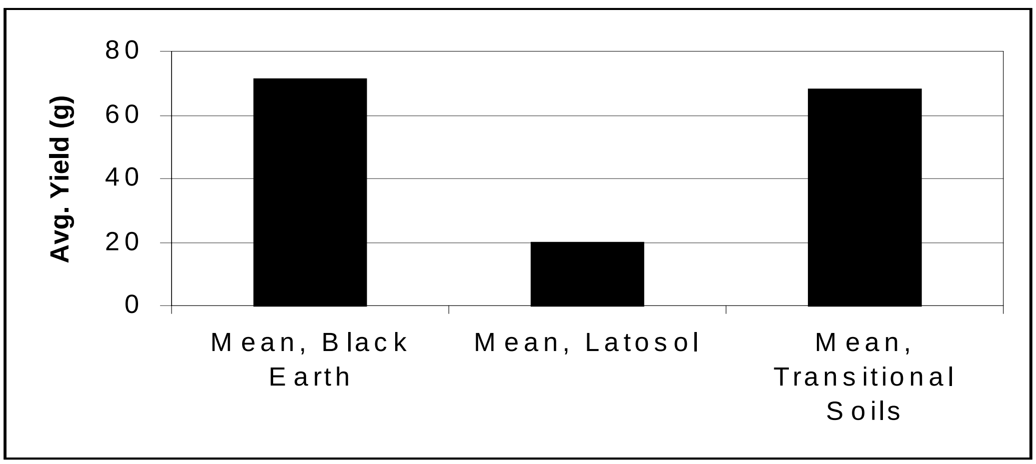
Given that the predominant use of Black Earth sites in the lower Negro and throughout Amazonia is for agriculture rather than hunting, the extraction of forest products or other economic activities, another important step in characterizing the anthropogenic environment is the determination of fertility differences between Black Earth and adjacent Latosols. I have first done this through a fertility experiment contrasting the growth of maize (Zea mays) on soils taken from Black Earth and Latosol swiddens and next through soil fertility analyses, as indicated in Chapter IV.

Given the dependence of traditional shifting agriculture on the burn as a way to mineralize ecosystem nutrients (see Chapter III), the differences in background fertility between Black Earth and adjacent soils is not only a question of total nutrient stocks in the soil when cropped or under forest vegetation. It is also a function of nutrient stocks in the plant biomass that supplies plant-available nutrients through the burn. Unless otherwise specified, I utilized soils *under cultivation* to carry out soil fertility studies, circumventing the need to assess relative contributions of each (soil nutrient stocks and plant biomass) to soil fertility. In other words, rather than measure 1) soil nutrient stocks under “natural” conditions (a condition which is difficult if not impossible to determine for Black Earth) and 2) plant biomass (for which experiments to deduce total amounts of nutrients released to the soil upon the burn would be required), I characterized soils in which *both* natural soil fertility and nutrients resulting from the burn are represented.

Results of the fertility experiment are plotted in Graphs VI-1 and VI-2. An additional soil class, “transitional” soils, has been included in the analysis. These are soils with a lighter color (less anthropogenic modification) than the prototypical “Terra Preta,” yet with characteristics that indicate anthropogenic origins. These include the high concentration of artifacts and crop responses similar to those growing on “legitimate” Terra Preta.



Graph VI-1. Growth Rates of Maize (Zea mays) on non-Anthropogenic Latosols, Black Earth and Transitional Soils



Graph VI-2. Maize (Zea mays) Yields As a Function of Soil Type

For this nutrient-demanding crop, growth rates are much higher for Black Earth than for non-anthropogenic soils, with maize on transitional soils growing at a rate similar to that of Black Earth. Graph VI-2 corroborates this tendency with data indicating higher average yields on Black Earth and transitional soils than on non-anthropogenic Latosols. Interestingly, transitional soils yielded more grain than the prototypical Black Earth, a discrepancy that can perhaps be explained by the more intensive mining of soil nutrients in the latter in recent history. 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.

Soil Chemical Assays

Results from laboratory analyses carried out on composite samples from Black Earth and Latosol swiddens of the central study region are presented in Table VI-1. Data indicate that concentrations of nutrient cations and available phosphorus are greater on Black Earth than on Latosols. Furthermore, other soil conditions 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 in 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 1982; van Raij 1991).

Table VI-1. 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

It is also interesting to identify those parameters that depart most from non-anthropogenic soils. 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 1985b, 1989) and is generally the limiting nutrient in 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.

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. While not readily apparent in the results of fertility experiments carried out with maize, this exception may prove to affect either the yields of certain potassium-demanding crops or the success of distinct subsistence strategies on Black Earth. While some pedochemical distinctions are more significant than others, in aggregate they confirm that important differences differentiate anthropogenic Black Earth from naturally-forming soils of the study region.

C. Identifying Adaptive Responses to Anthropogenic Environments

With the pedochemical difference between Black Earth and adjacent environments determined, the next step is to identify distinctive adaptive responses among caboclos as a function of this difference. This requires that both cognitive and behavioral manifestations be researched, in addition to those biophysical manifestations resulting from human subsistence behavior. While cognitive, behavioral and biophysical data will be triangulated throughout this and subsequent chapters, I first discuss some important cognitive distinctions between Black Earth and non-anthropogenic soils that represent an important aspect of perceptual adaptations to novel environmental contexts yet whose links to agricultural behavior are less evident. This study of more formal knowledge structures, less linked to practice but nonetheless informing human interaction with distinct soil types and ecosystems, confirms that distinctive understandings of the environment underlie the more readily-observable behavioral differences between them.

Cognitive Distinctions Between Anthropogenic and Non-Anthropogenic Environments

Soil Classification Systems

Folk classification systems highlight perceptual distinctions between classes of objects, and those criteria that differentiate soils perceptually. While these classification systems do not necessarily reflect utilitarian distinctions, 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 (other soil classes, for example). At a most fundamental level, it points to a recognition of difference between these two soils and to the relative saliency of each soil taxon.

Among collaborators of lower Negro and Urubú sites, great variability exists among soil classifications. This variability reflects in part the heterogeneity of the biophysical environment itself, which causes soil classes or modifiers to change as highly salient characteristics of soil appearance or performance change. This is evident in the distinctive nomenclature for the most common non-anthropogenic soils that prevail along the Urubú and Negro rivers: *Terra Roxa* (lit. "Purple Soil") and *Terra Vermelha* or *Amarela* ("Red" or "Yellow" Soil), respectively. Terra Roxa occurs in low-lying areas that are considered terra firme by locals, yet whose physiographic location influences soil properties (color, texture, etc.) through capillary moisture or past geological events. All other soils along the edge of the Urubú are either inundated (flooded forest) or anthropogenic, with Latosols (Terra Vermelha or *Barro Vermelho* – "Red Soil" or "Red Clay") occurring inland and in a few steep inclines leading to higher bluffs along the river's edge. Along the lower Negro, Terra Vermelha and Terra Amarela are found on high bluffs, on other lower-lying landforms that are clearly terra firme (with deep, highly leached horizons) and inland. These generally correspond to the Latosol order of the Brazilian classification system (Salgado Vieira 1988), although the sandier Podzolic soils are often present on sloped terrain.

While variability in both texture and color is found within these non-anthropogenic soils, I often treat them as a single taxon when comparing them to Black Earth. For more detailed information on the differentiation of classifications by informant, refer to Appendix B (Soil Classification Data). While this is in part an artifact of research that stresses the distinction between anthropogenic and non-anthropogenic environments, it is also justified by patterns of local cognition and behavior. On the Lower Negro and Urubú rivers alike, the umbrella term *Terra Comum* ("Common Soil") is often used to refer to the full range of non-anthropogenic soils of the terra firme. It also forms a contrast set with Black Earth that is interchangeable with the contrast set that exists between Black Earth and more differentiated classes of these spatially-predominant soils (Red Soil and Sandy Soil, for example). Furthermore, variation in the treatment of these non-anthropogenic soils is limited to textural differences and a few crops that are known to perform differently on the basis of texture (primarily banana). While the contrast set Black Earth – Common Soil is employed for most analyses, in certain cases I differentiate non-anthropogenic soils when it is necessary to demonstrate important relationships between these natural variations and the properties of Black Earth.

In addition to reflecting natural discontinuities, classification often varies among individuals from a single community who are familiar with the same variations in local landscapes. While perhaps resulting from different life experiences and perceptions, these differences also seem to reflect a dynamic classification system that is context- and purpose-dependent. As such, the same individual may give different responses to the same question, depending on his/her particular frame of reference. As such, it is possible that distinct, overlapping soil classifications exist for the same biophysical environment.

Certain patterns of variation nevertheless repeat themselves within informant responses and highlight important perceptual patterns in ethnopedological cognition. The most significant is the distinction between three common contrast sets: (Terra Preta – Terra Vermelha/Amarela/Roxa[1]), (Terra Preta – Barro Amarelo/Vermelho/Roxo – Terra Areiusca) and (Terra Preta – Terra Comum). When Black Earth is contrasted with taxa discriminated on the basis of color, differentiation into folk specific taxa is based on texture; when contrasted with textural descriptors, differentiation generally occurs according to color. This would indicate that color and textural discriminations are

[1] Slashes indicate interchangeable taxa that vary according to subtle landscape transitions (primarily of color) and are similar to the Red-Yellow Latosol soil order in the Brazilian classification system.

interchangeable, that they are both salient in the region at large, and that the descriptor that is prioritized may reflect unknown utilitarian or cognitive realities. When Terra Comum is used in a contrast set with Terra Preta, differentiation into folk specific taxa occurs on the basis of texture alone, indicating that when contrasted to Black Earth, color distinctions associated with "Common Soil" are semantically implicit.

The invariable classification of Terra Preta as a folk generic and the apparent interchangeability of certain referents for Latosols (i.e., Terra Comum/Terra Amarela/Terra Vermelha) permit the pooling of classifications across informants and locales to derive commonalities. This emphasis on agreement rather than variation is justified by the question of interest, namely the cognitive importance given to distinctive environments (Black Earth in relation to other non-anthropogenic soils of the terra firme) rather informant-to-informant variability.

Figures VI-1 and VI-2 depict the common (unbracketed terms), interchangeable (separated by backslashes) and optional (bracketed) taxa within the classification systems of lower Negro and Urubú sites, respectively. These figures were built from free-lists of regional soil classes and sub-classes. The inclusion of any given taxa in this first list was taken as evidence for its folk generic status. Black Earth was invariably listed within these folk generic groupings. Other members of the set included a variant of the local terminology used to denote the Red-Yellow Latosols of the Brazilian classification system (Terra Amarela, Terra Vermelha, Barro Vermelho or Terra Comum) in the lower Negro (Figure VI-1), and in the Urubú (Figure VI-2) the low-lying riparian soils (Terra Roxa, Barro Roxo).

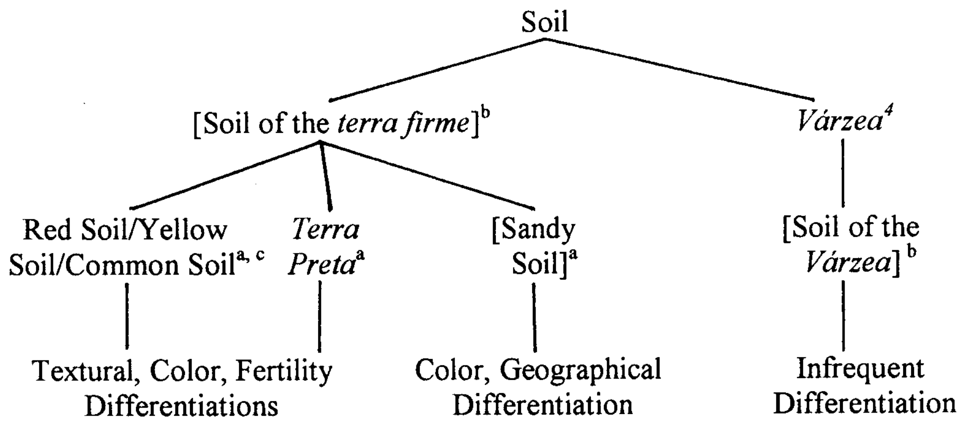


Figure VI-1. Commonalities among Soil Classifications in the Lower Negro[2]
[a] Refers to the most salient, or 'folk generic' (Berlin 1992), taxa.
[b] Bracketed terms represent optional or covert categories.
[c] A variation of this classification system is to substitute Red Clay/Yellow Clay for these taxa, and in contrast to Sandy Soil.

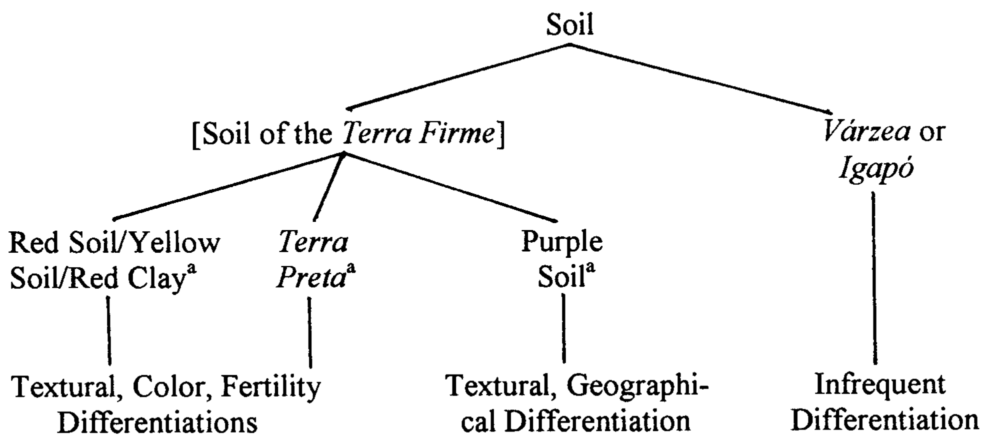


Figure VI-2. Commonalities among Soil Classifications in the Urubú Region
[a] Folk generic taxa.

[2] While the term *várzea* is generally utilized to refer to the fertile floodplain of whitewater rivers, it is used locally to refer to the flooded forests of the Anavilhanas archipelago and the flooded forest of the Urubú. While the "várzea" of the Rio Negro is cultivable due to deposition of sediment from the Rio Branco, these soils are not used in either region (for political reasons in the Negro and insufficient fertility in the Urubú). The "soil of the várzea" taxon is a covert category referring to várzea soils, indicating the lesser saliency of these soils in comparison to other folk generic taxa.

Fifty-eight percent of informants also included várzea (floodplain) in this classification to denote soils of the Anavilhanas Archipelago and the most abundant riparian soils of the Urubú. Yet this term does not form a contrast set with remaining soil classes. Rather, várzea forms a contrast set with the "terra firme", which is a covert category for most informants and more commonly refers to the landform where these soils are found than soil per se. The covert category including these soils would thus be termed "terra firme" or "soils of the terra firme", a phrase that was seldom expressed during the elicitation of soil classification systems yet common in other contexts. Perhaps this explains why inundated soils were generally the last to be mentioned upon asking informants to list all soil classes, even in the lower Negro where these soils are known to be cultivable. Furthermore, while *igapó* (flooded forest) is a more common term than "várzea" to refer to inundated blackwater environments, the former was never mentioned within soil elicitation exercises because the igapó is by definition forested and uncultivated, and therefore not "terra" in the common utilitarian sense of the word.

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 was the most common basis for the further differentiation of each soil class 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 indicates a similar degree of cognitive saliency between the two soil classes.

Item-by-Feature Matrices

Item-by-feature matrices were also used to contrast ethnopedological concepts (soil features) with locally-identified soil classes. Raw data (Appendix B) were analyzed in three ways. First, I calculated percentages of informant agreement on the features of each soil taxon, grouping responses for non-anthropogenic soils under the umbrella term Terra Comum to highlight the attributes (features) that account for most of the perceived distinctiveness in the taxon Terra Preta. Next, I ran a cluster analysis on item-by-feature matrices to identify the level at which distinct soil taxa are distinguished from others in the minds of local informants. Finally, I carried out a multidimensional scaling exercise on item-by-feature matrices to derive graphical representations of the perceptual proximity of Black Earth and other common soil taxa. For the last two exercises, five soil taxa were analyzed separately to illustrate the relationship of local perception of Black Earth with respect to the *variability* in regional soils. While other terms exist to denote the most common soil classes (those that were elicited in free listing exercises, for example, in Table B4 of Appendix B), some terms are understood as one and the same by local residents and were grouped accordingly (Yellow Soil and Red Soil, Red Clay and Clayey Soil, etc.).

For the first of these exercises I used levels of agreement (i.e., % individuals responding “yes” to item-by-feature associations) to identify those features that best define distinct soils in the minds of local residents. Tables VI-2 and VI-3 identify those inherent attributes and management characteristics (respectively) that most strongly define Terra Preta and Terra Comum among informants.

Table VI-2. Salient Attributes of Ethnopedological Taxa "Terra Preta" and "Terra Comum"

Level of Consensus	Terra Preta	Terra Comum
> 90%	black fertilized has life	raw (a product) of nature has life
80-90%	strong produces everything	weak when worked deep
70-80%	changes with depth soft/light (a product) of nature friable porous (for water)	red
60-70%	loose heavy cooled by dew	cooled by dew
50-60%	burnt dries quickly moistened by dew sandy shallow retains moisture hot	

While these data are self-explanatory, it is important to note that the most salient distinctions between soil taxa (aside from color) relate to soil fertility and to perceptions about the pristine nature of naturally-forming soils. Locals do not recognize Black Earth

Table VI-3. Salient Management Characteristics of Ethnopedological Taxa 'Terra Preta' and 'Terra Comum'

Level of Consensus	Terra Preta	Terra Comum
> 90%	requires high labor inputs labor intensive to weed previously fallowed areas fully recuperates through fallow invasives "close in" quickly	burnt soil does well necessary to use the burn labor intensive to fell forest spatial variability in fertility
80-90%	produces much "abundance" labor intensive to weed any area labor intensive to slash crops grow quickly burnt soil produces well soil maintains strength after the burn recuperates quickly after it weakens	
70-80%	susceptible to the "strong eye"	
60-70%	crops grown are seasonal necessary to use the burn economizes soil amendments	crops grown are seasonal must plant with the moon must use the coivara soil tires quickly
50-60%	problems with pests/disease must plant with the moon must use the coivara soil always produces despite weakening	labor intensive to weed previously fallowed areas fully recuperates through fallow

as an anthropogenic entity, as evidenced in the common saying, "if it were made by man, we would all be making it." They are hesitant, however, to call Black Earth a product of nature. This seems to have a great deal to do with culturally-shared and ingrained conceptualizations of the traditional swidden agricultural system. Soils are generally known to be "raw," and unfit for agriculture until subject to the burn. The dark color of Black Earth and the lesser dependence on an effective burn or long fallow period to maintain high nutrient stocks, discussed in more detail below, defy these conceptualizations of soil. Black Earth is therefore seen as a bit of an irony by locals: natural in the sense that soil is by definition derived from natural processes, yet inherently stronger and darker – attributes that are generally transient and derived from recent burning events. Many of these same properties are evident in the more dynamic or management-related properties of each taxon. This is evident, for example, in the widespread belief that Black Earth not only produces more *fartura* (abundance) than non-anthropogenic soils, but maintains its fertility after the burn and recuperates more quickly once fallowed (Table VI-3).

Other properties for which there are significant levels of consensus among informants relate to labor concerns. While Common Soil requires more labor to fell an area ("felling" referring specifically to the clearing of a mature forest), this labor output is limited to a short period in the dry season. Black Earth, on the other hand, requires similar labor investments to slash new swiddens (due to the thick growth of young fallow) and constant labor inputs throughout the cultivation period to control the more aggressive invasion of weeds. These factors play out in time allocation decisions, as will be demonstrated later in the chapter.

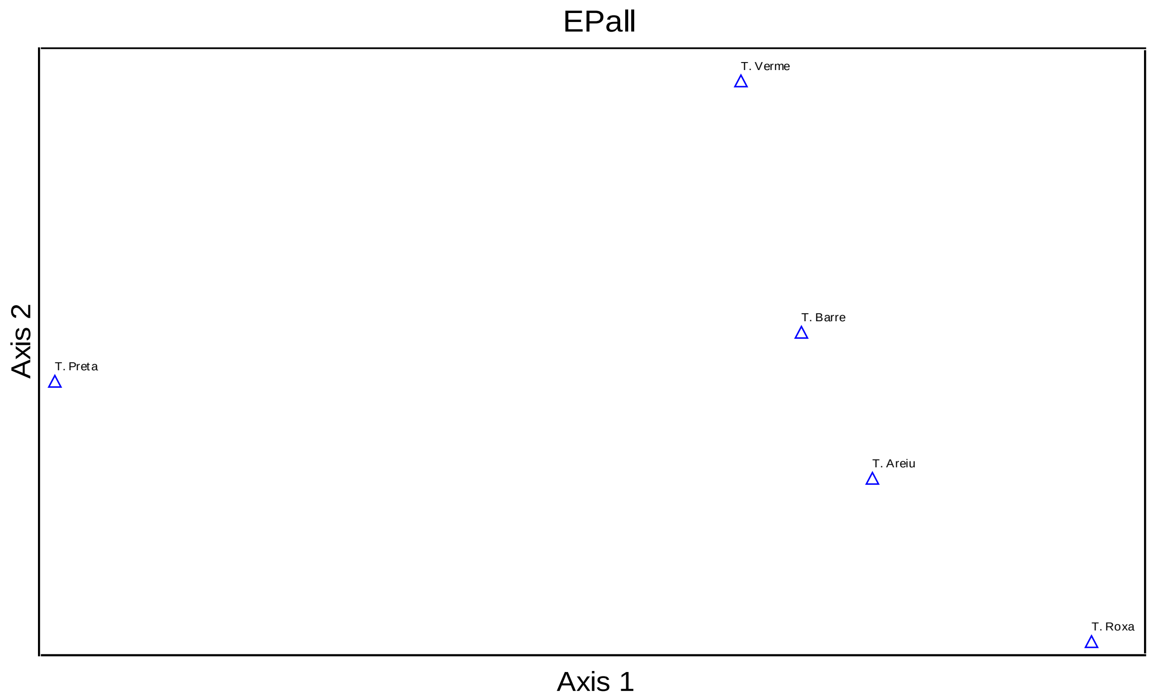
Cluster Analysis and Multidimensional Scaling

Two additional analyses help to generate a better understanding of the level at which distinct soil classes are differentiated from others in the minds of local residents: cluster analysis (Figure VI-3) and multi-dimensional scaling (Graph VI-3a and b). Both Figure VI-3 and Axis 1 of Graph VI-3a 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.

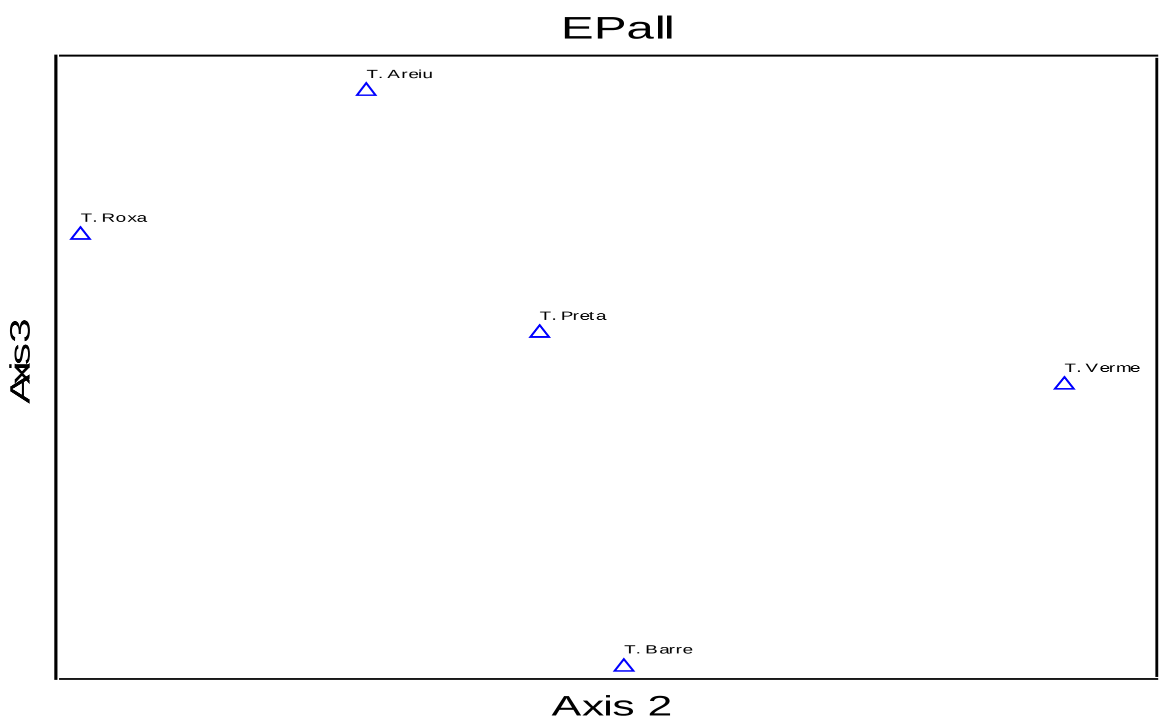
```
                         Distance (Objective Function)

             60.500      593.575     1126.650    1659.725    2192.800
             |-------+-------+-------+-------+-------+-------+-------+-------+
                         Information remaining (%)
           100.000      75.000      50.000      25.000       .000
             |-------+-------+-------+-------+-------+-------+-------+-------+

Terra Preta      |---------------------------------------------------------------|
                                                                                  |
Terra Vermelha  ---|                                                              |
                   |----------------|                                             |
Terra Barrenta  ---|                |                                             |
                                    |---------------------------------------------|
Terra Areiusca   |                  |
                 |------------------|
Terra Roxa       |
```

Figure VI-3. Perceptual Similarity of Soil Classes: Results of a Cluster Analysis of Ethnopedological Data

The graphical output of the multidimensional scaling procedure is a three-dimensional representation of multidimensional space. 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. Terra Preta differs most from the other soil taxa along Axis 1. 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 VI-4 (column 1), we see that the features of Black Earth that most differ from other soil classes



Graph VI-3a. Multidimensional Scaling of Soil Taxa: Axes 1 and 2



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

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

Axis 1 *Feature of Soil Class*	*r^2*	**Axis 2** *Feature of Soil Class*	*r^2*	**Axis 3** *Feature of Soil Class*	*r^2*
Pest & disease problems	0.992	Raw	0.979	Slippery/smooth	0.934
Problems with "strong" eye	0.985	Weak when worked	0.958	Wild	0.929
Labor int. to weed fallowed plot	0.980	Tires quickly	0.922	Sticky	0.917
Always fully recuperates w/fallow	0.980	Variab. in "strength" w/in swidden	0.898	Clayey	0.903
Labor intensive to weed	0.977	---------------		Cold	0.897
Maintains "strength" after burn	0.956	Necessary to use the burn	0.829	Sticks	0.853
Night's dew moistens soil	0.956	Deep	0.821	---------------	
Dries quickly	0.955	Natural (of nature)	0.809	Hard	0.823
Economizes soil amendments	0.946	Weak	0.806		
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.

include both desirable and undesirable characteristics. While fitosanitary problems (higher incidences of pests, disease and the "strong" eye), greater labor requirements for slashing and weeding and a shallow epipedon limit incentives for Black Earth cultivation, its chemical dynamics (fertility, nutrient retention capability, etc.) and lesser reliance on the burn (allowing the soil to be cleared in the rainy season) are also strong incentives for its cultivation.

Graph VI-3b 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 is not absolute but rather a function of the specific properties under analysis. Axes 2 and 3 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, the 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 indicate 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 in part reflect of traditional forms of environmental cognition. For example, the distinction between "raw" and "burnt" soil 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 that the burn is 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 apparently underlie the fact that all Black Earth farmers burn their swiddens despite ample evidence that cultivation is less burn-dependent than on Latosols.

The following section triangulates cognitive, behavioral and biophysical data to identify the ways in which the unique properties of Black Earth environments condition human adaptive strategies – both cognitive and behavioral. Through the triangulation of distinct data types, I have identified several realms of adaptive behavior that differ consistently between Black Earth and adjacent, non-anthropogenic environments. This corroboration of patterns from diverse sources provides strong evidence for the validity of observations, and therefore serves as a basis for testing the hypothesis that anthropogenic environments condition human adaptive behavior in unique ways.

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 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. – 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, the only thing I never planted was cilantro, but 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. – Aguinelo

Crop Performance Ratings

These distinctions are confirmed through crop performance ratings. Table VI-5 summarizes average informant responses to crop performance ratings in which the performance of select crops on Black Earth and Latosols were 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 VI-5. Informant Ratings of Crop Performance on Anthropogenic and Non-Anthropogenic Soils of Central Research Sites

Crop	Terra Preta (Mean)	Terra Preta (St. Dev.)	Terra Comum (Mean)	Terra Comum (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.

The 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 these differences, yet are more representative of the net differences (beyond variability in perceptions and localized fertility differences) given that they are aggregate responses. Recurring themes include the 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 not be taken as an indication that a larger number of crops adapt well to this anthropogenic environment, given that this list of crops is only a subset of the total number of available crops. The common descriptor "produces everything" (Table VI-2), used only in reference to Black Earth, nevertheless indicates that Black Earth has conditions amenable to a broader range of culturally important crops. This exercise is also limited because open-ended questionnaires targeting the benefits derived from each soil class fail to generate a complete list of crops (in which semi-domesticates, for example, are underrepresented). Derived data are useful, however, in demonstrating differences in cognition associated with Black Earth environments, for identifying crop classes most amenable to cultivating this soil, and for testing the verbalized distinctions in crop-soil associations across all informants.

Cropping Behavior

More conclusive evidence may be found in actual cropping associations on Black Earth and Latosols. It must be kept in mind, however, that differences between the ideal (maximizing yields by planting those crops that grow best on each soil class) and the real (actual cropping practices) reflect multifaceted and multi-causal decision-making processes. These differences cannot be explained, therefore, by a purely determinist stance (i.e., a causal relationship between the environment on the one hand, and adaptive process on the other). Rather, multiple influences (environmental, cultural, technological, political-economic) play a role in the resulting adaptive strategies, therefore highlighting implicitly diachronic and historical aspects of adaptive processes.

Data from botanical plots are used to study adaptive processes as manifested in actual cropping behavior. I have processed these botanical data in several ways such that distinct behavioral manifestations may be illustrated. First, I summarize raw data on the percentage representation of each crop on each soil class (Appendix C) by placing crops into distinct soil classes based on local discriminations. Second, I correlate informant ratings of crop performance (soil-crop associations) with actual planting behavior in Black Earth and Latosol swiddens. This activity provides some insight into the relationship between cognitive understandings and actual adaptive behavior, and evidences intentionality in the resulting botanical associations.

For these analyses 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 on 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 (Appendix C) into categories based on morphological differences in the plants themselves and, to some extent, perceptual distinctions made locally, are presented in Table VI-6. I generated a measure of divergence of cropping patterns on Black Earth from those on Latosols to identify crops that underlie the flexibility in human adaptation to anthropogenic Black Earth, where BE and LAT refer to cropping patterns on Black Earth and Latosols, respectively:

Formula 1: % Divergence of Cropping Patterns from Non-Anthropogenic Environments

$$\text{\% Divergence of Crop's Representation} = \frac{(\text{\% Representation}_{BE} - \text{\% Representation}_{LAT})}{\text{\% Representation}_{LAT}} \times 100$$

Several important patterns emerge here. The first relates to the productive cycles for common crops. The planting of short-cycle vegetable crops provides an adaptive advantage on Black Earth, where the colonization of invasive species generates an increasing disadvantage to the use of this soil with time (since the burn):

> On *Terra Preta* weeds are more *serrada* [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:

> You plant the first time, and then the second, na? Now the third doesn't produce anything, because she is, she "cerra muito." . . . It's not like mature forest. Mature forest "custa cerrar" [is reluctant to "close in"]. Not even if she is [growing on] Black Earth, she "custa cerrar." It's not like this one here, our old fallow. This here "cerra" too much. It's because it's not mature forest.
> – Luzia

This difference is evident in the percentage of tubers and fruit trees in relation to vegetable crops on each soil class, for each of the three statistical measures. Tubers mature, on average, in about a year's time and fruit trees produce for a period of several

Table VI-6. The Relative Representation of Diverse Crop Classes in Latosol and Black Earth Swiddens (expressed as percentages of swiddens, swidden area and individual plants that represent each crop class)

Crop Class:	**% of Black Earth Swiddens with Presence of Each Crop Class**	**% of Latossol 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 Latossols**
Vegetable (V)	28.19	4.39	74.43	9.25
Fruit (F)	5.91	23.77	20.20	58.89
Tuber (T)	12.32	36.69	42.74	100.00
Edible Graminea (EG)	0.57	3.93	1.83	8.43
Grain (G)	11.70	0.00	51.77	0.00
Non-Edible Utilitarian (U)	3.29	5.99	15.96	38.84
Edible Invasive (EI)	38.02	25.23	91.28	85.31
Manioc (M)	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 Latossols (% total plants)**
Vegetable (V)	26.18	0.66
Fruit (F)	17.86	7.43
Tuber (T)	32.74	80.03
Edible Graminea (EG)	0.53	0.55
Grain (G)	11.65	0.00
Non-Edible Utilitarian (U)	0.82	1.22
Edible Invasive (EI)	4.74	1.74
Manioc (M)	30.22	77.52

years, while vegetable crops are often mature after only three month's time. Vegetable crops are therefore favored on the more fertile Black Earth.

The age to maturity of crops and the dynamics of invasive species are not the sole factors accounting for these cropping differences, however. A second important factor, and one that perhaps contributes equally to the distribution of fruit trees, tuber and vegetable crops, is the apparent association between soil chemical and physical properties and crop choice. Individuals complained that vegetable crops do not grow well on Latosols, and most times produce nothing at all. Tubers and select fruit trees, on the other hand, often grow better on Latosols. While poor vegetable performance on Latosols likely results from low soil fertility, the better performance of tubers on Latosols could be due to the higher sand content on Black Earth – causing the soil to dry rapidly and perhaps also to hinder tuber growth. The difference in the performance of fruit trees may also find its origins in soil fertility differences, in which soil nutrient loads of available potassium (low), phosphorus (high) and other nutrients are imbalanced, producing the complexing and decreased availability of important nutrients. 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 produce only on Black Earth in the study region, as indicated by one farmer's comment that, "If you were to plant a corn plant outside *Terra Preta*, it won't grow."

Correlation of Cropping Behavior and Cropping Incentives

One final contribution to our understanding of human adaptive processes in anthropogenic and non-anthropogenic environments derives from the comparison of actual cropping behavior with informant ratings of crop performance on distinct soil classes. I use Pearson's correlation coefficients, therefore making strong assumptions about the level of measurement of cognitive data (crop performance ratings) and the nature of the population. While this step may be criticized on the grounds of imperfect isomorphism between conceptual discriminations of crops and classification of these differences (across individuals), they are employed here as descriptive measures to depict generalized trends in informant perception. Furthermore, they are effective in elucidating the relative influence of crop performance (fertility measures) on actual cropping behavior, as well as alternative influences that may explain observed discrepancies.

Crops present in both botanical plots and the crop-soil questionnaire are pooled in Table VI-7. Pearson's correlation coefficients (r) indicate the relationship between cognitive (crop performance) and behavioral (botanical) measures. While this is only a subset of crops planted in swiddens of the study region, findings are useful for examining how informant ratings of crop performance on each soil type correspond with actual planting activities. The most obvious trend is the positive relationship between crops that informants perceive as growing better on each soil and actual cropping associations in each environment, as evident in the first two columns of the correlation chart (below Table VI-7). The second two columns of this chart display the correlation between informant ratings of crop performance on one soil class and crop associations of the other, and serve purely heuristic purposes.

Comparable positive associations would indicate no relationship between more favorable cropping variations (from a strict fertility standpoint). Positive correlations in the first two columns and negative correlations in the last two would indicate that

Table VI-7. Correlating Informant Ratings of Crop Performance on Black Earth and Latosols with Actual Botanical Associations on These Soils

	Informant ratings:		*Botanical data:*					
			Black Earth			**Latosols**		
	Black Earth	**Latosols**	# Informants	% Swiddens	% Plants	# Informants	% Swiddens	% Plants
Pineapple	1.45	1.71	0	0.00	0	4	16.00	0.53
Banana	0.42	1.41	2	4.65	0.12	4	44.00	0.5
Sugar cane	1.50	1.13	1	2.33	0.53	4	16.00	0.3
Yams	1.50	1.88	2	16.28	0.62	3	24.00	0.57
Cariru	2.00	0.20	3	25.58	2.6	0	0.00	0
Red bean	2.00	0.38	4	20.93	2.42	0	0.00	0
Yucca	1.33	1.55	2	4.65	1.45	1	4.00	1.81
Papaya	2.00	0.50	6	37.21	6.33	1	4.00	0.07
Bitter manioc	0.75	1.88	4	41.86	30.23	9	92.00	77.51
West Indian gerkin	2.00	0.88	6	39.53	5.33	2	8.00	0.23
Watermelon	1.90	0.22	4	11.63	0.59	0	0.00	0
Maize	2.00	0.29	5	44.19	9.24	0	0.00	0
Lemon	1.42	1.42	0	0.00	0	1	4.00	0.14
Cucumber	2.00	0.50	2	13.95	3.82	0	0.00	0
Sweet pepper	2.00	0.50	5	16.28	3.93	1	8.00	0.37
Bell pepper	2.00	0.32	3	9.30	8.71	0	0.00	0
Okra	2.00	0.35	3	6.98	0.32	0	0.00	0
Tomato	2.00	0.10	3	6.98	1.54	0	0.00	0
Squash	1.92	0.50	6	23.26	1.01	1	4.00	0.07

Pearson's r	Black Earth	Latosols	BE/LAT	LAT/BE
Inf. R/# Inf.	0.4323	0.7755	-0.7811	-0.5042
Inf. R/% Swid.	0.2012	0.6647	-0.8011	-0.1778
Inf. R/% Plts.	-0.2684	0.4236	-0.5031	0.1973

individuals select the crops they plant based on soil fertility indices and local understandings of the environments where distinct crops grow better. While this pattern holds across most measures, there are two exceptions in columns one and four. These may be explained by the high number of manioc crops on Black Earth despite poor performance ratings (a logical pattern given the cultural importance of this crop), and the tendency to plant crops on Black Earth that are perceived as performing poorly on Latosols (columns one and four, respectively). A second important observation is the higher correlation in Latosol columns than for Black Earth. This reflects the strong constraints that farmers confront in selecting crops on Latosol (i.e., that soil fertility is a much greater incentive and constraint on Latosols than on Black Earth). One would expect the lesser constraint played by soil fertility indices on Black Earth to make it possible for other incentives to play a greater role in the resulting cropping practices. Pearson's correlation coefficients (r) are helpful in identifying these influences.

In Table VI-8 the relative influence of diverse incentives on cropping behavior is assessed through the calculation of Pearson's correlation coefficients (r). Data in the first row corroborate the positive influence of crop performance perceptions on cropping

Table VI-8. Deciphering the Relative Influence of Diverse Incentives on the Resulting Cropping Patterns on Black Earth and Latosols

Preference Criteria	Pearson's r Black Earth	Latosols
Crop performance ratings	0.43	0.79
More lucrative	0.14	-0.29
Quick returns	0.29	-0.67
More stable prices	-0.05	0.37
Less seasonal	-0.45	0.72
Less susceptible to pests	0.06	0.39
Requires less capital to cultivate	0.01	0.45
Requires less technical knowledge to cultivate	-0.05	0.37

behavior, and the greater influence of this incentive on Latosols than on Black Earth. Subsequent r values reflect the relationship between cropping patterns and other possible causal (independent) variables. Four additional variables have positive associations with cropping on Black Earth, yet relationships are weak. Higher and quicker economic returns are among these, and were often verbalized as incentives to Black Earth cultivation among local residents. In other words, while crop performance criteria are more strongly associated with Black Earth crop selection, economic incentives also appear to condition these decisions. Interestingly, these same variables show negative associations with Latosol cropping patterns, indicating that factors other than economic ones influence cropping decisions on these soils. The only positive economic association involves the greater stability of market prices for traditional Latosol crops.

The ability to cultivate Latosol crops throughout the year, low capital investments, little required technical knowledge and limited pest problems each show positive associations with cropping behavior on Latosols. While these could be interpreted as direct causes for the resulting cropping associations, these relationships may also be an artifact of the greater proportion of native crops on Latosols. While these factors may, in fact, provide incentives to farmers (as indicated by the identification of these variables in open-ended interviews), these influences may be only secondary – or simply incidental to the constraining influences of crop performance, a factor that selects for native crops on Latosols. The same may be said for Black Earth, in which these same factors would appear to be deterrents to cultivation, yet are overshadowed by other important incentives to Black Earth cultivation. One exception concerns the technical knowledge required to cultivate exotic vegetable crops on Black Earth – a factor that was perceived as a constraint to the successful cultivation of these soils among farmers with less experience in chemical pest control methods. In addition to the common tales of economic success on Black Earth, several individuals told tales of losing entire crops to pests.

These data indicate that an imperfect association between farmer perceptions of crop performance and their cropping behavior may rest on numerous criteria in addition to crop performance. These include economic incentives (quick and high returns) or deterrents (capital investments), ease of swidden management (pests, the need for technical knowledge, etc.) and other possible factors. The stronger association between cropping behavior and crop performance ratings on Latosols, however, suggests that this constraint (identified as such by locals) plays a greater role in cropping behavior than do other possible factors. Given that the influences analyzed here are by no means complete, it is impossible to make anything more than relative statements about these relationships. Data nevertheless indicate that Black Earth helps to reduce the constraint posed by soil fertility on cropping decisions. They also point to the role of myriad technological and historical factors (crop-specific adaptations, political-economics, etc.) that, together with a modified substrate, condition human adaptive process. This, in turn, highlights the insufficiency of a strict materialist framework (i.e., yield maximization) for broadening our understanding of human adaptation.

Fertility Management

Another behavioral manifestation of adaptive difference between Black Earth and Latosol swiddens is the management of nutrients within the swidden. I have identified five nutrient management practices practiced by collaborators, some of which are much more prevalent than others: the use of the burn, residue management, crop rotation, spatial association and fallow management.

The Burn

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. 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 access to the plantation. The coivara may be carried out on Latosols or Black Earth; however, it is much more common in traditional manioc swiddens (on Latosols). This may stem from a lesser need for 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 ability to burn Black Earth swiddens in the rainy season when burns are less intense, 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 its strength after the burn (Table VI-4). The burn is nevertheless 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 as a manifestation of flexible adaptive processes.

Residue Management

The second use of the burn is to manage invasive species, which I have classified here as residue management. 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 one 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. It is more common for individuals with a long history of Black Earth cultivation, and can therefore be understood as incipient (i.e., a practice that is adaptive, yet slower to be adopted by the population at large).

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.

Crop Rotation

Crop rotation or sequential cropping is very common in traditional agricultural systems (Francis 1986; Ramakrishnan 1992), yet is nearly absent in traditional manioc swiddens of the Amazon region. The practice is common for shifting cultivation systems, where the same crops are often grown on a suitable plot for several consecutive years (Ruthenberg 1980). The only practice that resembles rotation in these soils is the planting of more nutrient-demanding species in the first year of planting (yam, sweet potato, banana) and planting only manioc 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 rotations. 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

The logic of crop rotation is explained scientifically as a response to differing nutrient requirements (and impacts) of common crops. The practice is again isolated, serving to differentiate adaptive processes on Black Earth and Latosols for only a few more experienced Black Earth farmers. It again reflects the dynamic process of adapting to Black Earth and differentiating these use practices from the more traditional and widespread management practices associated with Latosol swiddens.

Spatial Association

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 associated nutrient requirements) to particular zones where these crops grow best to make an efficient use of nutrients throughout the farm. In both Black Earth nor Latosols, individuals failed to recognize innate differences in soil quality or strength as they move through the swidden. One possible exception involved a low-lying area (footslope) that had been selected for a fruit garden. Individuals do, however, recognize differences in burning effectiveness and even in crop performance, although these differences were always associated with the burn rather than as properties of the soil itself. Associations with 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 these patches are used for the same species that are distributed throughout 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.

Fallow Management

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 fertility management practice. I use the term "fallow management" to refer to the cyclical practice of clearing, planting and abandoning or managing 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, including the identification of distinct phases in the swidden fallow cycle and the duration, vegetation and soil chemical signatures associated with each phase (Jordan 1985a, 1989; Kass and Somarriba 1999).

The analysis of soil nutrient stocks as a function of time and stage in the swidden cycle (Jordan 1985a) is useful for comparing adaptive processes in Black Earth and Latosol swiddens. It is impossible to emulate the detail with which Jordan's study was carried out for Black Earth and Latosol swiddens of the study site. This is due to the limited one-year duration of field observations, and the fact that nutrient measurements were only carried out on the soil itself. However, it is possible to intuit something about the temporal dynamics of soil chemistry in these two swidden systems by classifying samples by soil class and cultivation stage (forest, burn, cultivated, abandoned), and by reconstructing soil nutrient stocks throughout the life cycle of the swidden. As will be shown below, the differential "background" fertility of soils within each soil class and the ability to find ideal exemplars of each swidden stage in each sample region somewhat limit the utility of this approach. A descriptive interpretation of the broad trends in soil chemical dynamics nevertheless provides important information to complement what we already know about these two systems. It also provides an essential link to our understanding of adaptive processes in these two environments.

By referring back to Figure III-1, we observe 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 slowly diminish to levels near those of the mature forest 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.

For each stage of the production cycle (Table VI-9), Black Earth swiddens are consistently higher in soil nutrient stocks and lower in toxic aluminum than adjacent Latosols. This difference appears to strongly ground the local perceptual differentiation of these two environments as well as divergent adaptive strategies for these two environments. Not only are soils more fertile before the burn, but also immediately following a burn when the more limited aboveground biomass (generally of young fallow vegetation) presumably contributes much less to the resulting soil chemistry than is true

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

Productive Phase and Soil Type		Ca^{++} ($mmol_c \cdot dm^{-3}$)	K^{+} ($mg \cdot dm^{-3}$)	Mg^{++} ($mmol_c \cdot dm^{-3}$)	Na^{+} ($mg \cdot dm^{-3}$)	Avail. P ($mg \cdot dm^{-3}$)	pH (H_2O)	Al^{+++} ($mmol_c \cdot dm^{-3}$)
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

for Latosols. This does not mean that farmers consistently clear Latosol swiddens in mature forest, but that the age of the vegetation must be approximately ten years for the swidden to produce a healthy crop (Ruthenberg 1980) and for soil organic matter to reach equilibrium (Ramakrishnan and Toky 1981). This figure is confirmed by local estimations:

> 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

> In my view, …you have to abandon for a period of three or four years, until [the fallow vegetation] gets taller, na?, and recuperates. Because direct, direct, no. It's like this [*Terra Preta*] that I have, you will see there, it was very worked. You plant watermelon in this *Terra Preta*, and it gives you pleasure to see it. Green, green…and very thick vines. This is the difference between the two, because let's say you plant in this [Red Soil], . . . you harvest what you planted in almost a year, na? Then in four years, when you go to slash the area again, she is not going to produce like the first time, na? She's weaker. Especially manioc, na? Banana doesn't produce at all. Only if you plant, if you were to clear a swidden in the mature forest there, and were to plant it for the first time. Then, it produces. – Pelado

> Manioc, at least in clay . . . 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 in medium to late successional forests 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.'" Moreover,

> On *Terra Preta* you don't find thick forest, no. As mature as the forest may be, it is low forest. At Faustino's it was pure mature forest. All that grew there was this Murú-Murú. At Marinho's there were some thick trees, but it is rare.
> – Honorato

Despite this tendency for slow biomass accumulation on Black Earth, swiddens are generally cleared from one to two-year fallow. This may stem from the limited availability of mature forest in Black Earth environments that have been subject to repetitive clearing, yet a more fundamental difference in the chemical "dynamics of Terra Preta" (Pabst 1991) and Latosols may also be responsible. Despite the higher nutrient demands of common crops on Black Earth, there seems to be a lesser dependence on the burn to achieve acceptable crop growth. Acceptable soil nutrient stocks, derived for any swidden from the combination of initial soil stocks and nutrients released from the vegetation upon the burn, seem to derive less from the liberation of nutrients from the standing biomass on Black Earth. The following statement attests to emic understandings of this same phenomenon:

> 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 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 contradicts 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 Davidescu 1982; van Raij 1991), yet Black Earth sites of the study region had limited soil potassium stocks. According to researchers at EMBRAPA, most crops require a minimum of 40 $mg \cdot dm^{-3}$ of potassium, a level reached only in the upper 10 centimeters of recently-burnt and cultivated Black

Earth soils (see Table VI-9). At the time of abandonment, potassium stocks in Black Earth are only 75% 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 for these same crops, further corroborate this limiting role played by potassium. Complaints about fruiting were common for squash, West Indian gerkin and papaya, crops for which there appears to be the strongest intentional planting in areas of high fertility.

Higher nutrient stocks in pre-burn and abandoned Black Earth areas, the younger age of fallow vegetation cleared for agriculture (see Table VI-10) and local understandings of the taxa Terra Preta and Terra Comum (see Appendix B) each support the conclusion that relative to Latosols, Black Earth soil contributes much more to the post-burn fertility than the liberation of nutrients from standing biomass per se. In the case of exchangeable potassium, the burn is likely to play a critical role in pushing soils over a critical threshold where preferred crops grow effectively, at least for the duration of their cycle of maturation. This is likely, in particular 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 1976), contributing more potassium in weight than any other nutrient with the exception of calcium (Nye and Greenland 1960).

It is interesting to make one additional observation about the final stage of the production cycle: swidden abandonment. If it were true that individuals fail to develop distinctive adaptive processes for novel, anthropogenic environments, we would expect them to mine the soil prior to abandonment. Some scholars have begun to observe that abandonment does not always occur as a function of soil chemistry in traditional Latosol swiddens, but also as a result of the costs and benefits associated with decreased yields and increased labor demands (for weeding) with swidden age. In the central study region, however, individuals almost unanimously state that they abandon Latosol swiddens when the soil "tires". Interestingly, soil nutrient stocks upon abandonment are much higher on Black Earth than levels for Latosol swiddens. Several motives could explain this difference, including the shorter cropping times of vegetable crops, the rapid colonization of invasive species and/or the higher nutrient demands of crops grown on Black Earth. The critical point to be made here, however, is that these two systems diverge in soil fertility levels upon abandonment, evidencing once again important differences in adaptive strategies for anthropogenic Black Earth.

The second important distinction in the fallow management practices carried out in Black Earth and Latosol swiddens is in fallow dynamics, namely the rate of clearing and abandonment of the swidden. This cycle is conditioned both by design (cultural practices and preferences) and the natural dynamic of fallow vegetation on each soil, each of these conditioning human adaptive strategies. Herein lies an interesting distinction, in that the increased rate of the planting-fallow-planting cycle on Black Earth represents a truly systemic difference – grounded not only in farmer choice, but in the dynamics of the environment itself, with mutual influences between them. Reasons for this difference include the rate of colonization by invasive species (leading to labor constraints), crop choice (nutrient demands and life cycle) and soil fertility.

Further evidence for distinctive adaptive processes on Black Earth and Latosols may be found in the length of time individuals maintain swiddens in each stage of the production cycle. The decision rests on feedback between behavioral and biophysical processes, and results in specific influences on soil fertility. Cropping duration depends on a number of factors, including the particular crops to be planted (exerting an influence through their growth cycle and nutrient requirements) and the colonization of invasive species. Fallow duration, on the other hand, depends on levels of soil depletion upon abandonment, the importance of an effective burn, the availability and accessibility of primary forest and labor limitations.

Data on total time in production, age of cleared fallow vegetation and the percentage of swiddens cleared from primary forest were collected for each class of swiddens and are presented in Table VI-10. 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 of that of Latosols. When

Table VI-10. Fallow Dynamics Contrasted for Black Earth and Latosol Swiddens

Parameter	Black Earth (months)	Latosol (months)
Total Time in Production:		
Average*	8.68	28.73
Max	60	50
Min	1	12
St. Dev.	11.07	10.61
Total Time in Production:	(outlier removed)	
Average*	4.56	28.73
Max	36	50
St. Dev.	6.32	10.61
Fallow Age:		
Average*	51.54	131.11
Max	120	180
Min	3	96
St. Dev.	36.68	29.82
% Swiddens Cleared from Primary Forest:	25.64	72.73

eliminating a farmer who mined a swidden intensively for six years straight (a strong outlier), these differences are even more pronounced – producing a 1:6 ratio. The maxima and minima reflect this same distinction. Secondly, the age of the cleared fallow vegetation is only about 2 ½ times greater on Latosols. Furthermore, while maximum fallow ages vary by only 50% (10 vs. 15 years), the ratio of minimum fallow age for Black Earth:Latosol is much higher (1:32). When considering the role of farmer decision-making in the resulting values, we find that farmers have much more control over the minimum fallow age for clearing a swidden than the maxima, which tends to reflect available resources rather than choice (the oldest available forest presumably liberating more nutrients for cultivation). This would indicate a strong divergence in management criteria for these two swidden systems, in particular a demand for older fallow on Latosols. This trend is strengthened by the fact that a much higher percentage of swiddens is cleared from mature forest on Latosols (due, in part, to their greater availability), and by the perceived speed at which fertility recuperates through the fallow on these soils:

> 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*. She can, this year, for example, na? 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

Distinctions in cultivation and fallow dynamics on Black Earth and Latosols have several important causes and implications in addition to inherent chemical and physical properties that may facilitate the recuperation of soil nutrient stocks. First, the shorter production cycles of crops both favored on and better adapted to Black Earth would favor a shorter production cycle in this environment. The tendency for Black Earth swiddens to be abandoned after the first crop is ironic given how common successive planting is to shifting cultivation systems in Amazonia and other regions (Francis 1986; Jordan 1985a; Ruthenberg 1980). The idea that Black Earth *cerra rápido* (closes in quickly with weeds) provides an explanation for this tendency for early swidden abandonment, due to the tendency for individuals to shy away from higher labor investments required to extend the production cycle of Black Earth swiddens. This complements the ease with which adjacent young fallow may be slashed and the heightened fertility in newly cleared swiddens, each of which are important incentive for favoring the cultivation of new swiddens over the maintenance of those already in production.

The implications of these practices include a faster expansion of cultivation into surrounding forest on Latosols (due to the long recuperation time required of fallow), and higher fertility indices in Black Earth swiddens upon abandonment. The ability to clear swiddens from areas of young fallow on Black Earth despite the planting of nutrient-demanding crops there could result, in part, from this management practice that effectively keeps soil nutrient stocks at a higher level in Black Earth swiddens. This complexity in human adaptive processes and dynamic feedback with environmental processes offer important insights into the range of factors that jointly influence human adaptation and human-environmental interactions in anthropogenic ecosystems.

Labor Concerns and Time Allocation

One final realm of adaptive behavior that differs between Black Earth and adjacent, non-anthropogenic environments, concerns cost-benefit assessments of productive activities in each environment and the actual time allocated to each (presumably as a function of perceived benefits). Tropical agriculture is characterized by low labor productivity, leading 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, then 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, with high labor investments to Latosol cultivation and fishing (see Table VI-11). The limited time dedicated to hunting is an exception, and likely results from drastically diminished game populations due to over-hunting in the region in recent decades. This has caused many families in the Lower Negro region to abandon this traditional economic activity altogether. Interestingly, these data also indicate that families are willing to dedicate as much time to Black Earth cultivation as to any other economic activity.

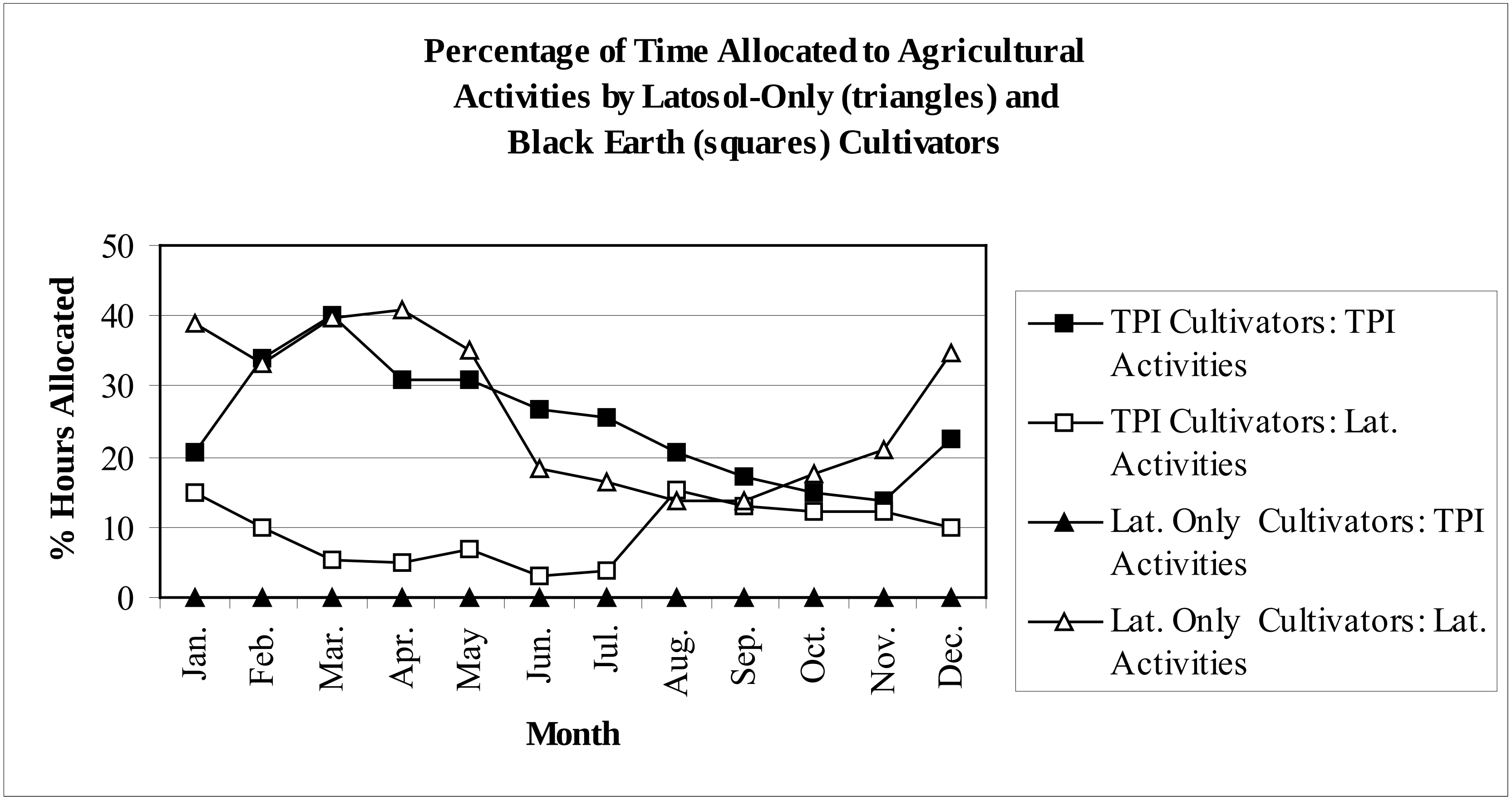
To determine how the presence of anthropogenic Black Earth environments influences differences in family labor allocations to agricultural activities, I have divided collaborators into two categories: those farming Black Earth (with or without complementary Latosol cultivation) and those farming Latosols only. This permits an

Table VI-11. 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

assessment of the influence of Black Earth cultivation on time allocation criteria and the allocation of valuable time and energy. Results of this activity are plotted in Graph VI-4.

It is first important to note that the uppermost curves (clear triangles, solid squares), representing time allocated to Black Earth (by Black Earth farmers who also have access to Latosols) and Latosol (by individuals who have access to Latosols alone) activities, 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 increased problems with 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



Graph VI-4. 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 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; Meggers 1971). In fact, what occurs is the opposite, indicating the importance of Black Earth in these integrated production systems.

Another striking pattern is the near symmetry in the curves that contrast both: 1) the time allocated to Black Earth with that allocated to Latosols among Black Earth farmers (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 VI-12). 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 VI-12. 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

The ability to cultivate bitter manioc in conjunction with exotics on these anthrosols 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 modern cultivation practices (which target more non-traditional crops). Yet this ability to intercrop does not fully compensate for lost manioc yields, as evidenced in the area figures of Table VI-12. 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 progressive increase in weed invasion with time (which is faster on Black Earth than on Latosols). The following botanical data are an indication of this role played by crop performance and labor constraints on farmer perceptions and on the cropping behavior associated with bitter manioc:

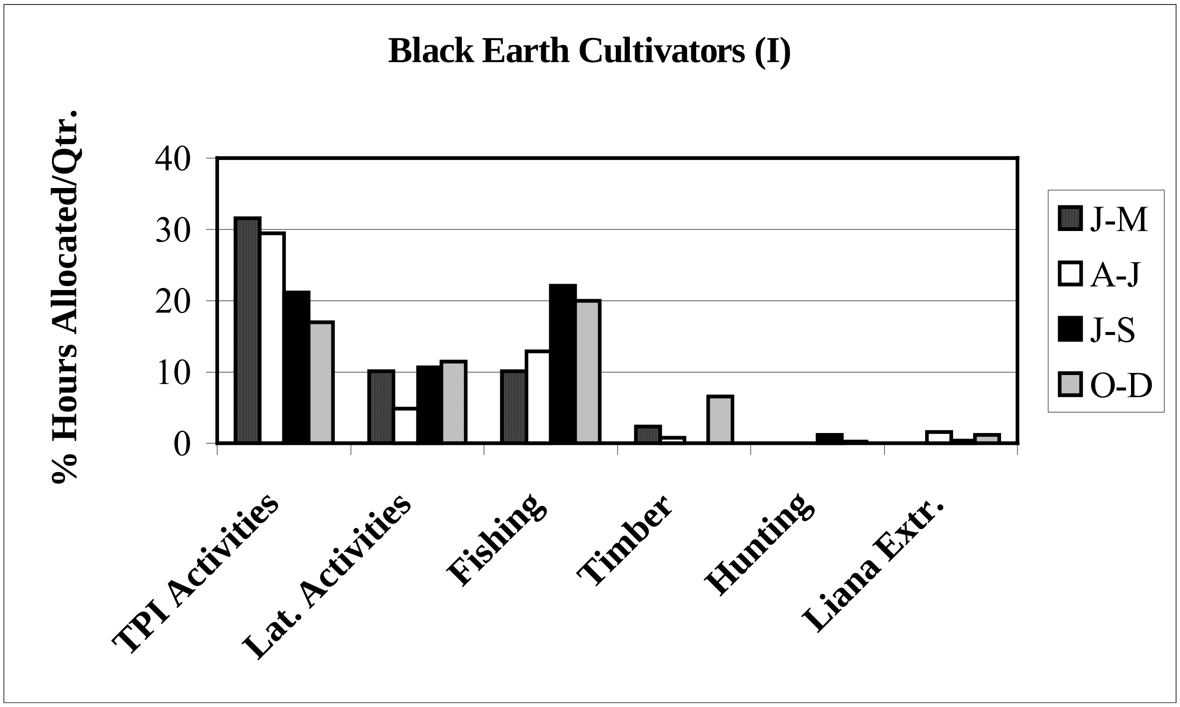
Table VI-13. The Abundance of Bitter Manioc on Black Earth and Latosol Swiddens

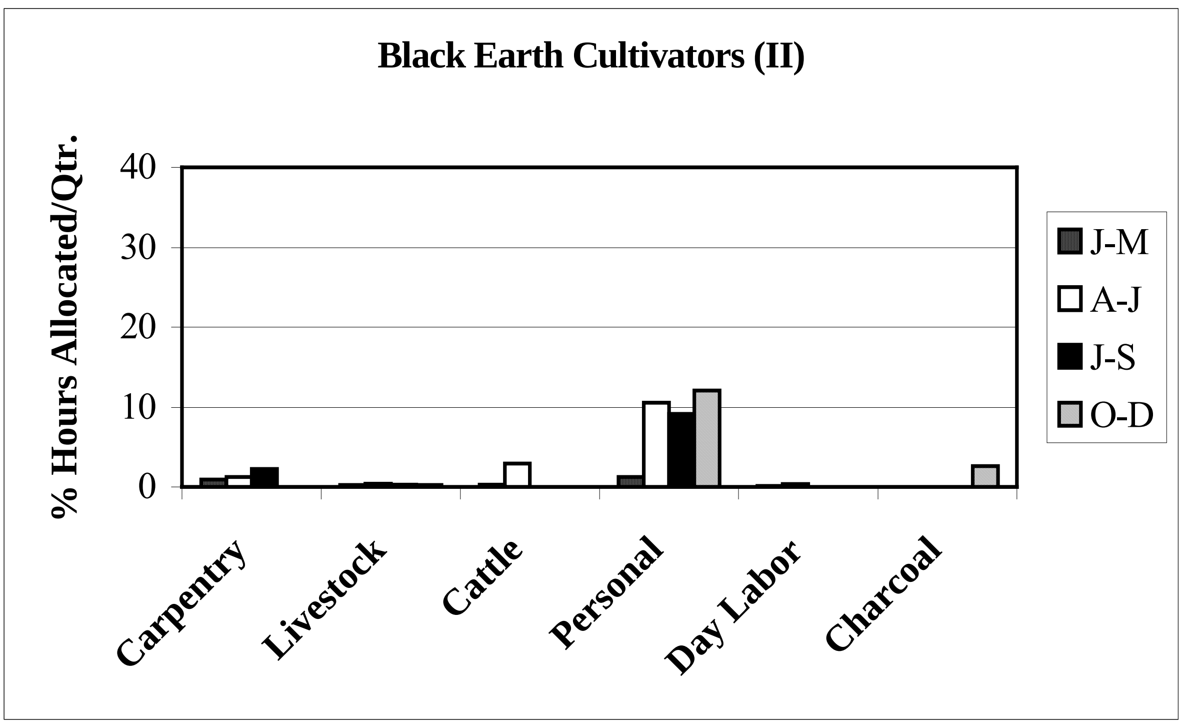
Crop	**Abundance, Latosols**		**Abundance, Black Earth**	
	% Swiddens	% Plants	% Swiddens	% Plants
Bitter Manioc	41.9	30.2	92.0	77.5

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, as evidenced by a paucity of Black Earth swiddens cleared solely for manioc and other traditional cultivars. This is presumably due to the labor invested in clearing a swidden, which is kept to a minimum when only one swidden is cleared (i.e., cultivating one type of soil alone) rather than one for each cropping system (i.e., one on each soil class)[3]. This is evident in the fact that only one of the 43 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 this swidden relative to other, more "legitimate" Black Earth sites (with ranges varying between 0.62 - 0.45 $mg \cdot dm^{-3}$ and 11.77 - 12.26 $mg \cdot dm^{-3}$ with depth, respectively).

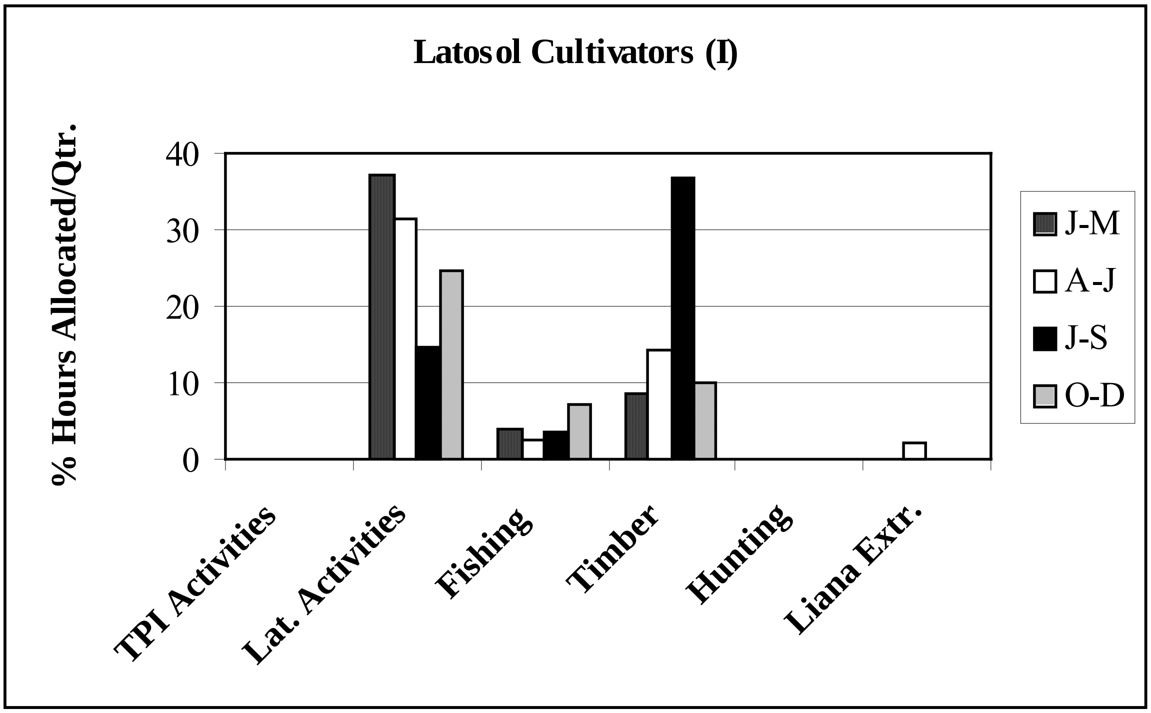
The differences in time allocated to Black Earth and Latosols throughout the course of the year also influence the relative time allocated to alternative productive activities in the lower Negro and Urubú. Graphs VI-5 and 6 plot the time allocated by Black Earth and Latosol farmers, respectively, to diverse economic activities per quarter. While the average proportion of total time dedicated to the predominant agricultural activity differs little between collaborators with and without access to Black Earth (25 and 27%, respectively), differences in the time these groups allocate to other complementary activities do exist. First, more time is dedicated to fishing by Black Earth farmers, and to timber extraction and carpentry by Latosol-only farmers. The first is a bit of an anomaly

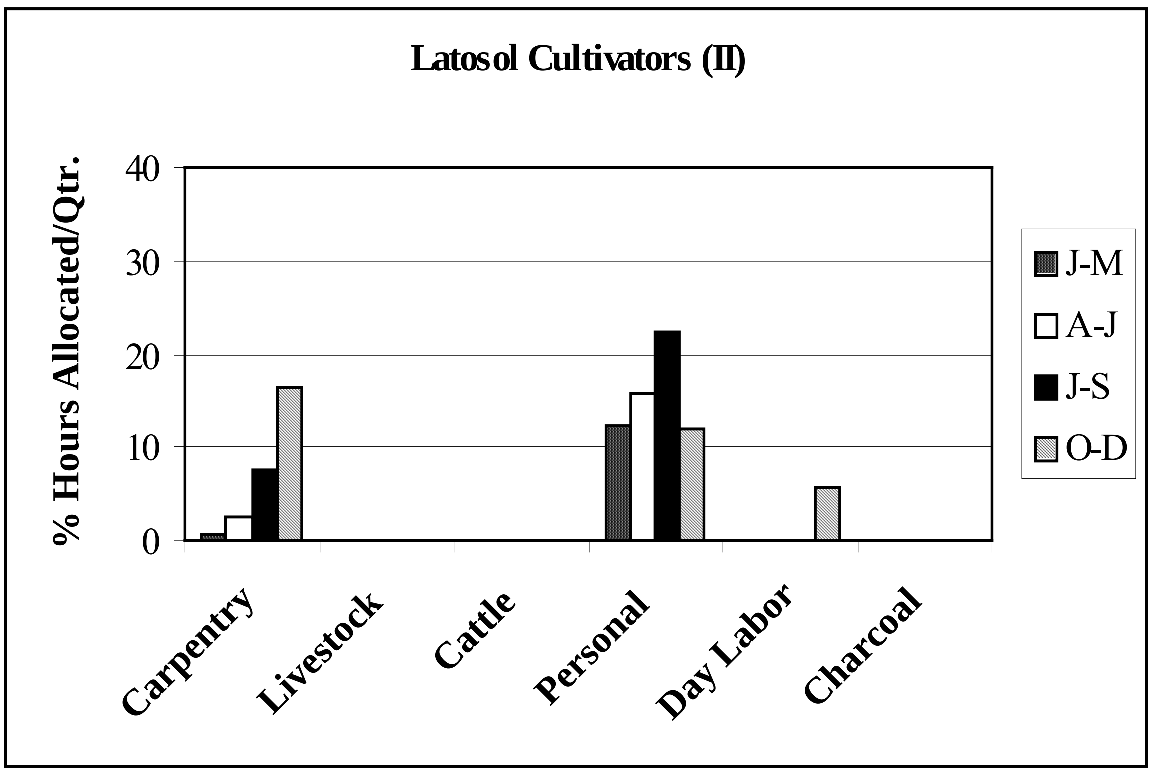
[3] Of eight Black Earth farmers, five nonetheless clear separate swiddens on non-anthropogenic soils for manioc cultivation, presumably to increase the yield of traditional staple crops.





Graph VI-5. Time Allocated to Diverse Economic Activities by Black Earth Cultivators





Graph VI-6. Time Allocated to Diverse Economic Activities by Latosol-Only Cultivators from a nutritional standpoint, given the greater potential for substituting crop for faunal protein on Black Earth. The second pattern makes more sense, given the ability of farmers to adjust their work with timber (a less seasonal activity) to the labor demands of manioc farming. Yet this would also hold true for Black Earth, for which demands on labor are similar to those of traditional manioc swiddens.

The most significant contribution of these data to the question of human adaptation to anthropogenic environments is that the activities most often accompanying the cultivation of Black Earth and Latosols are distinct, and complementary to agricultural activities with respect to the demands they place on household labor. The peaks of each complementary activity match the lows of the other, if not by the innate properties of the activity itself, then minimally with respect to the time individuals choose to dedicate to each. These patterns demonstrate not only a difference in adaptive strategy between Black Earth and Latosol environments, but also a strong adaptive logic for the novel anthropogenic context demonstrating once again that ingenuity and dynamism characterize adaptive processes.

D. Conclusions

To discuss the implications of these results for our conceptual models of human adaptation, it is important to refer to Moran's (1982) seminal work on human adaptability. Moran states that while the adaptations of non-human animals are primarily biological, a result of natural selection over evolutionary time scales, human adaptations – while overlaying similar biological adaptations – have much stronger behavioral and cultural manifestations. This is because the relatively short time frame (in evolutionary terms) in which humans spread across the continents and diverse environments allowed few biological adaptations to occur. Instead, the most effective mechanisms allowing distinct populations to inhabit novel climatic and geographical regions were behavioral and technological. While one could argue that other animals also possess culture or the ability to modify behavioral modes of conduct to improve adaptive fitness, critical here is the realm of adaptive possibilities ascribed to humans.

Cultural or behavioral adaptations include mechanisms that effectively improve the adaptive fitness of the individual or social group. These include social organization and its role in fostering the sharing of resources or division of labor to effectively occupy a broader ecological niche, technology and its role in improving the harvestability of novel resources, and spatio-temporal adjustments to natural cycles of abundance in resources. Each of these conceptualizations of adaptive process, while highlighting different mechanisms that improve adaptive fitness or the exploitation of critical resources, share a similar orientation to the environment. That is, the environment is an entity with particular properties – static or dynamic – to which humans must adapt in order to gain adaptive fitness. The environment itself is not subject to cultural process.

This view of the environment has been prevalent in the natural sciences as well, as evident in efforts to define and protect the "pristine" in nature. Examples are common in botanical guides to tropical forest vegetation, where distributions of native species are explained by "natural" (non-human –biophysical, climatic or physiographic) causes and discontinuities alone (Henderson 1995; Henderson et al. 1995). More often than not, the origin of these distributions is difficult to prove. Yet we have evidence that human presence and impacts were widespread in these environments, altering forest composition either directly through planting and managed succession or indirectly (as a by-product of settlement and subsistence) (Balée 1989, 1992; Denevan and Padoch 1987; Posey 1982, 1985; Stocks 1983).

Evidence that humans modify the environments through their interaction with it has stimulated a great deal of interest in anthropological circles about the interpenetration of "nature" and "culture" (Balée 1998; Crumley 1994). This historical ecological literature has produced two important influences on our view of "nature" and of human adaptation: that apparently pristine environments are often imbued with cultural artifacts, and that historical rather than evolutionary events are responsible for the changes in human-environmental interactions over time (Balée 1988). In short, it represents a departure from the primacy that was given to the environment in structuring human adaptive behavior by acknowledging the historical and ecological praxis of native peoples.

Findings in this chapter attest to this ecological praxis of humans, both in their direct modification of the environment and in the adaptive strategies they employ within these modified ecosystems. Both the chemical and morphological properties of Black Earth attest to anthropogenic origins: distinctive epipedons overlying parent material common to non-anthropogenic soils, abundance of potsherds and high levels of anthropogenic phosphorus. Results of soil chemical assays and fertility experiments with *Zea mays*, a nutrient-demanding crop, also show Black Earth to be more eutrophic (nutrient-rich) in relation to adjacent Latosols. These properties defy all expectations for non-anthropogenic soils of the region, which under regional climatic and geological conditions should be both more oligotrophic and less able to retain nutrient cations.

Findings also suggest that anthropogenic modifications of the environment must be viewed diachronically. First, multiple occupational processes were likely to have characterized Black Earth sites, including – minimally – formative (traditional settlements with intensive depositional processes) and modern periods (characterized by the removal of soil nutrients from the ecosystem through agriculture). Each of these periods was likely punctuated, however, by alternate periods of accretion and deflation of soil nutrients and by spatially heterogeneous impacts. The mutability of the environment is therefore best seen as an ongoing process, in which the cumulative effects of past generations the ecological processes resulting from these impacts jointly condition the environmental context confronted by subsequent groups. Contemporary groups such as those occupying the Central Amazon region have encountered a relatively eutrophic soil resulting from semi-permanent settlement of Amerindian societies (Heckenberger et al. 1999; Smith 1980). Those inhabiting this region in the future will perhaps come across more moderate fertility indices on anthropogenic soils due to soil nutrient losses through agriculture and vegetational or climatic influences. This complexity again favors the incorporation of humans into our understanding of ecosystemic processes.

Rooted in this acknowledgement that the environment derives its properties from both evolutionary ("natural") and historical ("cultural") events and processes, this chapter demonstrates how humans respond to these environmental modifications in their generation of adaptive strategies to enhance their livelihood. The adaptations that take place in "cultured" Black Earth environments include the evolution of both cognition and behavior. Cognitive adaptations to Black Earth include the incorporation of anthropogenic environments into folk classification systems, and the evolution of complex understandings of the properties of these environments. Behavioral adaptations, on the other hand, include the generation of distinctive cultural practices to better manage

Black Earth swiddens (fallowing practices, cropping strategies, etc.), technological adaptations (the use of non-traditional crops and inputs) and complex strategies to allocate scarce on-farm resources (labor, soil amendments, etc.). The evidence provides ample proof that prior anthropogenic modifications of the environment do, in fact, condition human adaptive processes on the terra firme.

Findings also add a more richly textured understanding of human adaptation by highlighting how dynamic historical (proximate) factors mediate these processes. The recognition of how economic forces, labor constraints, technical knowledge and cultural tradition influence how individuals perceive costs and benefits associated with the biophysical environment gives richness and historical depth to our understanding of human adaptation. It demonstrates how these factors both potentialize and constrain adaptability, and how the environment in and of itself only becomes a resource when individuals have the ability to leverage these factors to their subsistence advantage and to creatively construct productive strategies which best meet the needs of their families.

Chapter VII. THE PLASTICITY OF HUMAN-ENVIRONMENTAL INTERACTIONS IN BLACKWATER ECOSYSTEMS

A. The Research Question

This chapter is dedicated to testing the second of two research hypotheses upon which this dissertation is based:

Hypothesis 2: *The traditional shifting agricultural system of the Amazonian terra firme is plastic, conditioned not by absolute environmental limits but by the interaction between particular cultural and environmental processes.*

This hypothesis was employed to derive broader understandings about the plasticity of human-environmental interactions in blackwater ecosystems, and about the relative influence of ecosystem constraints and ecological praxis on human adaptation. I define "plasticity" as the range of adaptive possibilities in an ecological context, conditioned by the mutual influence of human behavior, ecosystem properties and other factors which mediate these interactions. Data presented in Chapter V demonstrate that distinctive adaptive manifestations do, in fact, characterize anthropogenic and non-anthropogenic terra firme environments. As such, human-environmental interactions in Blackwater ecosystems are not constrained by absolute environmental limits, as proposed by some Amazonianists (Meggers 1971; Gross 1975); rather, they are plastic. New questions emerge, therefore, that beg resolution. If the oligotrophic conditions of Amazonian blackwater environments do pose difficulties for livelihood as claimed, the question is no longer how these properties dictate human adaptive responses, but how these limitations condition the *plasticity* of adaptive manifestations. More specifically, how plastic are human-environmental interactions in blackwater terra firme environments, and what are the factors or contingencies that potentialize more plastic responses to Black Earth environments?

While Chapters VI and VII both address human adaptive process in Blackwater ecosystems, this chapter delineates biophysical and non-biophysical factors conditioning the plasticity of adaptive manifestations within diverse historical and geographical settings. Two approaches are taken here. First, research on adaptive responses to similar anthropogenic Black Earth environments in distant blackwater regions of Amazonia highlights factors, other than the biophysical environment, that influence human adaptation. The spatial differentiation in these adaptive processes highlights cultural, political-economic and technological contingencies that potentialize or constrain the plasticity of human-environmental interactions in diverse settings.

Second, temporal dimensions of plasticity in traditional swidden agriculture are discerned through the analysis of ethnographic, pedological and agronomic data from central research sites on the lower Negro and Urubú. The depth of inquiry in these central field sites will ground an analysis that is largely inferential and focuses on empirical and ethnographic data that are particularly suited to open windows of understanding into the past. Nevertheless, these data help ground our understandings of spatial manifestations of adaptive process in the contemporary setting, and place our understanding of the plasticity of human-environmental interactions within a diachronic framework.

B. Spatial Dimensions of Plasticity in Human-Environmental Interactions in Blackwater Regions of Amazonia

To inquire into geographical variations in the plasticity of human-environmental interactions in blackwater ecosystems, it is important first to determine that the diverse manifestations of human adaptive processes do not result from divergent biophysical or environmental stimuli. In other words, it is important to determine that the phenomenon called "Black Earth" is, in fact, similar in distant blackwater sites. The plasticity of adaptive responses in geographically-distant terra firme environments can then be compared, and the differences analyzed in terms of site-specific influences other than the biophysical context itself.

Identifying Common Environmental Stimuli in Distant Blackwater Regions

Pedological and ethnographic data from comparative blackwater sites have been compiled to demonstrate the similarity of Black Earth environments in each region. With the first, I assess the particular nature of pedochemical divergence of anthropogenic from non-anthropogenic ("common") soils in each site to determine whether Black Earth diverges in a similar way from the spatially-predominant soils in each setting. I do this by generating pedological measures of divergence that facilitate the comparison of distant settings on the basis of specific pedological indicators.

While soils tend to be sandier in the Santa Isabel region, where there is a higher proportion of Podzols with respect to Latosols, soil fertility indices on Black Earth tend to diverge from background soils in a similar way in distant blackwater settings. Results from soil chemical and physical analyses are presented in Table VII-1, where data are averaged by soil horizon. This treatment of the data gives rise to certain difficulties in interpretation given that sampling is done by soil horizon, for which depths vary between pedons. While this would appear to compromise the validity of results, weighted averages calculated according to the depth of anthropic horizons fail to reflect the properties of a given volume of soil and produce exaggerated fertility assessments for the deeper horizons.

From Table VII-1, it is difficult to make any absolute statements about the pedochemical similarity of Black Earth in distant blackwater regions because some parameters that should vary together when contrasting soils from distant regions actually vary in an inverse manner. This is the case when comparing Santa Isabel and lower Negro/Urubú sites, for example. While values of plant-available potassium and phosphorus are higher near Santa Isabel, available calcium and magnesium, Base Saturation and ECEC are lower. It is possible, however, to make some general statements about the nature of these anthropogenic soils and the similarities between them.

The “Percentage Divergence” measure in Appendix D (Tables D-4 through D-6) shows that patterns of divergence of anthrosols from non-anthropogenic soils are similar in distant blackwater settings. This measure was generated to determine the relative divergence of diverse chemical and physical parameters associated with anthropogenic modifications of the environment. For each region, naturally-forming soils are employed as the reference points from which Black Earth values deviate.

While five distinct measures of pedological plasticity were generated, I focus here on three of these that best express the similarities and differences between the Black Earth sites located in distant blackwater settings. The first two, the divergence of averages and of maxima, highlight Black Earth parameters that most deflect from

Table VII-1. Pedochemical Comparison of Black Earth Sites in Distant Blackwater Regions

Region	Hor.		Depth (cm)	pH (H2O)	K+	Na++ (ppm)	Av. P	Ca++	Mg++ (meq/100g)	Al+++	ECEC	Base Sat.	Tot. C	Tot. N	C. Sand (%)	F. Sand	Silt	Clay
Latosol,		Ave.	15.89	4.25	18.00	4.78	3.79	0.11	0.10	2.46	2.74	10.75	4.48	0.13	30.64	10.16	18.08	39.91
Central		SD	4.31	0.24	6.16	2.82	1.53	0.13	0.06	0.73	0.69	7.65	2.35	0.05	13.29	7.08	6.75	17.17
Rsch.		Ave.	28.70	4.37	8.80	2.60	1.74	0.03	0.03	1.75	1.85	5.51	1.92	0.06	22.05	9.29	20.11	49.36
Sites		SD	14.20	0.15	3.55	1.07	0.90	0.02	0.01	0.49	0.51	2.13	0.61	0.01	10.60	6.01	10.33	18.24
		Ave.	42.90	4.31	6.00	1.80	1.34	0.04	0.04	1.50	1.60	6.27	1.09	0.05	20.34	8.71	12.68	58.28
		SD	11.80	0.09	4.52	0.79	0.70	0.06	0.06	0.59	0.65	5.31			11.22	6.09	4.29	15.54
TPI -	**H1**	Ave.	29.71	5.55	16.25	10.25	68.63	5.41	0.66	0.47	6.63	85.52	3.23	0.10	45.18	13.75	14.90	21.17
Central		SD	20.33	0.58	8.91	7.89	65.70	3.11	0.59	0.71	2.94	24.52	0.50	0.02	12.62	2.30	4.45	10.83
Rsch.	**H2**	Ave.	28.29	5.16	4.75	2.50	37.37	1.63	0.22	0.72	2.59	64.16	1.46	0.05	38.49	12.75	11.69	37.07
Sites		SD	13.83	0.52	2.60	1.51	32.66	1.38	0.19	0.60	1.16	34.49	0.85	0.01	16.95	3.66	4.53	16.64
	H3	Ave.	38.33	4.91	2.86	1.57	46.91	0.66	0.12	0.69	1.48	49.99	0.62	0.03	30.85	10.60	11.93	46.61
		SD	21.81	0.33	1.07	0.79	63.67	0.45	0.14	0.31	0.45	25.38	0.31	0.01	15.54	5.34	4.74	19.93
TPI -	**H1**	Ave.	47.50	5.29	26.57	15.14	343.84	3.70	0.16	0.94	4.94	57.44	2.95	0.08	40.32	25.87	19.55	14.26
Santa		St.Dev.	21.38	0.52	8.30	12.98	277.35	5.20	0.21	0.97	4.78	40.73	1.63	0.03	15.10	7.13	7.45	6.98
Isabel	**H2**	Ave.	27.67	5.31	8.50	14.25	318.75	1.01	0.03	1.23	2.35	35.66	n/a	n/a	43.22	27.49	17.29	12.00
Region		St.Dev.	9.29	0.58	4.12	9.54	196.66	1.74	0.02	0.87	0.97	42.69	n/a	n/a	21.81	7.27	10.07	9.46
	H3	Ave.	20.00	5.18	4.67	14.33	303.27	0.04	0.02	1.72	1.85	9.89	n/a	n/a	32.92	23.10	18.80	25.18
		St.Dev.	n/a	0.12	3.06	10.97	237.77	0.02	0.02	1.50	1.54	5.22	n/a	n/a	28.56	11.42	7.57	21.39
TPI -	**H1**	Ave.													35.95	28.04	15.05	20.95
Canoas		St.Dev.													12.52	8.82	2.50	19.40
	H2	Ave.													33.68	27.80	12.97	25.55
		St.Dev.													16.34	10.92	2.85	30.02
	H3	Ave.													25.83	20.37	10.50	43.30
		St.Dev.													18.22	16.19	5.32	39.74
TPI -	**H1**	Ave.		5.63	44.00	14.00	52.17	3.84	0.51	0.34	6.08	99.08	1.99	0.05	52.26	27.65	7.48	12.60
Int. Ag.		St.Dev.	n/a	0.63	n/a	n/a	n/a	1.83	0.14	0.43	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Sites	**H2**	Ave.		5.97	30.00	10.00	40.13	3.38	0.30	0.05	3.85	98.73	n/a	n/a	54.90	27.73	7.22	10.15
		St.Dev.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	H3	Ave.		6.06	24.00	5.00	33.44	2.23	0.21	0.08	2.60	97.11	n/a	n/a	60.90	23.61	6.54	8.95
		St.Dev.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

background soils. They were measured by taking the difference between Black Earth (BE) and Latosol (LAT) values at each depth, dividing this number by the Latosol value and multiplying by 100, as follows:

$$\frac{(M_{j,\,BE} - M_{j,\,LAT})_{Hx}}{(M_{j,\,LAT})_{Hx}} \times 100 = \underline{\text{\% Divergence of M,}}$$

where: M = measure of divergence (averages, maxima, etc.)
j = soil physical or chemical parameter
Hx = soil horizon

This is similar to the botanical measure "% Divergence of Crop's Representation" (Chapter VI) in its focus on the divergence of values (species abundance, soil chemical indices) from some background state (i.e., Latosols).

The second measure, the % of Range Overlap, employs value *ranges* rather than averages to compare Black Earth to non-anthropogenic soils. It was calculated by taking the total overlap distance in Black Earth (BE) and Latosol (LAT) ranges (per horizon), dividing this value by the total value range for that parameter and horizon (across both soil classes) and multiplying by 100, as follows:

$$\frac{\text{Range Overlap } (\text{Intersection}_{j,\,BE/LAT})_{Hx}}{\text{Total Range } (\text{Max}_{j,\,BE/LAT} - \text{Min}_{j,\,BE/LAT})_{Hx}} \times 100 = \underline{(\text{\% Range Overlap})}_{Hx,}$$

where: j = soil physical or chemical parameter
Hx = soil horizon

This gives us not an indicator of plasticity, but of its opposite – the extent to which parameter ranges of the two soil classes *fail* to differentiate. Those parameters with a higher Maximum Overlap are therefore the *least* plastic.

It should be noted that a greater divergence of buried horizons in Appendix D tables does not represent a contradiction for anthrosols (where direct modifications are often limited to the epipedon), given that calculations of divergence reflect relative values[1]. This is desirable in a quantitative measure of divergence, defined as the degree of deflection from an established norm.

Below, I have listed Maximum Divergences for each pedon and region, for which the most plastic measures are listed by order of magnitude.

a) Maximum Divergence of Averages[2]

Lower Rio Negro/Urubú Regions:

P_2O_5 > Ca^{++} >> Base Sat. > Mg^{++} > ECEC > Depth

Santa Isabel Region:

P_2O_5 > Ca^{++} >> Base Sat. > Depth > ECEC > Mg^{++}

b) Maximum Divergence of Maxima

Lower Rio Negro/Urubú Regions:

P_2O_5 > Ca^{++} >> Mg^{++} > Base Sat. > Depth > ECEC

Santa Isabel Region:

P_2O_5 > Ca^{++} >> Base Sat. > Depth > ECEC > Mg^{++}

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[1] Extreme Latosol reference values in subsurface horizons are reflected in the calculations, causing the buried Black Earth horizons to exhibit a greater *divergence* from this norm for some parameters.

[2] The symbol ">>" refers to values that are at least four times greater than the next lower value.

By the above measures, available phosphorous and exchangeable calcium are by far the most plastic soil parameters for each region when subject to anthropogenic soil-forming processes. Base Saturation is also highly plastic in each region, while magnesium is more plastic in some soils than in others. Most importantly, for each measure of plasticity the same six parameters are invariably the most plastic, providing a strong indication that soils in each region deviate in similar ways from background soils when subject to anthropogenic soil modification.

The sequence of least plastic parameters for each region follows, as expressed by the Percentage of Range Overlap:

c) % of Range Overlap[3]

Lower Rio Negro/Urubú Regions:

Mg^{++} > ECEC > Depth > K^{+}

Santa Isabel Region:

Mg^{++} > K^{+} > Depth > Base Saturation > Al^{+++} > ECEC

By this measure, Mg^{++} is the least plastic soil parameter in each region. Yet this limitation is likely to be of little importance to crop performance. From soil chemistry, we know that the summation of calcium and magnesium ions (Ca^{++} + Mg^{++}) is more critical than Mg^{++} alone. The high values of exchangeable calcium on Black Earth would therefore compensate for low soil stocks of magnesium.

The divergence of other parameters varies by region. Exchangeable potassium and ECEC diverge only slightly from non-anthropogenic soils in each region, while the relative divergence of Al and Base Saturation varies. It is difficult to translate these

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[3] Sequence limited to values greater than 50 %.

absolute measures into numbers relevant to crop yields, given variable demands for diverse nutrients. However, from Table VII-1 and what we know about the fertility requirements of most common crops, we know that potassium is the most limiting nutrient for a broad range of crops (with most crops requiring about 40 ppm or $mg \cdot dm^3$). This nutrient is present in higher quantities in the Santa Isabel region and intensively-farmed sites than in central (Phase One) research sites. It would therefore appear as if these comparative sites have greater rather than less productive potential from the standpoint of limiting nutrients.

Given the variability in soil chemical parameters from region to region, further evidence must be brought to bear on the question of whether Black Earth represents a common environmental stimulus, independent of region. Interestingly enough, despite variability in adaptive strategies within these distant anthropogenic environments, local commentary on the potential of Black Earth to produce diverse crops is remarkably similar throughout each region. The primary exceptions stem from intensively-cultivated sites where the use of industrialized fertilizers expands the range of viable cropping strategies (see Table VII-2).

These similarities indicate an innate potential to cultivate "Black Earth crops"[4] in each region. Evidence points to the greater importance of non-pedological factors in conditioning the diversity of uses applied to Black Earth in distant blackwater regions.

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[4] A term often used among farmers of central research sites to refer to the crops specifically grown on Black Earth sites.

Table VII-2. Regional Perceptions on the Ability of Diverse Soils to Produce Common Crops

Region	**Black Earth**	**Non-Anthropogenic Soils**
Lower Negro/Urubú	Maize, beans, sugar cane, vegetable crops (cucumber, okra, pepper, tomato, W. Indian gerkin), watermelon	Bitter manioc, pineapple, sweet potato, yam; *clayey soil*: banana
Santa Isabel Region	Maize, pineapple, red bean (some vars.), squash, watermelon, West Indian gerkin	*Praia*: bitter manioc, cashew, pineapple; *clayey soil*: banana; *terra amarela*: banana, bitter manioc, sweet potato, yam
Rio Canoas	Maize, beans, watermelon, squash, papaya, vegetable crops, *pacovão* (banana var.)	Banana, bitter manioc, root crops, passion fruit
Açutuba, Rio Preto	Papaya, banana, passion fruit, citrus, coconut, cucumber	

A Comparative Study of Plasticity in Human-Environmental Interactions in the Blackwater Terra Firme

Given the evidence that Black Earth is, in fact, a similar entity in distant blackwater environments, it becomes possible to identify site-specific differences in the plasticity of human-environmental interactions on the terra firme and factors other than the biophysical environment that account for these divergent adaptations. For this comparative research, it was necessary to devise indicators of plasticity in adaptive response that were both identifiable during short field visits and indicative of intraregional differences. For cognitive data, soil classification systems were elicited through a free listing technique as a means for deciphering the cognitive saliency of distinct soil classes. These were more feasible than carrying out the more time-consuming and complex ethnopedological interviews, and also provide a rapid means of eliciting very broad patterns of cognition in soil relationships.

The significance of cropping patterns to our understanding of divergent use strategies for Black Earth and Latosols in central research sites, and the ease with which these differences may be observed in the field, justify the use of botanical indices as the primary biophysical indicator of plasticity in adaptive process. The relative divergence in cropping strategies on Black Earth and non-anthropogenic soils within distinct blackwater environments provides an indication of the role of Black Earth in broadening the range of subsistence options in each environment. In aggregate, these data also help point out the conditions under which plasticity in adaptive processes arises, or under which Black Earth is considered an important and unique resource.

Cognitive Salience of Black Earth Environments

The level at which distinct classes of objects are differentiated in a classificatory hierarchy has been used as an indicator of the cognitive saliency of these objects (Berlin 1992). While the level at which folk taxonomists differentiate a given object does not confirm the motive for this saliency – intellectual or utilitarian, the lesser degree of cognitive saliency (i.e., that evidenced by underdifferentiation) should serve as an indication the taxon's inferior intellectual and utilitarian status. A second indication of the cultural saliency of a given class of objects may be discerned by researching informant agreement (Berlin et al. 1981).

Through the identification of soil classes known to folk taxonomists, the level of differentiation of Black Earth and more prevalent non-anthropogenic soils, and the levels of informant agreement in each blackwater region, it is possible to intuit the cognitive saliency of Black Earth with respect to other soil classes. In conjunction with ethnographic data, it is also possible to make further associations between soil classification and the cultural importance of these classes (utilitarian concerns).

In Appendix B I have compiled data on soil classification systems of folk taxonomists in central research sites, the Santa Isabel region and Rio Canoas (Tables B-4, 5 and 6, respectively). While the tendency of individuals in the Rio Canoas to settle in individual homesteads facilitated the elicitation of soil taxa from individual families, short visits to larger communities in the Santa Isabel region often made this impossible. Fifty percent of the "informants" in this region are therefore groups rather than individuals.

While the reader may wish to refer to the Appendix to review tabulated raw data, it is important to make explicit several important trends that emerged through the elicitation of soil classes in each region. First, in each region Black Earth is found in contrast sets with other predominant soil classes, as indicated by its placement as a level-one term (or folk generic). However, informant agreement on this level of differentiation of Black Earth – in other words, its cognitive saliency – differs by region. This is particularly notable in the Santa Isabel region, where only 50% of informants place Black Earth in level-one contrast sets (i.e., as a folk generic) with other predominant soil classes. This is in sharp contrast to the 100% agreement on level-one classification of Black Earth in other blackwater regions, including the lower Negro, Urubú and Canoas regions[5]. Furthermore, while seven out of eight Santa Isabel informants classified Black Earth in level-one or -two contrast sets, one informant (in this instance, a number of individuals from a larger community) failed to identify Black Earth as a soil class at all. From these data and more qualitative observations such as the order in which terms were named, it appears as if the *Iví Cuí* (Sandy Soil) and *Barro* (Clay) are more salient folk generic taxa (as members of level-one contrast sets) than *Iví Pixuna* (Black Soil). This observation is supported by the classification of *Iví Pixuna* as a folk specific taxon (i.e., by informants from three out of the four communities where it is absent in level-one contrast sets), where it becomes a subset of the more salient *Iví Cuí*.

If we were to make the assumption that cognitive discriminations partially reflect utilitarian concerns, we might assume that Black Earth is economically important in most regions, yet of little importance in the Santa Isabel region. The coincidence of this lesser cognitive saliency of anthropogenic soils with this more remote and culturally-"intact" region might suggest that the strong cultural heritage of the Santa Isabel region (the more communal organization of labor, lasting historical ties to the land, language, etc.) somehow accounts for this difference. An assumption that cognitive salience and cultural importance of Black Earth derive from more modern influences would be premature without a closer look at use strategies in each environment.

The Role of Black Earth in Subsistence

As evident in Chapter VI, Black Earth is seen as an important resource in central research sites, effectively broadening the range of productive possibilities and income-generating activities for local residents. This is perhaps most evident in the disbelief that Black Earth is a result of human activity, and the comment, "*Se a Terra Preta fosse feito pelo homem, tudo mundo fazia*" ("If *Terra Preta* were made by man, everyone would be

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[5] While no systematic elicitation of soil classification systems was carried out on large-scale, intensive farms (Açutuba and Rio Preto), this level-one saliency of Black Earth was also evident from farmer narratives in these locales.

making it"). Yet this perception that adaptive possibilities are in fact more plastic as a result of these nutrient-enriched anthrosols differs a great deal by region. From this brief comparative study of distant blackwater environments, it is evident that this plasticity is conditioned by a number of factors – political-economics, cultural history and technology, to name a few.

The variation in anthrosols themselves – their absolute potential to produce different crops, so to speak – certainly influences this variability in the costs and benefits associated with Black Earth cultivation. This would be particularly true given the divergent geological histories of Western and Central Amazonia (influencing soil texture and nutrient-retention properties) and the distinctive use histories of Black Earth in each region (influencing the evolution of fertility indices on Black Earth). While these differences are partially confirmed by soil chemical data, the marked similarity of local commentary on the potential of Black Earth to produce diverse crops from region to region (Table VII-2) indicates that other factors are stronger determinants of resulting adaptive strategies.

Botanical data from swiddens and houseyard gardens in each region demonstrate these differences, and help to ground the interpretation of plasticity in adaptive processes in geographically-distant blackwater environments.

Cropping Practices – Swidden Agriculture. Tables VII-3 and 4 summarize the botanical differences between Black Earth and non-anthropogenic soils in each region, highlighting the divergence in use practices. Several important observations can be made to highlight region-specific differences in the treatment of Black Earth. The most striking observation is the total absence of swiddens on Black Earth near Santa Isabel. This correlation between agricultural usage and the lesser cognitive salience of Black Earth environments suggests that these anthrosols are, in fact, of little cultural importance despite intellectual recognition of these modified environments.

Table VII-3. Percentage of Swiddens with Each Crop Class and Species Present in Each Region and Soil Class[a]

Crop Class	Black Earth				Non-Anthrop. Soils			
	LRN/ Urubú	Santa Isabel	Rio Canoas	Intens. Ag. Sites	LRN/ Urubú	Santa Isabel	Rio Canoas	Intens. Ag. Sites
Perennial Fruit Trees	29.90	0.00	44.44	91.67	40.63	43.18	50.00	n/a
Vegetable Crops	31.96	0.00	11.11	8.33	6.25	2.27	0.00	n/a
Grains/Seeds	9.28	0.00	22.22	0.00	0.00	0.00	0.00	n/a
Voluntary Edibles	28.87	0.00	16.67	0.00	21.88	11.36	0.00	n/a
Edible Grasses	1.03	0.00	0.00	0.00	7.81	11.36	6.25	n/a
Tuber Crops	12.37	0.00	22.22	0.00	25.00	36.36	43.75	n/a
Ave. spp./site	*12.13*	*0.00*	*6.00*	*6.00*	*7.11*	*5.50*	*2.67*	n/a

[a] Due to time constraints, botanical data were limited to presence/absence recordings for each use zone and soil class.

Secondly, cropping practices on intensively-cultivated Black Earth sites tend to be highly skewed toward perennial fruit trees and vegetable crops, while Latosols soils are more favored for these crops among small-scale agriculturalists. This pattern is perhaps indicative of the ability of chemical fertilizers to correct soil chemistry to best suit preferred crops (see Table VII-2), partially reversing causal relations by allowing individual discretion to fully replace the strong pedological logic observed in the cropping practices of central research sites.

Finally, the average number of species in Black Earth swiddens is higher than on Latosols among families where Black Earth is actually utilized for agriculture, indicating a plastic response in the adaptive strategies employed in Black Earth environments within these regions. It is important to note, however, that these presence/absence data fail to reflect important patterns in crop *abundance*, in particular for the Rio Canoas where most cropland is dedicated to two economically-important crops: banana and bitter manioc. While Black Earth data indicate a greater species diversity (ave. spp./site), this pattern is only of economic importance for one family who has developed a complex cropping strategy on Black Earth. All other families favor clayey Latosols for their banana-manioc cropping system.

It is important to recognize that botanical data from central research sites were collected during a full year's time, while research at comparative research sites was limited to a day of observations per community (and less for homesteads). Species diversity measures (% species/site) are likely to be most sensitive to these sampling irregularities; measures of presence or absence across soil classes are likely to be less sensitive to these seasonal differences. Region-specific differences (i.e., the relative importance of Black Earth and non-anthropogenic soils in each region) should therefore be stressed over any absolute differences between regions (which introduce this error). To highlight this region-specific plasticity in cropping practices, I have applied the Percent Divergence measure (applied above to the soils of each region) to the cropping practices in each region. The resulting numbers (Table VII-4) reflect the divergence of cropping patterns on Black Earth from non-anthropogenic soils in each region.

These data help to visualize patterns in Table VII-3 by highlighting those crop classes within each setting whose cultivation is made more viable due to the presence Black Earth. They point to the reasons underlying a greater plasticity in productive practices on Black Earth where these exist. While Black Earth confers no apparent productive advantages to Santa Isabel agriculturalists who fail to open swiddens on these anthrosols, generalized crop-soil associations may be discerned for the lower

Table VII-4. Percentage Divergence[a] of Black Earth Cropping Patterns from Those on Non-Anthropogenic Soils

Crop Class	**LRN/ Urubú**	**Santa Isabel**	**Rio Canoas**	**Intensive Agric. Farms**
Perennial Fruit Trees	-26.41	-100.00	-11.11	n/a
Vegetable Crops	411.34	-100.00	*0.0, 11.11*[b]	n/a
Grains/Seeds	*0.0, 9.28*[b]	0.00	*0.0, 22.22*[b]	n/a
Voluntary Edibles	31.96	-100.00	*0.0, 16.67*[b]	n/a
Edible Grasses	-86.80	-100.00	-100.00	n/a
Tuber Crops	-50.52	-100.00	-49.21	n/a
Ave. spp./site	70.51	-100.00	125.00	n/a

[a] Calculation: % Divergence = ((tp-lat)/lat*100). Positive values reflect those crop classes that are more prevalent on Black Earth (i.e., the source of plasticity), while negative values reflect those crops that are more common on Latosols and Podzolic soils (Oxisols and Ultisols).
[b] Values for which a "% Divergence" calculation was impossible due to the absence of this crop class on Latosols.

Negro/Urubú and Canoas regions. While Black Earth is favored for the planting of grain and seed crops, voluntary edibles and vegetable crops, non-anthropogenic soils are favored for tuber crops, edible grasses and perennial fruit trees. The percentage divergence in the crop diversity index (# spp./site) is also positive for each region, suggesting again that a greater range of crops may be grown on Black Earth if the decision is made to utilize these soils for agriculture.

The inherent potential of Black Earth evident in crop presence data and informant commentaries is nevertheless little exploited. In both the Santa Isabel and Canoas regions, these soils are markedly underutilized for swidden agriculture. Of the four communities near Santa Isabel where Black Earth is most extensive and clearly identified through laboratory analyses, swiddens were absent. Observations on one cultivated Black Earth site that falls outside the sampled region nevertheless confirm the productive potential of these sites: healthy crops of maize, beans, squash and manioc were being grown here.

From preliminary ethnographic research, two factors emerge as determinants of this indifference to Black Earth in the Santa Isabel region. First, the strong ethnic fabric of local communities has contributed to the maintenance of many traditional technological and dietary patterns that have been lost in more centralized regions. Examples include technology for processing bitter manioc, a greater variety of food derivatives from manioc and a strong reliance on traditional crops. While some villages have experimented in planting exotic "Black Earth crops" (maize, beans, squash, vegetable crops), one informant claimed that only squash is eaten locally. He used the possibility of feeding chickens *crueira* (a manioc derivative) as a justification for their limited need for maize. A second factor is the limited demand for these crops in regional markets, whose predominantly indigenous patronage again suggests a strong reliance on traditional cultivars for household consumption. Santa Isabel communities stopped planting these crops for sale because "*não tinha saída*" (lit. "they had no outlet"). A similar limitation exists in the lower Negro, where municipal markets are easily flooded by Black Earth produce and the activities of a few individuals influence productive possibilities for others. Only those farmers with easy access to markets in Novo Airão *and* Manaus consistently farm Black Earth due to limited difficulties in selling their produce, an indication that important political economic factors underlie the plasticity in adaptive processes.

Similar observations were made in the Canoas region: in upstream homesteads closer to the roadway and marketing channels, Black Earth was nearly ignored. Families instead focus on the cultivation of banana (for sale) and manioc (for consumption) on the region's clayey Latosols. This productive strategy reflects a response to household demands for the traditional manioc staple, to opportunities presented by regional technical and economic assistance for banana (including, most importantly, transportation for this crop alone) and to local preference for Latosols for the cultivation of these crops. The one family to have developed a complex use strategy for Black Earth is located the furthest downstream, where what has become a traditional cultivation system for this family (residing on this site for the past 20 years) has resisted the more recent incentives for government-driven agricultural development. It is here evident how political-economic forces other than proximity to market per se (i.e., governmental policies) influence cultivation systems, as well as local perceptions of anthropogenic Black Earth as an important resource or as irrelevant to broader productive goals of the household.

In the event that analysis of farmer orientations to Black Earth in Canoas and Santa Isabel sites is slighted by the focus on swidden agriculture rather than a broader range of productive activities, I have included some baseline data on houseyard gardens. These gardens were the only alternative usage of Black Earth in the four regions under study, and therefore merit attention here.

Cropping Practices – Houseyard Gardens. To test the possibility that Black Earth confers certain productive advantages or plasticity to farmers through the broader array of species that may be planted in houseyard gardens, I have pooled presence/absence data for houseyard gardens in each region (Table VII-5). Excluded from these analyses are intensively-cultivated sites, where houseyard gardens are less integral to livelihood.

With the exception of the absence of annuals in more traditional houseyard gardens of the upper Negro, very few significant patterns emerge from these data. One interesting pattern that would need to be corroborated through more extensive sampling is the

Table VII-5. Percentage of Species in Each Botanical Class and Species Presence in Houseyard Gardens (by Region and Soil Class)

Botanical Class	**Black Earth**			**Non-Anthrop. Soil**		
	LRN/ Urubú	**Santa Isabel**	**Rio Canoas**	**LRN/ Urubú**	**Santa Isabel**	**Rio Canoas**
Native Annuals	6.0	0.0	12.5	8.8	0.0	8.0
Native Perennials	39.3	38.2	43.8	37.7	70.4	44.0
Exotic Annuals	4.3	0.0	0.0	8.2	0.0	4.0
Exotic Perennials	50.4	61.8	43.8	45.3	29.6	44.0
Ave. spp./site	14.6	6.8	16.0	22.7	6.8	12.5

tendency for native perennials to be planted on naturally-forming soils in houseyard gardens in the Santa Isabel region and for exotic perennials to be planted on Black Earth. This would seem a logical association for a region in which non-anthropogenic soils are sandy Podzols, a highly infertile soil. Here, native fruit trees may be best adapted to conditions that might prove to be limiting for exotic species. This pattern is more evident if Percentage Divergence measures are again calculated to highlight the crop classes for which Black Earth provides the greatest productive advantages and to stress those relationships for which the data are strongest[6] (Table VII-6).

Table VII-6. Percentage Divergence of Botanical Associations in Black Earth Houseyard Gardens from those on Non-Anthropogenic Soils

Crop Class	**Lower Negro/ Urubú**	**Santa Isabel**	**Rio Canoas**
Native Annuals	-32.05	0.00	56.25
Native Perennials	4.19	-45.67	-0.57
Exotic Annuals	-47.73	0.00	-100.00
Exotic Perennials	11.36	108.46	-0.57
Ave. spp./site	-35.61	0.74	28.00

[6] While houseyard gardens are less subject to seasonal changes in cropping associations than swiddens, the data should nevertheless be interpreted in a similar way to that suggested for swiddens due to the more limited time spent researching comparative sites. As such, within-region differences in class-specific associations between specific crops and soils should be stressed over region-to-region comparisons.

If we employ the Percentage Divergence measure again as a plasticity index (i.e., an index of advantages derived from the establishment of houseyard gardens on anthropogenic soils), the most striking pattern is the plasticity derived from the cultivation of exotic perennials in the Santa Isabel region. Another important observation, alluded to in Chapter VI, is the preference of Latosols over Black Earth in central research sites for the establishment of houseyard gardens. This is striking in its contrast with the upper Negro region, and can only partially be explained by the higher fertility of Central Amazon soils (which are presumably less constraining than the Podzols of the upper Negro to exotic species). These patterns nevertheless lose their significance when looking at the underlying numbers: while annuals are more common on Latosols, these represent only 23% of the total species in houseyard gardens.

To complement these data I have calculated correlation coefficients on the percentage of sites in each region with each crop present as a means of contrasting houseyard garden composition (Table VII-7). These coefficients serve as a measure of

Table VII-7. Pearson's Correlation Coefficients Comparing Houseyard Gardens by Region and Soil Class

Region/	**LRN/Urubú**		**URN**		**Canoas**	
Soil Class	**BE**	**Lat**	**BE**	**Lat**	**BE**	**Lat**
LRN/Urubú BE	*1.00*	0.72	0.64	0.44	0.11	0.26
LRN/Urubú Lat	0.72	*1.00*	0.50	0.37	-0.02	0.14
URN BE	0.64	0.50	*1.00*	0.58	0.11	0.23
URN Lat	0.44	0.37	0.58	*1.00*	0.05	0.17
Canoas BE	0.11	-0.02	0.11	0.05	*1.00*	0.13
Canoas Lat	0.26	0.14	0.23	0.17	0.13	*1.00*
Average Correls.	0.43	0.34	0.41	0.32	0.08	0.19

[a] Correlations were carried out on percentage data (the proportion of sites with each crop present).

species-by-species similarity of houseyard gardens by region and soil class, and complement the analysis of similarity based on botanical classes.

These data suggest that the most similar cropping associations across all regions and soil classes are found in the species composition of Black Earth and Latosol houseyard gardens within central research sites themselves. This would indicate that for the lower Negro, little plasticity in traditional use practices is derived from the cultivation of houseyard gardens on more nutrient-rich anthrosols. These data corroborate results of the above analysis of botanical classes. Houseyard gardens on Black Earth in the Santa Isabel region are also very similar to those of central research sites. This provides some indication that Black Earth gardens play a similar role in subsistence in each region (whether or not this function differs from that of Latosol gardens), and that a common logic does underlie the management of soil-botanical associations in these gardens of the Santa Isabel region.

The most dissimilar houseyard garden composition, on the other hand, is found between Latosol gardens of central research sites and Black Earth gardens of the Rio Canoas, where botanical associations lack any significant correlation at all. The second weakest relationship is found in the coefficient contrasting Black Earth gardens of the Rio Canoas with those of other comparative sites. These data indicate that houseyard gardens on Rio Canoas Black Earth sites are strongly divergent from those in other settings. I interpret this pattern as indicative of the lesser importance given to cultivation of houseyard gardens on Black Earth on the Canoas, leading to more random associations of species on these sites. The very association of these gardens with Black Earth in these sites apparently result more from the location of settlement areas on landforms where

Black Earth is most common than from intentional soil selection per se. This is most evident in the greater disregard for these soils when households (and by extension, houseyard gardens) fail to overlap with Black Earth.

The apparent discrepancy between high cognitive saliency and limited cultural importance of Black Earth in Rio Canoas sites presents a bit of an irony and merits attention here. While the limitations associated with broad comparative research preclude any conclusive analysis on the nature of this discrepancy between Santa Isabel and Canoas regions, a preliminary explanation may be found within family and regional histories. Long-time residents of Santa Isabel have limited experience cultivating Black Earth, given their strong reliance on traditional crops (for which no adaptive advantage is derived from Black Earth cultivation) for both consumption and sale, and the limited demand for exotic crops in regional markets. The few attempts to cultivate these soils were aborted due to failure to consume Black Earth produce locally (in particular maize, for which no technology exists to process the dry grain), and therefore too, the limited capacity of local markets to absorb Black Earth produce. Sale of exotic vegetable crops in Manaus is not viable due to long distances and transport costs, and the rate at which these crops go bad.

More recent immigrants of the Canoas region, on the other hand, have each had prior experiences with Black Earth cultivation as a result of their high demographic mobility, and are therefore more familiar with the properties and potential of Black Earth. Decisions not to cultivate these soils rest more on the role of political-economics (as mediated by governmental institutions) in skewing the costs and benefits of cultivating diverse crops toward banana and bitter manioc – two crops for which Black Earth is a deterrent rather than an incentive. Political-economic and cultural factors are therefore shown to be critical incentives and deterrents to Black Earth cultivation, as seen in the role of centralized markets and non-traditional diets (i.e., in the markets of Novo Airão) in making the cultivation of Black Earth desirable.

Political-economic factors should not be seen as monolithic structures to which humans adapt, but rather factors that are themselves partially influenced by local action. This is evidenced in the saturation of markets in Novo Airão by few Black Earth farmers – effectively limiting incentives for Black Earth cultivation among other individuals, and in the creation of market niches themselves. The latter is seen in the strategy developed by one Black Earth farmer who cultivates maize in a community of the lower Negro and sells the seed to his neighbors as poultry feed.

Discussion

Variation in local orientations toward Black Earth in distant blackwater environments again demonstrates how plasticity in adaptive processes should not be discussed in terms of absolutes, but rather in terms of contextual factors that potentialize or limit the ability of agriculturalists to capitalize upon a nutrient-enhanced environment. If we attempt to distill broad patterns in the orientation to anthropogenic Black Earth through the placement of comparative sites on a spectrum reflecting the centrality or isolation of these sites from modern urban influences (Figure VII-1) or other independent variables (first column), we discover the difficulty in boiling down patterns of use or non-use to simple dichotomies (traditional vs. modern, urban vs. rural, market vs. subsistence orientations, etc.). We discover, rather, that a complex interplay of factors underlies the

Figure VII-1. A Mosaic of Observed Orientations Toward Agriculture and Indian Black Earth

←--→

Greater Isolation ... Greater Centralization[7]

Parameter:	Locale: Upper Negro	Lower Negro	Rio Canoas	Industrialized Sites
- Importance of TPI	Low	High	Low	High → Medium
- Reliance on folk knowledge for TPI cultivation	High	High for fertility management, low for pest control	Medium for fert. management; low for other practices	Low for most cultural practices; medium for fertility management
- Reliance on native domesticates	High	Low for TPI, high for Latosols	Low	Low
- Dependence on local agricultural technology	High	Medium	Low	Low
- Market orientation of agricultural system	Low to Medium	Medium (yet variable among families)	High	Full
- Benefits and sustainability of TPI production system	----	Medium to High	----	Low
- Role of governmental policies in decision-making	Low	Medium (indirect)	High (direct)	Medium (indirect)

[7] Centrality is defined here in relative terms, and roughly corresponds to accessibility to urban cultural influences and centralized markets. It incorporates elements of distance (in absolute terms), available modes of transport (roads vs. riverine), and cultural and technological articulations with urban areas.

plasticity of the traditional swidden agricultural system, and the treatment of Black Earth as an important cultural resource.

This analysis demonstrates how, within the contemporary era, a great deal of variability exists in perceptions of and materialist orientations toward the environment. The departure of livelihood from more traditional, manioc-based swidden agriculture rests not only on the quality of the environment (i.e., the ability of humans to enhance the culturally-"limiting" soil substrate) but on political-economics, individual and cultural histories (learned and inherited knowledge systems, dietary preferences, etc.) and technological influences.

Evidence for the ways in which human adaptability to Black Earth environments has evolved through time may provide further understanding of the motives underlying the lesser cognitive saliency and more limited use of Black Earth in the Santa Isabel region. It also helps to ground more general arguments concerning the forces structuring human adaptation.

C. Temporal Dimensions of Plasticity in Human-Environmental Interactions in the Blackwater Regions of Amazonia

An understanding of the most important incentives for utilizing anthropogenic Black Earth in the contemporary setting also provides clues for the reconstruction of the plasticity of adaptive responses to Black Earth in the past. In other words, incentives that guide farmer decisions regarding soil selection and the practices to be carried out on each soil class highlight contingencies in the uses given to Black Earth, as well as subjectivity in the term "resource." The ability to draw inferences about the past through diachronic extrapolation ultimately rests on what we know about how these incentives themselves have been influenced by historical processes.

Given that the most plastic adaptations to Black Earth were observed in central research sites of the lower Negro and Urubú rivers, I have used this region to discern the historical contingencies underlying adaptive process. Findings are relevant to the region at large, however, and help to explain the spatial variation in adaptive process (and in the *plasticity* of these expressions) in contemporary settings.

Historical Contingencies in the Plasticity of Adaptive Responses to Black Earth

Technological Contingencies to Black Earth Cultivation

Many authors have recognized the linkages between technology and incentives underlying diverse resource procurement activities (Denevan 1992; Herrera et al. 1992). Others have alluded to the relative nature of natural and managed soil fertility as a function of available and economically important crops (Hecht and Posey 1989; Johnson 1974). Field observations indicate the most significant technological factor conditioning the benefits derived from Black Earth to be the domestication and introduction of crops that best respond to the enhanced nutrient loads in these soils – influences that have yet to be addressed in the literature. The primary indication for this limitation to Black Earth cultivation is poor performance of certain economically-important native domesticates on these modified soils. The higher fertility of Black Earth underlies the preference for these anthropogenic soils due to the ability to cultivate a distinct array of crops in these environments. As such, cropping behavior becomes an important indicator of the advantages to Black Earth cultivation. By studying the motives underlying the selection of crops for diverse soil types among contemporary residents (the matching of crops with the soils where these grow best), we are able to discern the factors that most influence Black Earth use. This also provides clues that help to reconstruct motives for distinct usages of Black Earth in earlier periods.

From crop performance data in Table VI-5 ("Informant Ratings of Crop Performance on Anthropogenic and Non-Anthropogenic Soils of Central Research Sites"), we know that Black Earth is better suited than Latosols for the cultivation of a broad range of common crops. Although this list of crops is by no means exhaustive, the focus on crop performance *potential* in cognitive (as opposed to botanical) data provides a relatively objective measure of crop performance as a function of soil quality alone – presumably uninfluenced by more dynamic political or economic incentives. While crops differ in their cultural and economic importance to local farmers, these data indicate that Black Earth affords farmers a greater range of cropping options, presumably enhancing the plasticity of human-environmental interactions.

Not all of these crops were present, however, throughout the agricultural history of the region. As such, the introduction of crops that grow well in either soil through time would have influenced economic opportunities and the plasticity of adaptive processes within each environment. Grain crops, for example, were introduced to the region in prehistory yet became a staple for some groups only in the latter part of this period (Roosevelt 1998, 1980). If we analyze crop performance ratings in light of evidence for where these crops were domesticated and when they were incorporated into Amazonian agriculture, we will have a better idea of the potential plasticity of adaptive processes in Black Earth environments through time.

Table VII-8 classifies crop performance ratings (the potential plasticity in subsistence afforded by each crop) by crop origins. With an understanding of when each crop was domesticated or introduced to the region, the benefits derived from Black Earth cultivation appear to be strongly time-dependent. Today, farmers rely on industrialized

Table VII-8. Crop Performance Ratings Classified by Crop Origin (based on informant rating of crop performance, where 2 means "produces well", 1 means "produces, but not well" and 0 means "does not produce")

Crop Origin	Crop	Terra Preta	Terra Comum
Lowland South America, Amazonia	Bitter Manioc	0.75 ± 0.87	1.88 ± 0.31
	Pineapple	1.45 ± 0.82	1.71 ± 0.62
	Star Nut Palm	1.83 ± 0.39	1.92 ± 0.29
	Mean:	**1.34** ± 0.69	**1.84** ± 0.41
The Americas	Bell Pepper [b]	2.00 ± 0.00	0.32 ± 0.64
	Maize	2.00 ± 0.00	0.29 ± 0.62
	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 Manioc	1.33 ± 0.65	1.55 ± 0.79
	Sweet Pepper	2.00 ± 0.00	0.50 ± 0.81
	Tomato [b]	2.00 ± 0.00	0.10 ± 0.32
	West Indian Gerkin [b]	2.00 ± 0.00	0.88 ± 0.80
	Mean:	**1.92** ± 0.10	**0.56** ± 0.68
Old World	Banana	0.42 ± 0.67	1.41 ± 0.70
	Coconut [a]	2.00 ± 0.00	0.55 ± 0.69
	Cucumber [b]	2.00 ± 0.00	0.50 ± 0.67
	Lemon	1.42 ± 0.90	1.42 ± 0.79
	Okra [b]	2.00 ± 0.00	0.35 ± 0.67
	Onion	1.64 ± 0.67	0.40 ± 0.66
	Rice [b]	2.00 ± 0.00	0.25 ± 0.71
	Sugar Cane	1.50 ± 0.80	1.13 ± 0.88
	Watermelon [b]	1.90 ± 0.32	0.22 ± 0.36
	Yam	1.50 ± 0.80	1.88 ± 0.31
	Mean:	**1.64** ± 0.42	**0.78** ± 0.64

[a] The coconut was domesticated in the western Pacific region, yet had made it to the Americas prior to European arrival. Without any information on its arrival to the Amazon region, it would be premature to consider it a crop available to the occupants of Black Earth sites prior to contact.
[b] Despite the somewhat widespread usage of these crops on small landholdings today, farmers continue to depend on centralized markets for seed. This provides some evidence that these crops began to play a role in regional agriculture only in recent decades.

seed for most vegetable crops (with the possible exception of certain varieties of squash and pepper), an indication that even those domesticated in the Americas are likely to be more recent introductions to the region. It also shows that the benefits of Black Earth cultivation in prehistory are likely to have derived from seed crops alone. The most significant benefits, from both agronomic and dietary standpoints, are likely to have derived from the introduction of maize, beans and squash from other regions throughout the Americas. Even these benefits should be assumed only with more direct paleobotanical evidence. This is true particularly for maize, for which absence of technology to process (and the custom to consume) the dry grain causes families who plant maize today to feed the dry grain to livestock rather than their own families.

The means in Table VII-8 provide more evidence that the advantages of Black Earth cultivation stem predominantly from crops that were domesticated outside the Amazon region. While it is true that many other native fruit trees – both domesticates and semi-domesticates – are absent in this list, they are generally cultivated in houseyard gardens in central research sites (which are much more common on Latosols). As such, the elicitation of crop-soil associations focused on swiddens – both active and transitional (to fruit gardens or managed fallow). A more extensive study would need to be carried out to derive stronger conclusions on the most probable benefits of Black Earth cultivation in prehistory. However, it is clear that the differential performance of diverse crops on anthropogenic and non-anthropogenic soils is a critical piece of the puzzle for reconstructing the plasticity of livelihood activities associated with Black Earth environments.

Political-Economic Contingencies to Black Earth Cultivation

It is important to recognize that decisions involving livelihood reflect not only an adaptive logic grounded in environmental parameters, but also the political-economic factors that provide incentives or deterrents for alternative practices. In recent decades, a great deal of literature has stemmed from the recognition that centralized markets exert strong influences on subsistence practices, even in remote regions (Anderson et al. 1995; Ozorio de Almeida 1992; Rudel and Horowitz 1993). Despite the tendency to think of the economic activities of traditional Amerindian groups as localized, apolitical and tightly coupled to local environmental conditions (Gross 1975; Rappaport 1967), there is increasing evidence that political-economic influences among even the most isolated groups were critical causal variables in subsistence behavior (Chernela 1993; Whitehead 1993). These influences were most certainly reflected in the decision-making processes of Black Earth occupants in prehistoric and early historic periods, as well, influencing perceptions on the costs and incentives associated with Black Earth cultivation. Important cues to these relationships may again be drawn from observations among Black Earth farmers of central research sites.

The imperfect association between crop performance ratings and actual cropping practices on Black Earth may be ascribed, in part, to political-economic incentives. Despite certain limitations associated with the measurement of cognitive data[8], correlation coefficients serve as a useful descriptive tool to discover the relationship

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[8] For example, the imperfect isomorphism between the conceptual discriminations of crops and the classification of these differences (across individuals), which represents a limitation inasmuch as these differences are treated as integers and used inferentially. Pearson's correlation coefficient (r), however, does a better job at elucidating relationships between variables than when data are converted to ordinal scales (ranked), for example when calculating Spearman's coefficient.

between actual behavior (the measures of relative abundance of each crop) and the incentives for cultivating diverse crops. The latter were identified through farmer ratings of: 1) the performance of a diverse array of crops on each soil class, and 2) diverse incentives or deterrents for the cultivation of these crops. Table VII-9 highlights the relationship between these economic and pedological incentives on the one hand, and three distinct measures of crop abundance (% of farms, % of swiddens, and % individual plants) on the other, through the calculation of Pearson's correlation coefficients (r). Informant ratings of incentives (crop performance incentives in Table VII-8, for example) have been converted to percentages for ease of interpretation.

Two important observations should be made from the correlation coefficients in Table VII-9. First, values for Pearson's r, calculated for crop performance ratings (how well diverse crops grow in each soil class) and cropping patterns (actual botanical associations), are positive for most cropping measures. This suggests that soil chemical signatures, together with other influences, play a causal role in crop selection. One exception is found in column 3 (Black Earth), where bitter manioc is planted in abundance despite few pedological (biophysical) incentives for doing so. This strong outlier shifts the directionality of this relationship due to its cultural importance. Furthermore, there is a disproportionate relationship between the high economic incentives for planting cash crops on Black Earth, and the total area and duration of these crops in the field (both of which are relatively low). The influences of these crops are therefore quickly reduced in relation to bitter manioc, which is abundant spatially and temporally (particularly in terms of the proportion of individual plants) and brings moderate to low returns in regional markets.

Table VII-9. Deciphering the Incentives for Contemporary Cropping Patterns on Black Earth and Latosols: Correlation Coefficients for Diverse Cropping Measures and Perceived Cropping Incentives

Cropping Incentives	**Black Earth**			**Latosols**		
	% Farms	% Swids.	% Plts.	% Farms	% Swids.	% Plts.
Crop performance rating	0.43	0.15	-0.32	0.79	0.74	0.52
More lucrative	0.14	-0.01	0.18	-0.29	-0.25	0.05
Quick returns	0.29	0.03	-0.27	-0.67	-0.66	-0.43
Outlier (bitter manioc) removed:						
Crop performance rating	0.53	0.47	0.50	0.81	0.72	0.75
More lucrative	0.14	-0.04	0.35	-0.67	-0.62	-0.21
Quick returns	0.33	0.25	0.33	-0.68	-0.67	-0.60

These discrepancies are clarified in the bottom section of the table, in which bitter manioc has been removed from the calculation of r. Here, the correlation coefficients show significant gains for Black Earth, indicating that the selection of crops other than manioc on these soils is largely contingent upon soil chemical incentives. In either case, it is evident that crop performance plays a critical role in crop selection yet does not account for the full variability in cropping behavior.

The second observation relates to two political-economic influences identified by local residents as importance incentives (or deterrents) to specific cropping practices. The first of these, "more lucrative," is a measure of crop-specific economic returns. The second political-economic incentive, "quick returns," refers to an incentive that was commonly expressed during my field research: namely, the ability to make quick cash for important purchases or emergencies. Values for Pearson's r are much lower for these incentives than for crop performance ratings, indicating that biophysical stimuli play a more important role in conditioning cropping practices than political-economics per se.

If we were to interpret r values as evidence for causal relations between independent and dependent variables, it would appear as if economic incentives were a *deterrent* to cropping practices on the region's Latosols. An explanation for this apparent contradiction emerges from the strength of association between crop performance incentives and cropping behavior on these soils. Rather than reflect a direct causal relation between market prices and cropping behavior, this negative relationship is likely to reflect the strongly deterministic incentives of crop performance on the region's nutrient-poor and predominant Latosols. The low fertility is likely to be a stronger constraint than market influences are a cropping incentive, and skew r values accordingly. This would be true particularly in a situation such as this one where the few crops that thrive in these soils confer few economic advantages to farmers, presumably due to the supply of these traditional staple crops in regional markets.

On Black Earth, the relationship between cropping behavior and political-economic incentives, while weak, nevertheless tends to be positive. This reversal of the negative correlation between cropping patterns and political-economic incentives on Latosols would suggest that the higher fertility on Black Earth allows farmers to respond in part to these non-biophysical incentives. The negative values for Black Earth in the third column are reversed and positive values increased when the outlier (bitter manioc) is removed, again indicating that economic incentives play an important role in Black Earth cultivation practices. Correlations (r values) based on the "percentage of swiddens" measure are nevertheless negligible for Black Earth. This measure is unsuited to indicate the economic benefits of Black Earth cultivation in real terms, due to the tendency of farmers to segregate crops according to crop management requirements, and due to the particular requirements of cash crops.

This tendency for farmers to respond more to political-economic incentives on Black Earth than on Latosols is better shown ethnographically in the claims by local residents that economic returns and the rate at which crops may be produced to generate quick cash are important incentives for Black Earth cultivation. These incentives of course stem from the ability of Black Earth farmers to cultivate fast-growing, non-traditional crops for sale in centralized markets. The higher fertility of Black Earth appears to de-couple adaptive behavior from environmental constraints, allowing farmers to respond to other, non-biophysical incentives.

Black Earth therefore shows great potential for alleviating the productive constraints faced by Amerindian horticulturalists, increasing the plasticity of traditional production systems of the terra firme. Yet these particular advantages are historically contingent, resting on the availability of crops that may capitalize upon more eutrophic environments and on other cultural or political-economic incentives to plant available crops.

Diachronic extrapolations of these findings are difficult given the crop-specific incentives underlying these patterns and the recent introduction of many common Black Earth crops. However, if the restricted availability of "Black Earth crops" in prehistoric times were compounded with a lessening of political-economic incentives for Black Earth cultivation, the plasticity in subsistence derived from these environments would be more restricted than today. On the other hand, it is possible that alternative incentives arose in earlier periods from the introduction of grain crops to Amazonia from other regions throughout the Americas. Incentives provided by low supply (resulting from the poor performance of these crops on the region's predominant soils) and high demand (due to their dietary role as substitute for animal protein, for example, or their role in leveraging political influence for local elites) may have provided sufficient incentive for Black Earth cultivation, as well as labor-intensive (intentional) soil modification.

Other political-economic factors influencing contemporary practices on Black Earth were noted in Chapter VI, where I presented data on the time allocated to distinct agricultural activities throughout the year (Graph VI-4). The peak in Black Earth cultivation occurred in the rainy season, during the period when whitewater floodplains – the only other environment where exotic vegetable crops may be grown without industrialized fertilizers – are inundated. In earlier times, this particular influence on the *seasonality* of Black Earth cultivation would have been less influenced by urban markets, perhaps causing it to be lessened, absent or reversed to reflect the lower incidence of fitosanitary problems in the dry season. Again, important political-economic contingencies govern the characteristics and plasticity of production practices in the terra firme through time.

Environmental Contingencies to Black Earth Cultivation

Given evidence for lasting human modifications of the environment (Balée 1989; McCann 1999; Mora et al. 1988), it is important to recognize that the environment itself has a history – both natural and cultural, and that human adaptive strategies may be partially contingent upon changes in the environment through time. Many authors have documented linkages between the structure and function of the environment, and diverse resource procurement strategies (Frechione et al. 1989; Gragson 1993; Moran 1991). Yet it is important also to address how environments themselves change through historical process. This is perhaps particularly true in the realm of Indian Black Earth, which by definition is a historic entity – originating through soil changes for which anthropogenic processes are minimally a trigger (Woods and McCann 1999). Furthermore, the deeper and darker Black Earth sites are found in preferred settlement locales that were likely subject to multiple stages of (re-)occupation (Smith 1980), as well as to the changing land-use practices of these groups. In theory, the usage given Black Earth sites during distinct stages of occupation would influence the range of subsistence opportunities available to subsequent occupants, again making the plasticity of human-environmental interactions historically contingent.

These environmental contingencies are perhaps the most difficult to prove, given the short amount of time in the field and the absence of baseline fertility studies associated with prior land usage. It is possible to use inference, however, based on basic understandings of soil genesis and field observations on the influence of contemporary land-use practices on site degradation.

Two forcing functions that influence the dynamics of soil fertility for anthropogenic soils over time are soil depth and soil nutrient loads. The depth of the anthropic horizon is critical to the sustained cultivation of anthrosols – whose subsoil properties resemble those of naturally-forming soils, while soil nutrient loads directly influence plant nutrition at any point in time.

From the first law of thermodynamics, we know that nutrients are finite entities. The nutrients driving crop growth must derive from some component of the ecosystem and be maintained or returned to the soil if an area is to be cultivated long term. We know that for the region of interest, nutrients for traditional swidden agriculture are derived primarily from the standing biomass of forest and fallow vegetation. In anthropogenic Black Earth a larger percentage are apparently extracted from soil stocks, as evidenced by the lesser dependence on old fallow and on the burn for restoring soil fertility. While this factor would seem to enhance the plasticity of human-environmental interaction long-term, the limited spatial extent of Black Earth, and the failure to expose nutrient-rich subsoil should the epipedon erode, ultimately limit the sustainability of the enhanced productive capacity of Black Earth. Ongoing "natural" or anthropogenic nutrient-maintaining processes (including nutrient cycling, additions, translocations and transformations) would need to occur at a rate consistent with rates of nutrient loss (harvest, erosion, leaching and volatilization) (Young 1997).

While the same principles apply to Black Earth as to other soils regarding finite nutrient loads, Black Earth has been known to have certain synergistic and dynamic properties that facilitate its conservation and enhance sustained production. First, heightened biotic activity and nutrient retention capacity stemming from nutrient additions may in fact lead to a sustained and progressive melanization of the soil matrix on Black Earth (Woods and McCann 1999). While it is difficult to see how this would happen in the absence of further organic inputs, this biotic activity would assist in maintaining soil organic matter at higher thresholds in Black Earth. Secondly, Pabst (1991) determined that it is not the *amount* but rather the *stability* of soil humus that differentiates Black Earth from adjacent soils. Nutrient release from these more reticent forms of soil organic matter would therefore be slower, favoring long-term over short-term productivity (Schroth, personal communication, 1998). Finally, the chemical synergy between soil pH, soil phosphorus, amounts of toxic aluminum and Cation

Exchange Capacity (van Raij 1991) would increase the availability of plant nutrients and facilitate nutrient retention over leaching losses.

The implications of these processes on sustained production are several. First, the tendency for any spontaneous “growth” (melanization) of Black Earth post-abandonment (Woods and McCann 1999) may be offset by mineralization in well-drained tropical soils (Buurman 1984), as well as by those processes leading to nutrient depletion (harvest, leaching, etc). Chemical synergy and the slow decomposition of soil organic matter, on the other hand, would tend to reduce nutrient losses in the short-term and extend their availability long term (respectively), which may explain the reduced dependence on the burn for restoring soil fertility. This would in theory permit a more rapid regeneration of fallow, enhancing the productive potential of these isolated patches of terra firme. The difficulty in quantifying the relative influences of these processes on the productivity of Black Earth and on the sustainability of common use regimes requires that we seek another means for deciphering the role of environment in mediating the productive potential of these sites through time.

Observations on intensively-farmed Black Earth sites provide alternative means to deduce the pedological influences of contemporary use practices, and to more clearly identify environmental contingencies in the plasticity of human-environmental interaction through time. Furthermore, the pedological changes resulting from long-term use may allow us to deduce something about past use practices (from which contemporary fertility indices are an artifact), and about impacts of contemporary uses.

One Japanese farmer of the Lower Negro, whose family has farmed the same Black Earth site for some 40 years or more, explains that:

> You must use chemical fertilizer. . . In the beginning she produced [without it], but we have to keep conserving the soil or she becomes weak...weak, then she tends to give out altogether. Then she becomes sand only, very sandy. This is why we conserve the organic material. . . . [If not], she becomes very dry, only sand . . . like this part here, white . . . she loses life. This here has life, soil has life! And starts dying, from getting too much sun and rain. She needs to be covered to be able to resist. – Kuni

Farmers at another intensively-farmed Black Earth site near Rio Preto da Eva also rely heavily on organic fertilizer. Each notes progressive loss in fertility and soil organic matter through use and exposure, which exacerbate the influences of weather on soil degradation. Through time, they claim that chemical benefits to Black Earth farming (i.e., the inherent fertility of Black Earth and its role in economizing soil amendments) disappear; incentives that remain are primarily textural. With the progressive leaching of clays, Black Earth becomes evermore sandy, facilitating mechanization yet limiting nutrient retention capacity. This confirms observations made by Smith (1980), who documents the loss of clays and organic matter from the surface horizon of cultivated Black Earth sites. This loss of organic matter may be deduced from Appendix D (Tables D-4, D-5). These data demonstrate how the organic carbon that is likely to have once been very high on these Black Earth sites as a result of cultural additions has since been lost.

A number of soil horizons on the Lower Negro were also selected on the basis of more detailed site histories and analyzed for total phosphorus present in each soil horizon. As a nutrient that is more stable in soils (Eidt 1977; van Raij 1991), its progressive leaching through the soil horizon becomes a proxy for the net sum of nutrients lost from the surface horizon. Those sites that were farmed more intensively were separated from those subject to less intensive cultivation; the phosphorus in each was contrasted by horizon (Table VII-10).

Table VII-10. The Leaching of Total Phosphorus on Black Earth As a Function of Use

Horizon *(Hx)*	**Sites with Long Periods of Use** *Mean Total P, Hx (%)*	**Minimal-Use Sites** *Mean Total P, Hx (%)*
H1	52.9	79.1
H2	43.3	20.4
H3	3.8	0.5
H4	0.0	0.0

These data suggest that under cultivation, Black Earth suffers a loss of nutrients downward through the soil horizon, in effect accelerating leaching processes. Secondly, it becomes evident that degradation is not only occurring on intensively-farmed sites, but also on Black Earth subject to more traditional use practices.

Two basic lessons may be derived from these data about the diachronic dimensions of subsistence plasticity. First, plasticity in human-environmental interaction is contingent upon ongoing modifications of the environment itself. The plasticity seen in adaptive manifestations on the terra firme in central research sites today attests to the role of past environmental modifications in enhancing productive opportunities among contemporary residents. Current use practices, on the other hand, seem to be causing progressive site degradation through nutrient extraction and exposure at a rate that surpasses the effects of any natural or cultural regenerative processes. The detrimental effects of contemporary management on lower Negro and Rio Urubú sites suggest that productive options for future occupants will be either restricted (via chemical degradation) or altered (by physical changes, for example, which facilitate mechanization).

Second, analysis of the impacts of current use practices vis-a-vis the fertile soils encountered by recent residents suggests that prior uses of these sites were either restricted to habitation (and intensive nutrient additions), less intensive (i.e., houseyard gardens) or balanced with significant management activities that restored fertility losses. In any case, past residents were likely to have encountered more eutrophic soils than will be true for future occupants of these sites. The high degree of preservation of these anthrosols and the rapid rate at which these soils degrade when deforested and cultivated suggest that these soils played a limited role in sustaining the more dense and sedentary populations of the past. It also suggests that plasticity of adaptive processes in the blackwater terra firme is at its peak today, in the areas where Black Earth plays an important role in the local economy.

Discussion

In this analysis of historical contingencies to the plasticity in human-environmental interactions it is evident that political-economics, technology and changes in the environment itself through "natural" and "cultural" influences jointly affect the range of possible subsistence options available to subsequent occupants. This, in turn, demonstrates that plasticity itself is historically-contingent. Contingencies that are most likely to have influenced the decision-making processes of Black Earth farmers throughout history are represented in graphical form in Figure VII-2, where the causality and directionality of linkages between historical factors, the biophysical environment and human decision-making processes are depicted.

If technological, political-economic and environmental contingencies are discussed in relation to the introduction of nutrient- and protein-rich grain crops, a significant

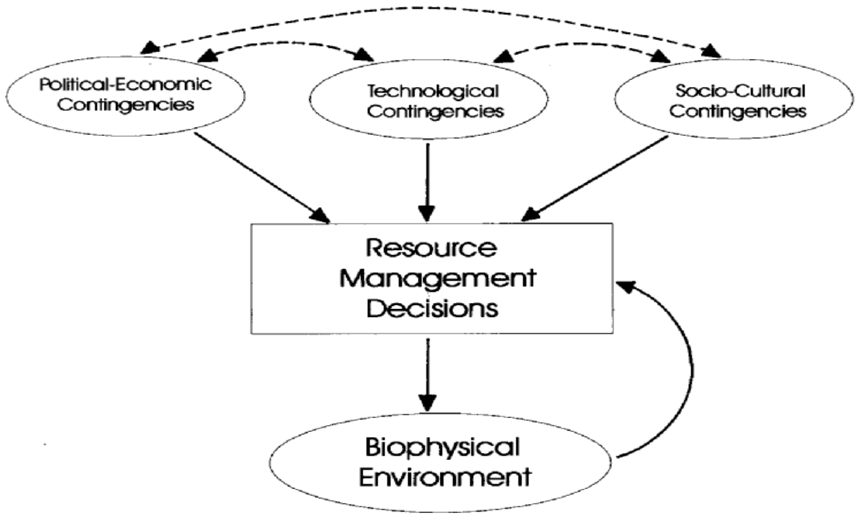

Figure VII-2. Decision-Making in Anthropogenic Environments: A Network of Causes and Contingencies

enhancement of plasticity in prehistory is likely to have occurred. This possibility must be tempered, however, by ethnographic evidence that maize plays a very limited role in diet among contemporary residents of rural Amazonia. If it was, in fact, important throughout the region's history as it was in some isolated regions studied by Roosevelt (1980), dietary habits and processing technology have since been lost. Furthermore, its cultivation would have placed more demands on soil, likely altering its composition and posing significant challenges to the sustained cultivation of these crops through time. The net evidence suggests that plasticity in human-environmental interactions of the terra firme in the region's past was more constrained than in the contemporary period – when introduced crops and favorable political-economic influences play an important role in expanding the range of economic activities available to local residents.

These data also aid in understanding the near-indifference that indigenous inhabitants of the Santa Isabel region exhibit toward Black Earth environments today. Common complaints by local residents that Black Earth cultivation is limited by the absence of seed and the limited demand for Black Earth crops in geographically-isolated municipal markets both suggest that cultural, technological and political-economic incentives of the contemporary milieu deter rather than favor Black Earth cultivation. This situation may present a certain parallel to earlier periods, in which urban markets, exotic crops and traditional cultural influences are likely to have limited the plasticity of adaptive responses to Black Earth environments.

The above data demonstrate the utility of applying a processual, diachronic approach to contemporary trends in adaptive process for reconstructing historical contingencies underlying plasticity in adaptive process and site evolution. Through identification of the variables that condition the ability of local residents to capitalize upon nutrient-enhanced soils in the contemporary setting, and intuiting how these variables themselves change through time, we are more able to understand the role of history in adaptive process. These understandings complement our current understanding of the constraining role of blackwater environments on human adaptive processes by highlighting the mediating role of historical factors in the plasticity of human-environmental interactions (specifically, the deviation of agricultural practices from the traditional manioc-based swidden system).

D. Conclusions

The data presented in this chapter demonstrate that while adaptive processes on the terra firme are plastic within anthropogenic environments in central research sites, this plasticity is spatially variable and historically-contingent. These historical contingencies include political-economic, technological and cultural factors, as well as the limited capacity of the environment to regenerate itself in the absence of ongoing cultural soil-building processes. The strong divergence in adaptive processes on Black Earth and Latosols in central research sites (Chapter VI) is perhaps a maximum expression of plasticity in adaptation to anthropogenic Black Earth. This is likely since an optimal array of factors (folk knowledge, political-economics, technology, etc.) favor more plastic human-environmental interactions on the terra firme in the contemporary setting. As we extend the analysis through space and time, we see how a multitude of contingencies influence both perceptions of Black Earth environments and the uses they are assigned within local and regional productive systems.

This is not to say that individuals themselves fail to contribute creatively to adaptive outcomes, playing only a reactive role to external contingencies. Quite the contrary: individuals actively process stimuli from outside structures (political-economic, technological, institutional, ecological). They also engage in ongoing creative decision-making processes in which specific farm-level resources (natural resources, household labor, knowledge, etc.) and capabilities are assessed and utilized to construct complex subsistence systems that vary by family and by region. In the process, they contribute to the forces themselves that impinge upon them: technology, knowledge systems and the supply-and-demand of regional markets. The evolution of these use systems through time reflect the dynamic influences of outside constraints and opportunities as well as these farm-level decisions and capabilities, contributing to a complex mosaic of adaptive processes in space and time.

Chapter VIII: THE STRUCTURATION OF HUMAN ECOSYSTEMS

> The fact that human practices never take place in a "pristine" environment, but always in a landscape shaped by the past ecological praxis of others, only serves to emphasize the importance of understanding the historical dynamics of human usages.
>
> – Neil Whitehead (1998:36)

A. Introduction

In Chapter III I provided a brief summary of conceptual models employed in understanding human adaptation and the human ecology of Amazonia. As explained in these pages, early models of human adaptation in the region stressed the role of the environment in setting upper limits on cultural development and shaping adaptive process, while more recent approaches emphasize the role of human behavior in buffering these limitations, modifying the environment, and ultimately, structuring adaptive process itself. Neil Whitehead (1998) has termed this active role of humans in modifying the environment and structuring their particular uses of it "ecological praxis," and defines it as "the persistent features in the sociocultural repertoire of human physical and mental behavior that is overtly oriented to . . . structure usages of the environment" (Whitehead 1998:30). It stresses opportunity rather than constraint. Furthermore, vis-a-vis prior understandings of environmental limits, it begs the question: What role – if any – does the environment play in conditioning or constraining human adaptation?

Blackwater ecosystems of Amazonia (the so-called "rivers of hunger"), where oligotrophic conditions have been blamed for constraining human adaptation and cultural evolution, are a most fitting setting for exploring this question. It is here that the role of environmental constraints on human adaptive processes should be maximally expressed (Moran 1991). It was shown in Chapter VI that relatively eutrophic anthropogenic environments exist in blackwater regions, and that anthropogenic modifications of soil have expanded the range of possible adaptive processes in these "limiting" environments. Black Earth ecosystems are an anomaly for the terra firme, both in terms of the relatively eutrophic soil conditions and the productive systems which characterize them (exotic crops, lesser dependence on the burn, etc.). Yet are there limits to the expansion of livelihood options in these environments – to the historical and ecological praxis of human occupants? What does research on the adaptation to anthropogenic Black Earth environments tell us about human ecosystems in general, and about the articulation between environmental and cultural determinants?

In this chapter I introduce a conceptual model that I call the Structuration of Human Ecosystems to address this dialectic between ecosystem constraints and ecological praxis, and to explicate the full range of observed human-environmental expressions in blackwater, terra firme environments. I pull from extant theoretical models that address each side of this dichotomy – historical ecology for our understanding of historical and ecological praxis, and ecosystem ecology for an understanding of ecosystem constraints, employing Giddens' theory of structuration as a unifying framework. This model stresses process, interactionalism and the integration of practice and diverse structures (environment, culture, political-economics, technology) to explain the processes by which individuals adapt to changing stimuli in material and non-material environments and forge novel subsistence strategies on the basis of ever-changing challenges and opportunities.

B. Contributions of Existing Theoretical Models

The conceptual framework guiding this research and the interpretations found therein is rooted in several intellectual traditions that have had profound impacts on our understanding of human ecosystems. The strengths and limitations of each of these models for explicating the full range of human-environmental interactions in Amazonian terra firme environments, and the factors that structure these interactions through time, are identified below.

Ecosystem Ecology

Ecosystem ecology has provided a strong framework for understanding the material interactions between humans and the biotic and abiotic components of ecosystems. Through its grounding in systems theory and cybernetics, it has been possible to envision humans as a component of ecosystems rather than as perturbations on the regular functioning of "pristine" environments. In earlier applications of ecosystem theory to human societies, humans – through belief systems and behavior – catalyze the necessary negative feedbacks that keep human society from reaching carrying capacity and suffering the effects of exceeding system limits (Rappaport 1967). The focus on homeostasis within ecology (for non-human ecosystems) at the time (Golley 1993) catalyzed a strongly functional approach that focused on humans as regulators of steady-state conditions.

Ecosystem ecology provides a critical contribution to our understanding of the ecological mechanisms (nutrient cycling, energy fluxes) that may, in conjunction with or counter to other structuring factors, limit system productivity and population growth. This, in turn, provides an essential link to our understanding of the plasticity of human-environmental interaction by demonstrating the mechanisms by which manipulation of nutrient and energy fluxes by humans to enhance productivity is potentialized and constrained. While other influences may condition this plasticity simultaneously, ecosystem ecology holds the most promise for understanding the role of *ecology* in conditioning, potentializing and constraining the range of human-environmental interactions through time. This framework also holds important implications for understanding adaptive process by providing a vocabulary for understanding how nutrient cycles constrain productivity in natural and modified (i.e., agricultural) environments, and how these cycles are altered through lasting anthropogenic modifications of ecosystems.

The application of ecosystem ecology to human societies is limited, however, for a number of reasons. First, its focus on “regularities, cyclical processes and general behaviors” (Graham 1998:124) is ineffective in explicating system change and erratic expressions of human-environmental interaction. By extension, the role of the individual in structuring social and material relationships is overlooked. Secondly, the primacy given to ecological causation (with absolute biophysical laws as guiding forces) detracts from the defining forces of cultural, historical and political-economic influences. Finally, despite human influences on material and energy fluxes, the structure, function and dynamics of ecosystems are understood as products of evolutionary/natural rather than historical/cultural processes. This is due, in part, to the drive to find universal laws to explain and predict system behavior (see Odum 1957; Odum and Pinkerton 1955; Patten 1959). When humans are incorporated into ecosystem analyses, their behavior is therefore seen as either constrained by the regulatory influences of material and energy fluxes (Rappaport 1968) or as perturbations to these natural dynamics (Uhl et al. 1990). Field research demonstrated, however, that in addition to the evolution of the ecosystem itself through the ecological praxis of past occupants (i.e., the formation of Black Earth), contemporary economic, technological and cultural factors help to structure human ecosystems through time. These factors must be incorporated into ecosystem studies alongside biophysical understandings.

Landscape Ecology

Landscape ecology provides an alternative framework to that of ecosystem ecology by stressing an environment that is by definition anthropogenic and biocultural (Rival 1998). Landscapes are understood as historical entities, whose structure, function and dynamics reflect both natural and cultural processes (Graham 1998; Naveh and Leiberman 1990). This inclusivity of human impacts is in part a function of the greater emphasis on scale (and, by extension, heterogeneity) and of the spatial and temporal manifestations of cultural process on the landscape. Crumely (1998) identifies several advantages of the landscape concept for understanding cultural process: it addresses time and space simultaneously, records both intentional and unintentional human acts, and addresses the bidirectionality of human influence on the global ecosystem and the influence of these past events in shaping human choice.

Landscape ecology has generated several important contributions to our understanding of human ecosystems: its implicit historicity (and recognition of diachronic dimensions of adaptive process); a framework for studying the impacts of cultural process on the natural world and, in turn, on human adaptation itself; and a transactional approach to human-environmental interaction. Landscape ecology contributes to our understanding of plasticity in human-environmental interaction by acknowledging the ways in which historical processes condition land use. The model is more limited than ecosystem ecology, however, for understanding the biophysical mechanisms linking human economic behavior to regional ecology and the role of environment in structuring livelihood. It is also limited in placing humans outside the natural environment rather than within it – as external agents or disturbances to proper system function, and assuming human impacts on “natural” ecosystems to be always negative (Crumley 1998). In the study region, past modifications of the environment have expanded the productive opportunities for contemporary residents. Furthermore, contemporary groups are not generating Black Earth despite the expressed desirability of doing so, demonstrating that there are important limitations to purposive ecosystem modification that must be considered.

Human Ecology

The literature in human ecology has generated an ongoing dialogue on the role of environment in conditioning human adaptation and the evolution of society. This tradition was particularly strong in Amazonia, where from early on regional ecosystems were seen as constraining livelihood. While the limitations of this model are well understood (see Chapter III), human ecology has provided the most extensive understanding of human adaptation to date, particularly in the Amazon region where this body of literature has proliferated. It has provided insight not only into environmental limits, but into the role of specific properties of the environment in conditioning social organization (Moran 1991), socio-cultural evolution (Steward 1948) and resource management (Chernela 1989). To the extent that it has explored diverse social and technological mechanisms to overcome environmental limits, it is also key to our understanding of plasticity in human-environmental interaction, in particular within modes of subsistence. These understandings are critical to my research findings – namely, to the role of crop introductions and adaptive behavioral responses in expanding the range of viable subsistence practices in Black Earth environments.

Scholars within this tradition have nevertheless been slow to embrace the view of the environment itself as a cultural and historical entity with respect to adaptive process, with the exception of environmental ideologies (Descola 1994). While this transition has begun to take place through the discovery of anthropogenic environments (Balee 1989; Graham 1998; Stocks 1983), the grounding of human ecology in the concept of adaptation – in which the environment is characterized in evolutionary rather than historical terms – limits its ability to embrace a more dialectical view of human-environmental interaction. It is therefore a critical framework for understanding human adaptation, yet too limited to account for the interpenetration of anthropogenic influences on the environment (Black Earth) and for the influence of natural, cultural and historical processes on adaptive manifestations.

Historical Ecology

The most comprehensive anthropological or ecological tradition to date addressing the complexities of human environmental interaction while overcoming many of the weaknesses of past approaches is historical ecology. According to Crumley (1994), it moves beyond landscape ecology in breaking down the dichotomy between human and "natural" landscapes by employing an interactive (dialectical) rather than deterministic historical analog. In Amazonia, this approach provided a refreshing alternative to the common “denial of historical praxis” that took root through environmental determinism. A recognition of the historical and ecological praxis of native peoples sharply contrasts with this earlier view, and is essential to our understanding of the ability of humans to generate novel ecosystems and to profoundly alter productive strategies in these environments.

While central tenets characterize this intellectual tradition, scholarly interpretations vary. While Crumley focuses on tracing the interactive sequences between culture and environment through the study of changing landscapes (a historicist analysis of the natural world), others deem this ineffective in identifying causal variables (Winterhalder 1994) and in capturing the human-centered explanation implicit in the term “historical” (Whitehead 1998). Later conceptualizations of historical ecology suggest we begin “with the premise that historical, not evolutionary, events are responsible for the principle changes in relationships between human societies and their immediate environments” (Balée 1998:13). Whitehead’s suggestion that we place persons rather than nature “at the center of explanations of changing ecological relationships through time” (1998:31) and make “human decision-making, and the consciousness that drives it, the independent variable in our analysis of environmental dynamics” (1998:36) is central to our understanding of the role of human will in shaping adaptive process. It also helps to explain the creative processing of novel technological (exotic crops), biophysical (anthropogenic Black Earth) and political-economic (high prices of exotic crops) opportunities to enhance productive possibilities in the Central Amazon. Historical ecology moves beyond ecosystem ecology on the one hand, and human ecology on the other, in accounting for human influences on the environment and for the dialectics of ecosystem modification and environmental limits, respectively. Attention to ecological praxis also implicitly acknowledges the role of the individual in shaping and expanding the range of human-environmental interactions, pointing to plasticity in adaptive process.

Historical ecology is also limited for addressing the question of plasticity in human-environmental interactions, however, by failing to address the *limits* to the historicity of environment and to the ecological praxis of humans. While it may be true that history – in particular human agency – has causal primacy over evolutionary processes in shaping adaptive process, the very tangible role played by environmental constraints is lost in the analysis.

While the ecosystem may indeed lose its importance as a constraining factor as traditional societies become increasingly "open" to material, technological and cultural inputs, it continues to play a role in subsistence and adaptive manifestations, in the latitude of productive options and in the costs and benefits (monetary, labor, etc.) of livelihood options. This is evidenced in the continued use of fallow to restore soil fertility (presumably due to the limited depth of soil enhancement), in local disbelief in the modifiability of soils and in the feasibility of planting exotic crops on Black Earth alone (despite the *technological* possibilities for enhancing soil fertility through industrialized fertilizers). We also see the role of environmental limits at the global scale – in the limited supply of nonrenewable energy, productivity of renewables and capacity of the environment to absorb human waste and greenhouse gases (Hawken et al. 1999). Humans do not simply "make" novel ecosystems; they enter into dialectical exchange with an environment that has its own forcing functions – forces that influence its structure, function and dynamics in specific ways. The ecosystem and the mechanisms through which it influences human behavior must be brought back into the analysis, yet without the assumptions of causal primacy or homeostasis that were once central to ecological approaches.

C. The Bridging of Social and Ecological Theory: The Dialectic Between Ecosystem Constraint and Ecological Praxis

> Historical anthropology analyzes the interplay of all structures of human activity – such as polity, economy-ecology, society, culture and so forth – with historical events, understood as the human praxis that innovatively evinces and so imperfectly reproduces these structures through time.
>
> – Neil Whitehead (1998:31)

> The Rio Negro terra firme forests, because they are at the extreme of a gradient of poverty, are more geared to nutrient conservation and recycling than to producing net yield available to herbivores and humans.
>
> – Emilio Moran (1991:365)

In Chapter III I outlined properties of blackwater ecosystems that are known to limit the productivity of "natural" and converted ecosystems: a poor soil substrate (resulting from high rainfall and temperatures, and old, geologically stable landforms), low faunal biomass in aquatic and terrestrial ecosystems, and acid, nutrient-poor water that makes inundated areas unfit for agriculture. Yet research findings point to a highly plastic relationship between humans and the environment in blackwater regions – in both ecosystem modification and adaptive process. Not only have Amerindian groups enhanced the soil substrate in isolated pockets of terra firme to create long-lasting changes in soil chemistry, but contemporary groups have proven to be highly adaptive in incorporating Black Earth into complex livelihood strategies. In combination, these events have effectively expanded the range of possible productive activities.

The apparent contradiction between a biophysical environment that constrains (human) ecosystem productivity and evidence for the ecological praxis of blackwater inhabitants begs resolution. Recent theoretical models have come far in tempering the long-held environmentally determinist stance in Amazonian studies by bringing history and human agency into the forefront of scholarship on both the environment and human interactions with the environment (Balée 1998, Crumley 1994). Yet this human-centered approach to the evolution of human-environmental interactions has yet to be tempered by an understanding of the unique role played by ecosystem properties in structuring this dialectic. While the anthropic epipedon on Black Earth is more fertile than non-anthropogenic terra firme soils, its depth and nutrient stocks (namely, K^+) are limited, and the processes leading to Black Earth formation have defied local residents and scientists alike for decades. Furthermore, ecosystem limits are seen in the degradation of Black Earth when cultivated in the absence of ongoing cultural soil-building processes. As such, the role of the ecosystem in structuring human adaptive process must be addressed together with the enactment of human will on these landscapes.

While ecosystem ecology is the model best suited for conceptualizing specific ecological mechanisms interacting with human adaptive behavior, other models are needed to encompass the relationship between structure and agency and the historical contingencies (technological, political-economic, etc.) that structure human-environmental interactions through time). To account for the full range of human-environmental interactions – from the most determinist (cultural, ecological or political-economic) to fully interactional frameworks, and to encompass this relationship between ecological praxis and the constraining forces of ecosystem dynamics, a new framework is needed. This model should incorporate the strengths of extant concepts and paradigms.

In the remaining part of this chapter, I would like to outline what I see as a promising theoretical approach to the plasticity and evolution of human ecosystems. It begins with a novel bridging of social and ecological theories such that the tension between determinist understandings and ecological praxis is made central to the analysis. What I propose is in many ways a historicist ecology; the specific factors and system properties that constrain and enable ecological praxis, however, are made central to the analysis.

Giddens' Theory of Structuration and Its Application to Human Ecosystems

The effective bridging of human and ecosystem studies has been hindered by very real difficulties in simultaneously addressing biological, cultural and societal processes and the particularities of each. The difficulty confronted by scholars attempting to build a unified understanding of human ecosystems is hindered by fundamental differences in ontological and theoretical understandings (ideational and materialist, humanist and naturalist, etc.). Extant theoretical frameworks are nevertheless instrumental in elucidating multiple dimensions of the human-environmental problematic.

In this section, I wish to highlight central tenets of a theoretical tradition that has yet to be employed to address the constraints and contingencies influencing material-environmental processes over time, and to discuss how these might be linked with ecosystem theory to explicate the human-environmental dialectic. This bridging of apparently disparate theoretical traditions is particularly useful for placing the tension between constraint and possibility, interdependence and dependence, "nature" and "culture," at the center of analysis.

Outline of the Theory

Structuration theory, first coherently proposed by Giddens (1984), represents an attempt to bridge apparent contradictions between an early emphasis on the ordering of forms (institutional, ideational, psychological) within which social actors are situated, and recent views in which actors hold greater historical and ontological force (see Dirks et al. 1994). Political economy and structural Marxism assume, "together with earlier anthropologies, that human action and historical process are almost entirely structurally or systemically determined" (Ortner 1984:144). Practice theory, which emerged in the 1980's, affords greater latitude to humans in conditioning historical process. Giddens attempts to bridge these two traditions, viewing individuals as *both* culturally and historically-constituted, and as agents in an active sense. What emerges is a certain dialectic between individual and structure, between active constitution of and resistance to dominant modes of behavior, and between material and cultural life. According to Giddens, "to treat structural properties as methodologically 'given' is not to hold that they are not produced and reproduced through human agency" (1984:288).

An application of social theory alone to an analysis of material-ecological phenomena will inevitably fail to explain the full range of processes, motivations and constraints on human environmental behavior. However, a few fundamental aspects of the theory of structuration (and the elements of practice theory found therein) provide a framework through which a more processual understanding of human ecosystems, and of the factors that structure human-environmental interactions, may be generated. These include:

1) Giddens' notion of strategic conduct. All human beings are seen as knowledgeable agents, with a profound understanding of the conditions and consequences of their daily activities. Social forces operate through agents' reason and motivation (purposive action). For Giddens, however, the primacy given to "discursive and practical consciousness" does not negate the importance of structural properties. Purposive action, in the aggregate, is central to structural change.
2) A concomitant focus on structure and system constraint. Implicit in the Theory of Structuration is the tension between agency and structure, and factors that both enable and constrain human activity. If individuals are knowledgeable actors, then how (if at all) are their actions influenced by structural properties of the systems in which they are embedded? Giddens dubs the relation between structure and agency the "duality of structure," in which constraint operates "through the active involvement of the agents concerned, not as some force of which they are passive recipients" (289).
3) An understanding of history as social practice. This view might be seen as the temporal dimension of the "duality of structure" discussed above, in its placement of human agency and purposive action within more institutionalized structures and at the center of the historical problematic. Practice theorists such as Ortner share this view of social and historical process as "holding together,

rather than polarizing, structure and agency, material and cultural life" (Dirks et al 1994:15).

4) A more contemporary understanding of culture that questions Culture's timelessness. In acknowledging that culture is both enduring and dynamic, individual and collective, this view allows us to understand that it is not simply "culture contact" that produces change within societies, but the everyday actions of individuals and their processing of experience.

Structuration Theory and Human Ecosystems

These concepts are useful for understanding the dialectic between a constraining blackwater environment and the role of human agency in generating novel productive opportunities within this environment. Yet these understandings must be adapted to the particularities of human-ecological interactions. Giddens' concept of purposive action is central to our understanding of ecological praxis. In the case of Black Earth, lasting soil modifications may represent a direct product of strategic environmental conduct. More likely, however, is that it represents a by-product (unintended consequence) of purposive action toward another end, such as favored conditions of trade and/or subsistence – conditions that might have facilitated sedentary lifestyles and in turn permitted the formation of Black Earth. Modification of historically-entrenched modes of subsistence cognition and behavior also requires a great deal of creativity, and is a form of strategic environmental conduct. Examples include alternative conceptual and behavioral frameworks that assimilate and adapt to the unique properties of Black Earth (i.e., cognitive models of Black Earth as less natural or raw, less dependent on the burn, etc., and behavioral orientations that quicken fallow cycles). Individuals pull from a repertoire of environmental[1] knowledge and purposive thought and behavior (reasoning processes, trial-and-error) when devising these novel adaptive strategies.

Strategic modification of livelihood strategies also occurs on the basis of ever-changing incentives in material and non-material realms. Both intended and unintended consequences of this purposive conduct generate novel conditions (i.e., anthrosols, an expanded knowledge base, local modification of market niches) from which system evolution and novel forms of strategic conduct ensue. This was seen in the rapid saturation of regional markets with exotic crops – in effect restricting political-economic incentives among local Black Earth farmers, and in the challenge faced by individuals in generating sustainable use practices on Black Earth as (or before) these environments themselves change through historical process.

Also critical to human ecosystem theory is Giddens' concept of the duality of structure. It is precisely this dialectic between human agency and the constraining influences of diverse systems (ecological, political-economic and technological systems, human cognition, etc.) that is useful to our understanding of the processes shaping human adaptation and human-environmental interaction. In Rio Canoas and Santa Isabel sites, political-economic, cultural and technological factors were shown to structure uses of the environment. This understanding of external structuring agents must be tempered, however, by our understanding of the particularities of each of these systems. In Black Earth ecosystems, while biophysical, political-economic and technological systems are partially constituted through social action (through soil modification, saturation of

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[1] "Environment" is used differently here, encompassing human response to and construction of a number of external structures (environments): biophysical, political-economic, technological and socio-cultural.

municipal markets, altered fertility management systems, etc.), these systems may also be understood in terms of structuring influences that are independent from local praxis.

While political-economic and technological systems may be understood as fully constituted by social action when encompassing both local and global dimensions of practice, the ecosystem as structure must be understood as possessing an ontological and directive status in its own right. Material and energy cycles particular to terra firme ecosystems structure subsistence behavior from without by setting an upper limit on extractable nutrients and shortening fallow periods, or by influencing the amount of labor required to convert oligotrophic soils into a more fertile substrate. This is more in line with Craib's (1992) and Thompson's (1989) recognition of "relatively enduring and independent structures" (Wilmott 1997:101) and Wight's (1999) view of institutions and structures themselves as agents. For ecological applications, ecosystem properties (nutrient distribution in soils and vegetation, climatic forcing functions, etc.) must be incorporated into the analysis at the appropriate scale and resolution.

Giddens' view of history as social practice has strong parallels with historical ecological research. And yet, similar to historical ecology, a direct application of structuration theory to human ecosystems would exaggerate the ecological praxis of humans. History-as-practice is evident in human impacts on the biophysical world itself (intentional or not), and in adaptive strategies that effectively incorporate novel (anthropogenic or "natural") elements of the environment into extant subsistence strategies based on perceived and "created" opportunities. However, the modification of the soil substrate is constrained – by labor limitations where modified intentionally, and by population density and sedentism otherwise. When re-interpreted for the material-ecological realm, this primacy given to social practice is nevertheless useful for understanding the role of human intent in assimilating, modifying and creatively ordering diverse structures in ways that best meet perceived goals and needs. For the blackwater terra firme, this is evidenced in the effective assimilation of diverse opportunities (a more fertile anthropogenic soil, exotic crops, and peaks in the price of these crops during periods of floodplain inundation) into production systems, thereby expanding the range of viable economic activities.

Finally, by embracing the more dynamic nature of culture, more attention may be paid to the role of praxis – of both individuals (purposive conduct) and structures – in system *evolution* (as opposed to system reproduction). In central research sites, both routine and improvised purposive action contributes to the *evolution* of both ecosystems (Black Earth) and adaptive processes (i.e., through the generation of shared use strategies for Black Earth) through time. Routine behaviors associated with an era of prehistory in which semi-permanent settlement was the norm presumably led to the formation of Black Earth; purposive action improvised to adapt productive strategies (timing, crops planted, etc.) to anthropogenic environments and specific political-economic opportunities is producing lasting effects on the environment today. Purposive action is central to the dynamic conditions that underlie the dialectic between environment and adaptive behaviors – modifying each of these, and structuring future productive possibilities and environmental constraints through use-induced degradation.

This view of culture emphasizes the critical role of a society's own internal dynamic (over culture contact, for example) in producing characteristic social and ecological relationships. The evolution of human-environmental interactions is therefore seen as illustrative of the normal state of affairs, in which dynamic and creative processes of cultural, technological and political-economic change are customary – even in culturally-remote regions. This view of culture supports research findings in which the plasticity of human-environmental interactions is ever-changing, influenced by ecological praxis as well as by the active processing of diverse structuring agents through time. The treatment of Western influences as a series of influential forces or events punctuating a much deeper history is more illustrative of a historical reality in which the influence of diverse factors (endogenous and exogenous, indigenous and Western, local and global) mutually structure human ecosystems through time.

The reader may question whether the application of concepts derived from the analysis of social systems to the material-ecological realm does not disregard Giddens' original intent. The theory of structuration is a powerful framework for understanding the "constitution of human ecosystems," if you will, provided that deviation from the theory's original premises are made explicit. The application of structuration theory to human ecosystems requires the following clarifications:

1) the agent-structure dialectic applies to the material-environmental realm of human action, with the original focus on social institutions analyzed to the extent that these structure human ecological behavior,
2) "structure" must be made more inclusive, encompassing those influences with relatively enduring and patterned influences on material-environmental relations in addition to (ecological-, technological-, political-economic-, cognitive- or social-)structure-as-practice, and

3) greater ontological status must be ascribed to the ecosystem (relative to “social institutions” and to ecological praxis) and to its role in structuring human-environmental interactions.

The application of structuration theory to human ecosystems highlights the role of ecological praxis by focusing on the role of purposive conduct, dynamic cultural and cognitive influences, and history as social practice in the structuring of human-environmental interactions. Furthermore, by acknowledging the role of the ecosystem as structure and affording it an ontological status over and above human behavior, structuration theory has a unique ability to bridge ecological praxis with what we know about ecosystem constraints. This theoretical integration requires that special attention be given to the particular role played by local and global ecosystems in structuring human usages of the natural world.

Ecosystem Ecology and the Tempering of Ecological Praxis

One of the fundamental problems in conceptualizing relationships between natural and human ecosystems is the question of dependence versus independence of humans and the natural world. To date, the most promising realm of ecological understanding for conceptualizing how the ecosystem conditions plasticity in human-environmental interactions is ecosystem ecology. Historical ecology and landscape ecology both highlight important aspects of human-environmental relationships, the former in its attention to historical processes in the environment and the latter in its explicit concern for human impact on the natural environment (due to its attention to scale and spatial heterogeneity). However, their ability to fully explicate research findings is limited by the primacy given to historical over ecological processes, and by the view of humans as external agents rather than components of ecosystems, respectively. Through an understanding of the physical and biological principles governing ecosystems, we gain an understanding of how limitations to the productivity of these environments influence human societies.

The ecosystem is "a fundamental ecological unit that refers to associated species of living organisms in a nonliving physical environment and to the structural and functional relationships among them" (Moran 1982:8). These functional relationships refer, in part, to the cycling of nutrients within an ecosystem, and between it and the outside world. It is here that the present research relies on an understanding of ecosystem ecology. The traditional swidden system has been understood through this framework, in which agroecosystem productivity is strongly linked to forest biomass and to the quantity of nutrients released through the burn. The older the forest, the greater the nutrient stocks in the system, and the longer the system may be farmed prior to plot abandonment. In theory, through the creation of a more eutrophic substrate a greater percentage of nutrients would then derive from soils, thereby partially de-coupling agricultural productivity from forest biomass. Evidence for this is found in the ability to shorten fallow times despite the cultivation of more nutrient-demanding crops, and in local understandings that Black Earth agriculture is less dependent on the burn. It is precisely these understandings that provide a critical link to our understanding of the plasticity in human-environmental interactions as derived from anthropogenic modifications of the ecosystem.

From an early date, ecosystem theory was grounded in biocybernetic theories that identified principles regulating biological systems and leading to their self-stabilization and organization via positive and negative feedback mechanisms. While earlier applications of biocybernetic theory focused on ecosystems as equilibrium systems, in which system departure from steady state conditions was known to catalyze negative feedback mechanisms and to cause the system to revert to this "normal" state, increased evidence of system dynamicity led scholars to embrace the idea of dynamic equilibria. In a state of dynamic equilibrium, open systems are capable of tending toward steady-state conditions despite constant matter and energy exchange with the surrounding environment and temporary changes in ecosystem structure and function. These understandings have been applied to human ecosystems to understand system carrying capacity, as expressed through the coupling of population and critical resources and the ramifications of extending beyond ecosystem limits.

The Use of Ecosystem Ecology to Study Human Societies

From a review of the ecological and anthropological literature that incorporates humans into ecosystem analysis, I have identified two basic theoretical trends that roughly correspond to disciplinary boundaries (with some important exceptions). The first applies the ecosystem concept as a heuristic device to draw analogies between the ecosystem and social systems (households, communities and so on) (Wilk 1990, Netting 1990). This approach takes social systems as the subject of analysis rather than the ecosystem per se, such that the structure and functioning of these social groupings become subjects worthy of study in their own right.

The second approach may be termed an operational model, in which the ecosystem concept is appropriated in a more literal and functional sense. In this approach, humans interact directly with the structure and function of "natural" ecosystems, the latter of which become the central unit of analysis. Many authors also subject humans (analytically) to the same "currency" used to study non-human ecosystems (energy, matter, information). I have identified three approaches that assume this more literal use of the ecosystem concept. In the first, humans are seen as external agents that influence ecosystem functioning through disturbance (a human-induced departure from the steady-state) (Macedo and Anderson 1993; Uhl 1990). In the second approach, humans are considered an important element of "natural" ecosystems and therefore analyzable through a similar lens as that employed to understand "pristine" ecosystems (Gragson 1993; Wilson and King 1994). Some of these studies subject humans to the same laws and principles that order these natural systems, despite more proximate cultural regulating mechanisms (Good 1987; Rappaport 1968; Vayda 1974). In either case, ecological rather than cultural systems become the foundation of analysis.

The final operational use of the ecosystem concept is perhaps the most synthetic, in its literal or operational use of the ecosystem concept and simultaneous aperture to multicausality in cultural process (Crumley 1993; Hastorf 1990). Embracing multi-causal relationships brings history into human ecosystems, effectively overcoming what Brush (1975) saw as the most critical problem facing ecosystem analyses of human societies: the relationship between homeostasis, cultural change and evolution. It is this approach that comes closest to explicating the dialectic between ecosystem constraint and ecological praxis in the study region, by helping to explain the role of the diverse factors that structure human ecosystems through time.

According to Crumley (1993), there are two types of historical analogues: environmental, in which the environment (through evolutionary or historical processes) determines the patterning of the landscape, and environmental-cultural, in which a dialectic exists between environmental and cultural causation. Crumley takes the second approach, in which the dynamics resulting from external climatic changes reflect both environmental forcing functions themselves, and the cultural and socio-political influences of the societies affected by climate change. Crumley takes an important step in focusing on this dialectic between cultural and environmental causation and on culture as a frame of reference through which environmental stimuli are processed and understood.

This framework is insufficient for explicating the present research findings, however, in which environmental changes emerge from within human societies (despite the fact that those who generated and those who cultivate Black Earth may be distinct) rather than from external influences (climate, etc.). Furthermore, to explain these findings it is critical to focus not only on culture but on diverse influences (culture, regional history, political-economics, technology and human agency) that pattern human-environmental interaction through time. A more powerful explanatory framework would stress system evolution (i.e., through active assimilation of novel environmental stimuli into existing modes of behavior), and differ from Crumley's emphasis on the role played by culture – namely, enhancing a society's *resilience to* (homeostasis) rather than *assimilation or provocation of* environmental disturbances.

Hastorf's historical analysis of Andean societies provides perhaps the strongest foundation for the present research. Despite her use of archaeological rather than ethnogrphic methods to study human ecosystems, the result is similar to the linking of ecosystem theory with the theory of structuration. By focusing on internal, socio-political sources of change, she frees the analysis from strict environmental causality as does Crumley. Yet her use of systems theory rather than historical ecology permits a closer look at internal factors catalyzing change. As a result, any part of society is seen as a possible nexus for contradiction and change. She also moves beyond conventional ecosystem ecology in her implicit historicity, acknowledging how historical contingency and individual agency may produce diverse consequences from a similar triggering event.

The historical contingency in Hastorf's model is applicable to my own discovery that distinct cultural responses to the same biophysical stimulus (Indian Black Earth) are likely to have resulted from divergent political-economic, cultural and technological factors. I demonstrate how local residents process novel environmental stimuli, how human agency itself influences systemic influences (for example, the saturation of local markets and ongoing modifications of the soil substrate) and how these influences in turn condition environmental behavior (i.e., causing farmers to adapt cultivation strategies to larger markets or to use organic amendments when soils degrade). Hastorf's analysis departs from the ecosystem framework, however, in what I view here as an essential link between those very models she attempts to bridge: the relationship between ecological constraints and ecological praxis.

While ecosystem ecology provides a conceptual model through which productive potential and constraints on human societies may be viewed, structuration theory does just the opposite – it explores the range of human agency in conditioning societal outcomes. It is this very dialectic that I explore in the present study, and which departs from prior models of human ecosystems. The oligotrophic ecosystem provides an ideal context for analyzing this dialectic between the limitations posed by ecosystem properties and the latitude of human agency and economic behavior in the face of these limitations. It is here also that my two research questions, human adaptation and the plasticity in human-environmental interaction, are most directly interrelated.

In the blackwater ecosystems of Amazonia, the oligotrophic conditions of aquatic and terrestrial ecosystems would suggest that great effort is required for ecosystem modification. Yet the pedological divergence of Black Earth from background soils in Chapters VI and VII is evidence that ecosystems are plastic when subject to cultural influences. Furthermore, both cognition and use of Black Earth environments depart from attitudes toward non-anthropogenic environments, suggesting that subsistence practices (adaptive processes) are also plastic in the face of novel and changing environmental stimuli. Given this evidence for plasticity in human-environmental interaction, the proposed approach to human ecosystems is useful for assessing whether biophysical factors act to constrain the modifiability of ecosystems and human adaptation, and for identifying factors that condition these processes through time.

D. The Structuration of Human Ecosystems: A Framework for Conceptualizing Human Ecosystem Plasticity and Evolution

The application of Giddens' theory of structuration to human ecosystems is again useful for elucidating the tension between structural constraints and human agency. Its emphasis on the role of humans in constituting diverse structures themselves dissolves the idea of a monolithic structure that constrains human behavior. When applied to human ecosystems, it is a framework that readily encompasses recent trends in historical ecology in which the historical and ecological praxis of humans is central to the analysis and to the "structuring" of human-environmental relationships. However, the limitation of its application to ecological phenomena stems from the incomplete structuring of the environment by human action. While humans have the ability to modify the environment, the environment must also be afforded an ontological status of its own, independent from human action, as a function of properties derived from evolutionary processes. As such, it is critical to bridge the theory of structuration with ecosystem ecology to maintain this perspective on environmental properties and forcing functions.

I have coined the resulting theory the "Structuration of Human Ecosystems". It is a theory that is grounded in the following aspects of human-environmental interaction in the literature and in the blackwater regions of Amazonia:

1) Ecological praxis. Through intentional and unintentional strategic conduct, humans are able to modify the environment and to structure their uses of it.
2) The dialectic between culture and environment. Ecological praxis is tempered by the environment, which conditions human behavior as it is modified by it.
3) The duality of structure. Diverse historical contingencies structure this interaction between humans and the environment, including (minimally) technology, political-economics, culture and the environment itself as both unchanging (a product of evolution) and altered through historical process. Yet these structures themselves are in part constituted by human action, with structure emerging through agency – both local and global.

4) Environment as a product of both evolutionary and historical processes. The environment differs from other structures in deriving its properties both from dynamic historical and more static, evolutionary processes. As such, it is not entirely constituted through human action; rather, ecological praxis is in part constrained by relatively enduring environmental properties.

These properties of human-environmental interaction are illustrated in research findings from the blackwater regions of Amazonian Brazil. The role of ecological praxis is first seen in the presence of Black Earth environments. The high fertility of these soils contrasts markedly with the more predominant Latosols, as evidenced in higher proportions of nutrient ions, elevated Cation Exchange Capacity and pH, and lower proportions of toxic aluminum. Perhaps the best illustration of ecological praxis within the environment itself is the more even distribution of nutrients between soil and standing stocks and the high concentration of soil phosphorus. Each of these properties is in sharp contrast with adjacent, non-anthropogenic environments where system nutrients are locked up in the standing biomass and where phosphorus is known to be a limiting nutrient. While this ecosystem modification is more likely a by-product of particular patterns of settlement than intentional soil modification per se, it nevertheless results from strategic conduct oriented to other environmental uses (nutrient deposition through intense extractivism, etc.).

Ecological praxis is also seen in the generation of complex adaptive strategies to effectively exploit this modified environment. Cognitive understandings of Black Earth environments are shown to depart from cognition of Latosols, yet assume a similar status in terms of their perceptual saliency. This is shown in the soil classification systems of central research sites, in which Black Earth is listed in contrast sets with other predominant soil classes and further differentiated according to similar criteria. The active processing of these relatively novel environmental stimuli (i.e., those emerging through historical process) is also evidenced in the departure of Black Earth understandings from those of other common soil classes. A large number of features are used to differentiate Black Earth from other soils in the minds of local residents (see Table VI-4), indicating that a high degree of cognitive differentiation characterizes these soils. A majority of these features represent the higher fertility and higher incidence of weeds on Black Earth.

The data also point to behavioral adaptations that are indicative of ecological praxis. The cropping of exotic vegetable and grain crops demonstrates the tendency of individuals to capitalize upon higher fertility indices, political-economic incentives and seasonal market fluctuations to enhance profit margins. Furthermore, shortened fallow cycles show how these cultivation practices reflect complex adaptations to environmental conditions, and effectively maintain fertility at higher levels throughout the swidden cycle. Time allocated to Black Earth and diverted from other productive activities also demonstrates how culture is dynamic, capable of incorporating novel opportunities into existing and traditional modes of land use.

Yet results also demonstrate that this ecological praxis is not absolute – that the environment also plays a role in constraining and enabling adaptive processes. The strong differentiation between uses of Black Earth and Latosols demonstrates how the more static properties of environment condition certain land uses over others, even if these properties are themselves undergoing change through historical impacts. While the higher fertility of Black Earth appears to de-couple adaptive behavior from environmental constraints on the terra firme (see Table VI-8), the processes leading to Black Earth formation defy the ethnopedological knowledge base of contemporary residents. Furthermore, soils are shown to degrade under cultivation even on these more fertile anthropogenic soils, demonstrating how the environment continues to structure human usages. Human-environmental interactions must again be seen as dialectical.

While the environment may be a constraining force to human activity, individuals are cognizant and strategic in the behavioral adaptations they make within changing landscapes. They are knowledgeable actors responding to changing political-economic, technological and ecological stimuli, altering the environment knowingly and unknowingly in the process and thereby helping to "structure" future human-environmental interactions. Through this transactionalism, humans are seen as having greater agency for structuring the biophysical environment (intentionally or not), and the modified environment is then capable of re-structuring social relations or subsistence.

It is important to recognize, however, that as individuals develop cognitive and behavioral adaptations to the unique conditions in Black Earth environments, the environment itself changes through historical process (see Table VII-11). These changes pose ongoing challenges to humans as they develop cognitive and behavioral adaptations to environmental conditions. While Black Earth farmers are shown to develop complex adaptive strategies in these historicized landscapes, they have failed to generate practices to maintain system productivity long-term. Only recently have long-term Black Earth farmers begun to compost to restore soil organic matter and attempt to recuperate degraded soils. The evolving role of the soil substrate through time (i.e., through alternate periods of accretion and degradation) underlie important ecological linkages between temporally-discrete populations, and demonstrate important temporal dimensions to the dialectic between humans and the environment. Both cultural (cognitive, behavioral) and biophysical conditions upon which this human-environmental interaction occurs should be understood as dynamic.

The third aspect of this structuration model of human ecosystems is the duality of structure, or the role of human action in constituting diverse structures that in turn constrain and enable human behavior. In the context of human ecosystems, this dialectic between humans and the biophysical environment is influenced by diverse structures that exist both independently of local practice and through this practice. These include, minimally, technology, culture, political-economics and the environment itself.

Technology is shown to structure human-environmental interactions in these blackwater ecosystems by influencing the usefulness of distinct environmental contexts and use strategies. Exotic crops, more valued in centralized markets, enhance incentives to Black Earth cultivation that would otherwise be minimal, while the absence of technology to process dry maize grains minimizes the cultivation of grain crops for household consumption – in particular where seed is not used to feed domestic livestock. Culture is also shown to structure adaptive processes. This is apparent in the role of dietary preferences in limiting demand for Black Earth crops in Santa Isabel markets, and therefore to, Black Earth cultivation. It is also evident in the manner in which modified patterns of environmental cognition and management in central research sites continue to reflect tradition. This is seen in informant disagreement about conventional ways of cognizing the environment when applied to Black Earth (i.e., about whether it is "natural" and “raw” like other forested terra firme environments). Cultural beliefs that the environment is “raw” and must be domesticated through the burn to be cultivated are likely to underlie the tendency to burn Black Earth rather than restore system fertility through organic amendments. Additionally, cultural understandings partially determine whether Black Earth cultivation is successful, given that modern agricultural techniques such as chemical pest control methods are not equally understood by all residents. Finally, political-economic influences are shown to structure human-environmental interactions by influencing crop selection, as well as the timing of Black Earth cultivation to coincide with the inundation of floodplain environments (where traditional “Black Earth crops” may be grown and seasonally saturate centralized markets). Black Earth appears to gain importance as traditional diets change, technology (i.e., exotic crops) becomes available and market influences take hold.

These influences are again shown in the following figure, where diverse structures are shown to impinge upon human decision-making processes, and therefore too, on the environmental impacts of these decisions:

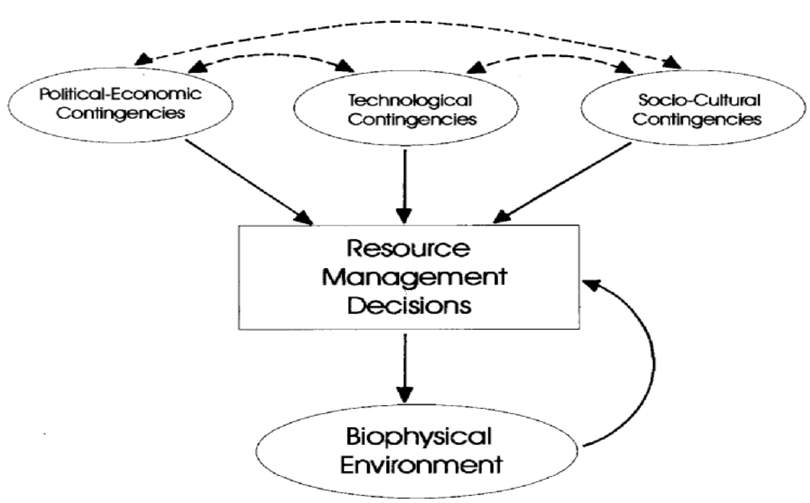

Figure VIII-1. The Structuration Model of Human Ecosystems

The environment again plays a critical role in structuring human-environmental interactions, and may also be understood in part as an external structure influencing decision-making processes. The influence of the environment and these other structures should also be seen as dialectical, mutually influencing human adaptive process rather than exerting their influences independently. This is seen, for example, in the ability of Black Earth farmers to respond to *political-economic* incentives for the cultivation of exotic crops only when the soil substrate (*environment* as structure) is more fertile, a mutual influence that partially de-couples environment and subsistence on the terra firme (see, for example, discussion on pages 215-216).

Finally, Giddens' contribution to our understanding of these diverse structural influences stems not from their mere existence, but rather from their dual nature. Giddens sees each of these influences as constituted by human action rather than as monolithic and unchanging structures limiting the latitude of this behavior. This holds important implications for our view of ecological praxis; it demonstrates how individuals actively assimilate opportunities inherent within these structures, and in turn modify them. Some aspects of technological and political-economic structures, such as availability of exotic crops and economic demand for these crops in Manaus, must be viewed as relatively immutable structures with respect to local adaptive processes. This is true for the Canoas region, where demand for banana and governmental incentives for the cultivation of this crop may be seen as an essentially immutable political-economic structure. The more stable aspects of these structures would nevertheless be understood by Giddens as constituted through human action at global scales.

In addition to this globalized praxis, however, local residents themselves are shown to influence these diverse structures. This is evidenced in their creation of market niches (i.e., maize sold as feed for local livestock), their saturation of municipal demand for Black Earth crops (therefore constraining other Black Earth farmers), and their creative generation of “soft technologies” (Hecht and Posey 1989) on Black Earth that differ from traditional management practices on Latosols. This creative influence of individuals as they reinforce or counteract more stable structural influences make these structures more dynamic than the already rapidly changing global technological and economic arenas. Ongoing changes in these external structures contribute to the dynamic interaction between humans and the environment, structuring cognitive and behavioral adaptations as well as the environment as its properties evolve through these novel uses.

From my research, it may seem as if external structures such as exotic technology (crops) and urban political-economic influences are more critical than human agency in re-structuring human-environmental relations in Black Earth environments. However, ecological praxis is clearly evidenced in the creative processing of stimuli from these external structures (the Black Earth environment, seasonally high prices for vegetable crops, etc.) to generate novel, fully endogenous subsistence systems in order to derive the most benefit from the modified environment. The utility of structuration theory therefore derives from its conceptualization of the dialectic between diverse structures and human praxis, and the transformative role each has on human ecosystem plasticity and evolution.

One final aspect of this structuration model of human ecosystems that merits attention here is the recognition that environment is distinct from other structural influences both in origin and function. The environment exists as a relatively enduring structure that may nevertheless be modified through the ecological praxis of local residents. However, its more lasting properties result from evolutionary processes rather than human action in the aggregate, the structure that results being qualitatively distinct from other anthropogenic structures. Ecosystem ecology is best suited to explicate this component of human ecosystem evolution, as well as the role of environmental limitations or forcing functions.in constraining the historical and ecological praxis of local actors.

The environment must be see as both dynamic (modifiable through historical processes) and relatively enduring (a result of evolutionary processes), with environmental constraints stemming from either of these qualities. On the first hand, historical impacts on the environment might expand or constrain the adaptive possibilities of future residents. Expansion of productive opportunities was seen in the creation of more fertile soils by Amerindian groups – enhancing productive opportunities among contemporary Black Earth farmers, while degradation ensuing from current patterns of use are likely to restrict uses among future occupants. On the other hand, the long evolutionary and geological history of Amazonia and contemporary climatic forcing functions influence the degree to which humans may alter the environment and in turn their uses of it. Limitations on this modification are seen in the limited depth of anthropogenic soil horizons – a factor that restricts the useful life of Black Earth in the absence of opposing soil-building processes, and in the limited productivity of surrounding ecosystems whose nutrients must be concentrated through intensive burning for Black Earth to form. This geological history also underlies the permanence of Black Earth once formed, however, through synergistic interactions between soil chemical indices. In this case, enhanced resilience to climate-induced leaching, catalyzed by cultural additions yet maintained through the complex interaction between Cation Exchange Capacity, pH and biotic activity (Woods and McCann 1999), demonstrates that even geological processes may potentialize historically-induced ecological praxis.

Ecosystem ecology therefore helps to explicate the particularities of environmental "structures" that derive their properties from both evolutionary and historical events. Environmental limits to ecological praxis were evident in the agricultural practices carried out in blackwater regions of Amazonia. The limited capacity of Black Earth to regenerate itself in the absence of ongoing cultural soil-building processes is supported in the literature (Smith 1980) and in informant commentary, which indicates that sites with a long history of use slowly lose organic matter and clays, as well as their dark color and high fertility. Environmental limits were also seen in the impact of use on the leaching of soil nutrients (Table VII-11), and in the gradual loss of soil chemical advantages on Black Earth sites subject to long periods of cultivation. These indications that contemporary use practices are leading to Black Earth degradation would suggest that the impacts of cultivation counteract those of Black Earth formation processes. The fact that contemporary residents encountered highly fertile anthropogenic soils despite this tendency for soils to degrade under agriculture would also suggest that the importance of Black Earth (and the plasticity of adaptive manifestations of the terra firme) are at their peak today, in the regions where these soils play an important role in agriculture.

It is necessary, however, to recognize that environmental limitations to human behavior are not absolute. Limits to soil productivity are manifested not only in the quality of naturally-occurring resources such as nutrient-poor terra firme soils.

Constraints also ensue from the time or effort presumably required to modify these soils (if intentional), the density or duration of settlement and the ability of surrounding political-economic and natural environments to support these populations (in the case of unintentional modification), and by the limited depth of the resulting anthropic epipedon. If these soils are a simple artifact of more sedentary modes of settlement, as suspected, then the absence of Black Earth sites in the Barcelos region might say something more about the capability of the environment in this region to support larger, more permanent human settlements. The predominance of terra firme soils with very poor drainage in this region limit even traditional manioc-based cultivation today. It is likely that these properties, which effectively limit both the productivity and spatial extent of cultivable soils, kept Amerindian population densities to a minimum in this setting during the period in which other regions experienced a growth in cultural complexity that presumably catalyzed Black Earth formation. In this case, environmental limits to soil modification would have resulted from other factors that constrained human settlement. As such, any constraints on human activity as imposed by environment-as-structure do not stem from social practice alone, but represent an outcome of specific evolutionary and historical processes, among these past human uses that enable or constrain the ecological praxis of later inhabitants.

To conclude, this structurational approach to human ecosystem plasticity and evolution, similar to historical ecology, sees humans in a dialectical relationship with environment and with diverse systems. The properties of the environment afford human communities diverse productive uses, with the limitations to these practices manifested in ways particular to specific uses of the environment and to diverse structuring agents (technology, political-economics, etc). If one or another of these uses provokes alterations in the biophysical environment itself (or in any of these other structuring influences, for that matter), then this dialectic exchange may occur on the basis of novel conditions and incentives – as mediated through the articulation of ecological and non-ecological realms. The influence of external mediating factors such as political-economics on decision-making processes is shown to evolve according to novel productive capabilities even if political-economic "structures" themselves change only little. Socio-economic, historical and cultural contexts are therefore viewed in their relationship to the environment, with humans mediating the particular influences of these factors through creative adaptive processes and systemic cultural influences (polity, technology, etc.).

In this view, humans generate novel productive niches on the basis of both historical process and environment, and on the basis of both historical contingencies and social (ecological) practice-as-history. While environment structures productive constraints and potential, the degree and nature of these influences are themselves contingent on ecological praxis and particular historical influences. In combination, structuration and ecosystem theory allow for a more effective understanding of the role of ecology in the plasticity of human-environmental interaction, and of both individuals and ecosystems as historical agents.

E. Application of Research Findings

In addition to the theoretical contributions of this research, I have identified two important areas of application: in the management of human ecosystems in land-based economies, and in environmental education. A description of these applications follows.

Ecosystem Management

The focus on local, traditional systems of land use has proven to be highly instructive for broad-based policy initiatives. This relationship stems in part from what small-scale societies tell us about how the particularities of local and regional ecosystems influence profit margins, and ultimately the sustainability, of alternative models of land use. Human ecosystems that are neatly inscribed from the standpoint of material and technological inputs (the idealized "closed system") are helpful in demonstrating how *innate* properties of local ecosystems influence the viability of diverse productive activities.

One might ask what research on more isolated and closed systems can possibly tell us about the contemporary economic climate, where these inherent ecosystem properties lose relevance in the face of unlimited material inputs from outside the system (from petroleum-derived fertilizers, for example). These inputs in effect create novel ecosystems through material (nutrient) and technological inputs, intensifying the exploitation of existing resources. Given this relatively recent change in the scale of de-coupling of ecosystem properties from land use (and of material and technological transfers from distant environments), are innate properties of these systems relevant to land-use policy? The answer for land-based economies, in particular throughout the third world, is "yes." Here, the importance of ecosystem properties and dynamics is derived from relative inaccessibility (in economic and/or geographic terms) of exogenous inputs, from dynamic and often unreliable market influences (increasing the risk associated with dependence on outside inputs) and from the ability of local resources to substitute exogenous inputs and enhance profit margins. Idealizing the closed system is also useful for heuristic purposes. Researching systems on the margins of the market economy illustrates how distinct factors condition the viability of diverse land-use strategies, and the factors that should be considered in the spatial and social differentiation of land-use policy.

The study of subsistence and market orientations to agriculture on relatively eutrophic (nutrient-rich) soils (i.e., Black Earth) and oligotrophic soils (Latosols, Podzols, etc.) along a trajectory up the Negro River illustrates how richness of the environment influences the viability of intensive agriculture. Market-oriented agriculture on oligotrophic soils is limited to a small radius near the urban center of Manaus, where the costs of heavy chemical inputs and benefits of road-accessible markets are shifted in favor of this intensive model of land-use. On more eutrophic pockets of Black Earth, however, market orientations extend up the Negro for some 150 km despite the absence or minimal use of chemical fertilizers. The cultivation of exotic cash crops drops off sharply beyond this point. This location seems to act as a fulcrum-of-viability, so to speak, in which moving down- or upstream from this point favors or deters market orientations to agriculture, respectively. Key variables influencing the adoption of these exogenous production practices are, minimally, resource quality (which influences reliance on exogenous material and technological inputs) and market accessibility. While this scenario appears to be descriptive only, it also illustrates the likelihood of success of exogenous (conventional or intensified) models of land use.

In discussing the relevance of these findings to land-use policy, it is important to highlight the relationship between open and closed systems on the one hand, and between the resource base and resource management on the other. In a closed system, the particularities of local and/or regional ecosystems strongly condition productive potential. In open systems, on the other hand, land-use strategies may be divorced from the particularities of the resource base, and exogenous models of land use (from a nutrient standpoint) become viable alternatives. It is important to note that the distinction between open and closed systems is not only an artifact of localized modes of land use; it is also created through policy. Economic policies may favor intensive modes of production (in which heavy inputs of exogenous materials and technology are required) or more extensive modes of land use (characterized by a strong coupling of ecosystem properties and resource use). If we are to promote intensive modes of production in more remote regions of developing nations, then we risk subjecting resource-poor families to the whims of fluctuating markets, fail to capitalize upon natural capital (which may be exploited through labor rather than capital inputs) and compromise the resilience of natural ecosystems for replenishing this capital.

The Model. In regions where resource quality does not sustain intensified models of land use with minimal inputs and risk, it is important to devise policies that allow a stronger coupling of innate ecosystem properties with land-use strategies and policies, and to reduce dependence on outside inputs. In oligotrophic ecosystems, where resource density and/or quality is limited, this might include value-added processing at the local level, through which a greater proportion of earnings derive from labor rather than natural capital. More proximate, resource-rich areas would be used for intensification. I would not advocate arbitrary cut-offs in policy that differentiate between regions to be treated as closed systems *a priori*, an approach that could justifiably be interpreted as furthering the gap of economic opportunity between the rich and the poor. Rather, it is important to identify where macro-level policies are not benefiting the long-term social and ecological viability of existing modes of production, and to further differentiate policy accordingly to better meet the needs of these populations. Intensification would be favored where technological and material inputs favor rather than deter sustained use, economic well-being and the viability of the resource base that sustains these activities. Beyond the fulcrum where shifting market influences most compromise social well-being and the rational use of resources, homogeneous economic policies must be reformulated to ensure the sustainability of land use practices and therefore environmental integrity.

Further lessons may be derived from the importance of what might be called "subsistence complimentarity," or the complex interplay of multiple subsistence activities that together sustain rural families. Most government-sponsored development or settlement schemes promote a single productive activity, disregarding the tradition of complementing livelihood activities (fishing and agriculture, market and subsistence activities, etc.) and the logic behind these more complex use systems. This short-sightedness again increases risk of failure, places food security at risk and undermines the ability of families to revert to prior (endogenous) use strategies in times of need due to the erosion of local knowledge and of natural resources that once sustained these activities. Finally, the importance of local variation in resource quality to livelihood in Amazonia should be taken into account by agrarian reform initiatives, which to date pay little attention to biophysical criteria – a factor which undermines their success (Cravo, personal communication).

Environmental Education

The philosophical underpinnings of Western environmental understanding, in which the individual is seen as ontologically separate from pristine “natural” ecosystems, limit the scope of environmental understanding, education and conservation. Human activity is seen as independent from nature, and therefore divorced from fundamental principles governing natural systems. When our behavior is analyzed from ecological perspectives, our role in compromising the integrity of ecosystem structure and function are stressed. Absent is an understanding of humans as biotic components of ecosystems, different in their ability to use technology and global transfers of material to stretch the limits of localized ecosystems, but nevertheless subject to natural laws at a global scale.

These philosophical underpinnings to environmental scholarship and practice have had profound implications for the environment itself. First, conservation initiatives have been strongly biased towards the physical separation of humans from “natural” ecosystems (through parks and reserves, for example), at the expense of a more effective integration of humans and the biophysical environment. This is a most didactic representation of Western environmental philosophy in its physical and artificial isolation of humans from “nature,” and has led to a number of problems. Among these are the removal of traditional people from local environments with which they have been intimately associated for centuries, the ineffective policing of park boundaries and the isolation of non-human species. Furthermore, the last is generally determined by political criteria, or in the best case scenario through the use of ecological criteria that nevertheless stunt species’ response to climatic change – and ultimately, evolution itself.

Second, the ontological distinction between humans and nature has caused us to view humans as somehow above the constraining influences of the environment. It grounds our faith in the economic as both goal and indicator, and underlies the paucity of ecological markers in policy and project evaluations. The sheer scale of global economic, political and material interactions has exacerbated this problem by making the energetic and biophysical processes of ecosystem theory seem obsolete for human ecosystems, in particular within first-world nations where the myth of boundlessness is heightened by our ever-expanding access to world resources. This has led to obscurity within environmental discourse and practice, where the recycling of materials is given more emphasis than consumption itself.

The impacts of an ecological scholarship that addresses environmental problems from this fundamental ideological level would be profound indeed. By placing humans at the center of our ecological models and ideology, as a component of “natural” systems (and therefore subject to the governing laws of these systems), collective consciousness about our personal roles in the depletion of global resources would increase. Environmental discourse would increasingly shift from its current emphasis on the exotic (tropical deforestation, the conservation of exotic species, etc.) to the personal and familiar through an emphasis on the connectivity between personal behavior and global environments. The myth that resources are boundless would slowly erode under a heightened understanding of how political and economic factors mediate access to materials (through terms of trade, etc.), further this illusion of the bountiful and privilege certain groups, countries and regions at expense of others. Finally, the recognition of bounded economic growth holds much promise for bridging ecological and economic concerns.

The model of human ecosystems presented in this chapter acknowledges both environmental limits and the forces that structure human-environmental interactions through time. Research on small-scale societies (the idealized closed system) highlights how the properties of localized ecosystems condition and constrain human economic activity, and point to the role of cosmology, demographics (fertility, fecundity, infanticide) and technology (irrigation, medicine, etc.) in articulating these constraints within human society. The union of ecological and social theory makes it possible to show how the productive and consumptive potential of human ecosystems expands and contracts through technological advances and access to external inputs. It also demonstrates how human populations themselves suffer decline when extending beyond the limits of ecosystems at diverse scales, and how this unsustainable expansion of population or economic activity may compromise the “innate” potential of ecosystems to sustain future productive or extractive uses. In brief, it is an environmental paradigm that forces us to face head-on the limits to population growth and resource consumption.

BIBLIOGRAPHY

Acuña, Cristoval de
1859 New Discovery of the Great River of the Amazons. In *Expeditions into the Valley of the Amazons, 1539, 1540, 1639*, pp. 47-134. London: Hakluyt Society.

Alcorn, Janis B.
1989 Process as Resource: The Traditional Agricultural Ideology of Bora and Huastec Resource Management and its Implications for Research. In D.A. Posey and W. Balée (eds.), *Resource Management in Amazonia: Indigenous and Folk Strategies*. New York: New York Botanical Gardens.

Anderson, Anthony B. and Edviges M. Ioris
1992 Valuing the Rain Forest: Economic Strategies by Small-Scale Forest Extractivists in the Amazon Estuary. *Human Ecology* 20(3):337-369.

Anderson, Anthony B., Pennie Magee, Anne Gely and Mario Augusto Goncalves Jardim
1995 Forest Management Patterns in the Floodplain of the Amazon Estuary. *Conservation Biology* 9(1):47-61.

Anderson, Anthony B. And Darrell B. Posey
1989 Management of a Tropical Scrub Savanna by the Gorotire Kayapo of Brazil. In *Resource Management in Amazonia: Indigenous and Folk Strategies*, D.A. Posey and W. Balee (eds). New York Botanical Gardens (*Advances in Economic Botany* 7:159-173).

Anderson, J.M. and J.S.I. Ingram (eds)
1993 *Tropical Soil Biology and Fertility: A Handbook of Methods*, 2 ed. Wallingford, U.K.: CAB International.

Andreae, B.
1980 *The Economics of Tropical Agriculture*. Farnham, U.K.: Commonwealth Agricultural Bureaux.

Bailey, R.C., G. Head, M. Jenike, B. Owen, R. Rechtman and E. Zechenter
1989 Huntin and Gathering in Tropical Rain Forest: Is it Possible? *American Anthropologist* 91(1):59-82.

Balée, William
1992 People of the Fallow: A Historical Ecology of Foraging in Lowland South America. In *Conservation of Neotropical Forests*, Kent H. Redford and Christine Padoch (eds), pp. 35-57. New York: Columbia University Press.
1989 The Culture of Amazonian Forests. *Advances in Economic Botany* 7:1-21.

Balée, William (ed.)
1998 *Advances in Historical Ecology*. New York: Columbia University Press.

Balée, William and Anne Gély
1989 Managed Forest Succession in Amazonia: The Ka'apor Case. In *Resource Management in Amazonia: Indigenous and Folk Strategies*, D.A. Posey and W. Balée (eds.), pp. 129-158. New York: New York Botanical Garden.

Balée, William
1995 Historical Ecology of Amazonia. In *Indigenous Peoples and the Future of Amazonia: An Ecological Anthropology of an Endangered World*, L.E. Sponsel (ed.), pp. 97-110. Tucson: University of Arizona Press.
1989 Managed Forest Succession in Amazonia: The Ka'apor Case. *Advances in Economic Botany* 7:129-158. Evidence for the Successional Status of Liana Forest. *Biotropica* 22(1):36-47.

Balée, William and D.G. Campbell
1990 Evidence for the Successional Status of Liana Forest (Xingu River Basin, Amazonian Brazil). *Biotropica* 22(1):36-47.

Berlin, Brent
1992 *Ethnobiological Classification: Principles of Categorization of Plants and Animals in Traditional Societies*. Princeton: Princeton University Press.

Berlin, Brent, James Shilts Boster and John P. O'Neill
1992 The Perceptual Bases of Ethnobiological Classification: Evidence from Aguaruna Jívaro Ornithology. *Journal of Ethnobiology* 1(1):95-108.

Bernard, Russell H.
1994 *Research Methods in Anthropology: Qualitative and Quantitative Approaches*, 2 ed. Thousands Oaks: Sage Publications.

Boster, James
1983 A Comparison of the Diversity of Jivaroan Gardens with that of the Tropical Forest. *Human Ecology* 11(1):47-68.

Brinkman, W.K.F. and J.C. de Nascimento
1973 The Effect of Slash and Burn Agriculture on Plant Nutrients in the Tertiary Region of Central Amazonia. *Acta Amazonica* 3(1):55-61.

Brochado, J.P.
1980 Social Ecology of the Marajoara Culture. Unpublished paper cited by Myers 1992.
1977 *Alimentação na Floresta Tropical*. Caderno No. 2. Pôrto Alegre, Brazil: Universidade Federal do Rio Grande do Sul.

Brush, S.R.
1975 The Concept of Carrying Capacity for Systems of Shifting Cultivation. *American Anthropologist* 77(4):799-811.

Bunker, Stephen G.
1985 *Underdeveloping the Amazon: Extraction, Unequal Exchange, and the Failure of the Modern State*. Urbana: University of Illinois Press.

Buol, S.W., F.D. Hole and R.J. McCracken
1980 *Soil Genesis and Classification*. Ames: Iowa State University Press.

Buurman, P.
1984 Introduction, Part III: Organic Matter-Sesquioxide Interactions and the Dynamics of Podzolization. In *Podzols,* P. Buurman (Ed.), pp. 54-71. New York: Van Nostrand Reinhold Company Inc.

Carneiro, R.L.
1988 The Circumscription Theory. *American Behavioral Scientist* 31(4):497-511.
1985 Slash-and-Burn Cultivation among the Kuikuru and Its Implications for Cultural Development in the Amazon Basin. In *Adaptive Responses of Native Amazonians*, R.B. Hames and W.T. Vickers (eds.), pp. 65-111. New York: Academic Press.
1983 Cultivation of Manioc Among the Kuikuru. In *Adaptive Responses of Native Amazonians*, R.B. Hames and W.T. Vickers (eds), pp. 65-111. New York: Academic Press.

Chagnon, N. and R. Hames
1979 Protein Deficiency and Tribal Warfare in Amazonia: New Data. *Science* 203:910-13.

Chernela, Janet M.
1993 *The Wanano Indians of the Brazilian Amazon*. Austin: University of Texas Press.
1989 Managing Rivers of Hunger: The Tukano of Brazil. *Advances in Economic Botany* 7:238-248.

Chibnik, Michael
1994 *Risky Rivers: The Economics and Politics of Floodplain Farming in Amazonia*. Tucson: University of Arizona Press. 267 pp.

Clarke, W.C.
1971 *Place and People: An Ecology of a New Guinean Community*. Berkeley: University of California Press.

Clay, Jason W.
1988 *Indigenous Peoples and Tropical Forests: Models of Land Use and Management from Latin America*. Cultural Survival Report 27. Cambridge: Cultural Survival, Inc.

Conklin, Harold C.
1957 *Hanunoo Agriculture: A Report on an Integrated System of Shifting Cutivation in the Philippines*. FAO Forestry Development Paper no. 12. Rome: FAO.

Craib, I.
1992 *Anthony Giddens*. London: Routledge.

Crumley, Carole L.
1998 Forward. In *Advances in Historical Ecology*, William Balée (ed.), pp. 1-16. New York: Columbia University Press.
1993 Analyzing Historical Ecotonal Shifts. *Ecological Applications* 3(3):377-384.

Crumley, Carole L. (ed.)
1994 *Historical Ecology: Cultural Knowledge and Changing Landscapes*. Santa Fe: School of American Research Press.

D'Andrade, Roy
1995 *The Development of Cognitive Anthropology*. Cambridge and New York: Cambridge University Press.

Denevan, William M.
1996 A Bluff Model of Riverine Settlement in Prehistoric Amazonia. *Annals of the Association of American Geographers* 86(4):654-681.
1992 Stone vs. Metal Axes: The Ambiguity of Shifting Cultivation in Prehistoric Amazonia. *Journal of the Steward Anthropological Society* 20:153-165.
1976 The Aboriginal Population of Amazonia. In *The Native Population of the Americas in 1492*, W. Denevan (ed.), pp. 205-234. Madison: University of Wisconsin Press.

Denevan, William M. and Christine Padoch (eds)
1987 *Swidden-Fallow Agroforestry in the Peruvian Amazon*. Advances in Economic Botany, Vol. 5. New York: New York Botanical Garden.

Descola, Philippe
1995 *In the Society of Nature: A Native Ecology in Amazonia*. Cambridge and New York: Cambridge University Press.

Despres, Leo A.
1991 *Manaus: Social Life and Work in Brazil's Free Trade Zone*. Albany: State University of New York Press.

Dirks, Nicholas B., Geoff Eley and Sherry B. Ortner (eds.)
1994 *Culture/Power/History: A Reader in Contemporary Social Theory*. Princeton: Princeton University Press.

Eden, Michael J., Warwick Bray, Leonor Herrera and Colin McEwan
1984 Terra Preta Soils and their Archaeological Context in the Caquetá Basin of Southeast Colombia. *American Antiquity* 49(1):125-140.

Eidt, Robert C.
1977 Detection and Examination of Anthrosols by Phosphate Analysis. *Science* 197(4311):1327-33.

Emmons, Louise H. and François Feer
1990 *Neotropical Rainforest Mammals: A Field Guide*. Chicago: University of Chicago Press.

Falesi, Italo Claudio
1972 O Estado Atual dos Conhecimentos Sobre os Solos da Amazônia Brasileira. Zoneamento Agrícola da Amazônia (1a Aproximaçao). *Boletím Técnico do Instituto de Pesquisa Agropecuaria do Norte* 54:17-67.

Ferreira Reis, Arthur Cézar
1906 *História do Amazonas*. Manaus: Editora Itatiaia Limitada.

Forman, Richard T.T. and Michel Godron
1986 *Landscape Ecology*. New York: John Wiley and Sons.

Francis, Charles A. (editor)
1986 *Multiple Cropping Systems*. New York: MacMillan Publishing Co.

Frechione, J., D.A. Posey and L.F.da Silva
1989 The Perception of Ecological Zones and Natural Resources in the Brazilian Amazon: An Ethnoecology of Lake Coari. *Advances in Economic Botany* 7:260-282.

Frikel, P.
1959 Agricultura dos Índios Mundurukú. *Antropologia* (*Boletím do Museu Paraense Emílio Goeldi*) 4:1-35.

Giddens, Anthony
1984 *The Constitution of Society: Outline of the Theory of Structuration*. Berkeley: University of California Press.

Gladwin, Christina H.
1988 Indigenous Knowledge Systems, The Cognitive Revolution, and Agricultural Decision-Making. *Agriculture and Human Values*: 32-41.

Golley, Frank Benjamin
1993 *A History of the Ecosystem Concept in Ecology: More Than the Sum of the Parts.* New Haven: Yale University Press.

Good, Kenneth R.
1987 Limiting Factors in Amazonian Ecology. In *Food and Evolution*, Harris and Ross (eds), pp. 407-421. Philadelphia: Temple University Press.

Goulding, Michael, Mirian Leal Carvalho and Efrem G. Ferreira
1988 *Rio Negro, Rich Life in Poor Water*. The Hague: SPB Academic Publishing.

Grace, M.R.
1977 *Cassava Processing*. Rome: FAO.

Gragson, Ted L.
1993 Human Foraging in Lowland South America: Pattern and Process of Resource Procurement. *Research in Economic Anthropology* 14:107-138.

Graham, Elizabeth
1999 1998 Metaphor and Metamorphism: Some Thoughts on Environmental Metahistory. In *Advances in Historical Ecology*, William Balée (ed.), pp. 119-140. New York: Columbia University Press.

Gross, D.
1975 Protein Capture and Cultural Development in the Amazon Basin. *American Anthropologist* 77:526-49.

Hames, Raymond
1983 Monoculture, Polyculture, and Polyvariety in Tropical Forest Swidden Cultivation. *Human Ecology* 11(1):13-34.

Harris, D.R.
1971 The Ecology of Swidden Cultivation in the Upper Orinoco Rain Forest, Venezuela. *The Geographical Review* 61(4):475-495.

Hastorf, Christine A.
1990 The Ecosystem Model and Long-Term Prehistoric Change: An Example from the Andes. In *The Ecosystem Approach to Anthropology: From Concept to Practice*, Emilio Moran (ed.). Ann Arbor: University of Michigan Press.

Hawken, Paul, Amory Lovins and L. Hunter Lovins
1999 *Natural Capitalism*. Boston: Little, Brown and Company.

Headland, Thomas N.
1988 The Wild Yam Question: How Well Could Independent Hunter-Gatherers Live in a Tropical Rain Forest Ecosystem? *Human Ecology* 15(4):463-491.

Hecht, Susanna B. and Darrell A. Posey
1989 Preliminary Results on Soil Management Techniques of the Kayapó Indians. *Advances in Economic Botany* 7:174-188.

Heckenberger, M.J., J.B. Petersen and E.G. Neves
1999 Village Size and Permanence in Amazonia: Two Archaeological Examples from Brazil. *Latin American Antiquity* 10(4):353-376.

Henderson, Andrew
1995 *Palms of the Amazon*. New York: Oxford University Press.

Henderson, Andrew, Gloria Galeano and Rodrigo Bernal
1995 *Palms of the Americas*. Princeton: Princeton University Press.

Herrera, Luisa Fernanda, Inés Cavelier, Camilo Rodriquez and Santiago Mora
1992 The Technical Transformation of an Agricultural System in the Columbian Amazon. *World Archaeology* 24(1):98-113.

Herrera, Rafael
1985 Nutrient Cycling in Amazonian Forests, Ch. 6. In *Amazonia*, Ghillean T. Prance and Thomas E. Lovejoy (eds), pp. 95-105. Oxford: Pergamon Press.

Holland, Dorothy and Naomi Quinn
1987 *Cultural Models in Language and Thought*. New York: Cambridge University Press.

Holleman, L.W.J. and A. Aten
1956 *Processing of Cassava and Cassava Products in Rural Industries*. Rome: FAO.

Irvine, Dominique
1989Succession Management and Resource Distribution in an Amazonian Rain Forest. *Advances in Economic Botany* 7:223-237.

Jenny, H.
1941 *Factors of Soil Formation: A System of Quantitative Pedology*. New York: McGraw-Hill.

Johnson, Allen
1974 Ethnoecology and Planting Practices in a Swidden Agricultural System. *American Ethnologist* 1(1):87-102.

Jordan, Carl F.
1989 *An Amazonian Rainforest: The Structure and Function of a Nutrient Stressed Ecosystem and the Impact of Slash and Burn Agriculture*. UNESCO and the Parthenon Publishing Group.
1985a Productivity and Nutrient Dynamics During Slash-and-Burn Agriculture, Ch. 5. In *An Amazonian Rainforest: The Structure and Function of a Nutrient Stressed Ecosystem and the Impact of Slash-and-Burn Agriculture*, Vol. 2, Man and the Biosphere Series, pp. 69-92. UNESCO and The Parthenon Publishing Group.

1985b Soils of the Amazon Rainforest. In *Amazonia*, Ghillean T. Prance and Thomas E. Lovejoy (eds), pp. 83-94. Oxford: Pergamon Press.

Kass, D.C.L. and E. Somarriba
1999 Traditional Fallow in Latin America. *Agroforestry Systems* 47:13-36.

Kern, Dirse Clara
1988 *Caracterizaçao Pedológica de Solos com Terra Preta Arqueólogica na Regiao de Oriximiná-Pará*. Master's Thesis in Soils. Porto Alegre: Universidade Federal do Rio Grande do Sul.

Klinge, H.
1967 Podzol Soils: A Source of Blackwater Rivers in Amazonia. Conselho Nacional de Pesquisa, *Liminologia* 3:117-25.

Krantz, B.A.
1974 *Cropping Patterns for Increasing and Stabilizing Agricultural Production in the Semi-Arid Tropics*. Hyderabad, India: International Workshop on Farming Systems. ICRISAT.

Lathrap, Donald W.
1970 *The Upper Amazon*. New York: Praeger.

Leonardi, Victor
1996 *Entre Árvores e Esquecimentos: História Social nos Sertões do Brasil.* Brasília: Editora Universidade de Brasília.

Macedo, Domingo S. and Anthony B. Anderson
1993 Early Ecological Changes Associated with Logging in an Amazonian Floodplain. *Biotropica* 25(2):151-163.

Magdoff, Fred
1992 *Building Soils for Better Crops*. Lincoln: University of Nebraska Press.

McCann, Joseph M.
1999 Before 1492: The Making of the Pre-Columbian Landscape (Part I: The Environment). *Ecological Restoration* 17:1(15-30).

McCann, J.M., W.I. Woods and D.W. Meyer
2000 Organic Matter and Anthrosols in Amazonia: Interpreting the Amerindian Legacy. In *Sustainable Management of Soil Organic Matter*, R.M. Rees, B.C. Ball, C.D. Campbell and C.A. Watson (eds.), pp. 180-189. CAB International.

Meggers, Betty J.
1971 Amazonia: Man and Culture in a Counterfeit Paradise. Chicago: Aldine.

Mora, C.S., L.F. Herrera, I. Cavelier F. and C. Rodriguez
1990 *Cultivars, Anthropic Soils and Stability: A Preliminary Report of Archaeological Research in Araracuara, Colombian Amazonia*. Latin American Archaeology Reports, No. 2. Pittsburgh: University of Pittsburgh.

Moran, Emilio F.
1994 *Through Amazonian Eyes: The Human Ecology of Amazonian Populations*. Iowa City: University of Iowa Press.
1991 Human Adaptive Strategies in Amazonian Blackwater Ecosystems. *American Anthropologist* 93:361-82.
1989 Models of Native and Folk Adaptation in the Amazon. *Advances in Economic Botany* 7:22-29. The New York Botanical Garden.
1982 *Human Adaptability: An Introduction to Ecological Anthropology*. Boulder: Westview Press.

Myers, Thomas P.
1992 Agricultural Limitations of the Amazon in Theory and Practice. *World Archaeology* 24:82-97.

Naveh, Zev and Arthur S. Lieberman
1984 *Landscape Ecology: Theory and Application*. New York: Springer-Verlag.

Netting, Robert
1990 Links and Boundaries: Reconsidering the Alpine Village Ecosystem. In *The Ecosystem Approach to Anthropology: From Concept to Practice*, Emilio Moran (ed.). Ann Arbor: University of Michigan Press.

Nimuendaju, Curt
1955 Reconhecimento dos Rios Içana, Ayari e Uaupés. *Journal de la Société des Américanistes* 64:149-78.

Norman, M.J.T.
1979 *Annual Cropping Systems in the Tropics*. Gainesville: University Presses of Florida.

Nye, P.H. and D.J. Greenland
1964 Changes in the Soil After Clearing Tropical Forest. *Plant and Soil* 21(1):101-112.
1960 *The Soil Under Shifting Cultivation*. Harpenden, England: Commonwealth Bureau of Soils. Technical Communication no. 51.

Obert, Edward Frederic
1963 *Thermodynamics*. New York: McGraw-Hill.

Odum, Howard T.
1957 Trophic Structure and Productivity of Silver Springs, Florida. *Ecological Monographs* 27:55-112.

Odum, Howard T. and Richard C. Pinkerton
1955 Time's Speed Regulator: The Optimum Efficiency for Maximum Power Output in Physical and Biological Systems. *American Scientist* 43:331-43.

Ortner, Sherry
1984 Theory in Anthropology Since the Sixties. *Comparative Studies in Society and History* 26(1):126-166.

Ozorio de Almeida, A.L.
1990"The Economic Dynamic of Colonization"; "The Expansion of the Market". In *The Colonization of the Amazon*, pp. 129-146; 121-128. Austin: The University of Texas Press.

Pabst, Erich
1991 Critérios de Distinçao entre Terra Preta e Latossolo na Regiao de Belterra e os Seus Significados para a Discussao Pedogenética. *Boletim do Museu Paraense de História Natural e Etnografia* 7(1):5-19.

Padoch, Christine and Wil de Jong
1991 Diversity, Variation and Change in Ribereño Agriculture. In Kent H. Redford and Christine Padoch (eds), *Conservation of Neotropical Forests*. New York: Colombia University Press.

Palmatary, Helen C.
1960 The Archaeology of the Lower Tapajós Valley, Brazil. *Transactions of the American Philosophical Society* 50(3).

Parker, Eugene
1989 A Neglected Human Resource in Amazonia: The Amazon Caboclo. In *Resource Management in Amazonia: Indigenous and Folk Strategies*, D.A. Posey and W. Balée (eds.). New York Botanical Gardens (*Advances in Economic Botany* 7:249-259).

Patten, Bernard C.
1958 An Introduction to the Cybernetics of the Ecosystem: The Trophic-Dynamic Aspect. *Ecology* 40:221-31.

Peters, J. and Leon F. Neuenschwander
1988 *Slash and Burn Farming in the Third World*. Moscow, Idaho: University of Idaho Press.

Porro, Antônio
1992 História Indígena do Alto e Médio Amazonas: Séculos XVI a XVIII. In *História dos Índios no Brasil*, pp. 175-196. São Paulo: Companhia das Letras.
1987 O Antigo Comércio Indígena na Amazônia. *Diario Leitura* 5(56):2-3.

Posey, Darrell Addison
1985 Indigenous Management of Tropical Forest Ecosystems: The Case of the Kayapo Indians of the Brazilian Amazon. *Agroforestry Systems* 3:139-158.
1982 Nomadic Agriculture of the Amazon. *Garden* 6(1):18-24. New York: The New York Botanical Gardens.

Ramakrishnan, P.S.
1992 *Shifting Agriculture and Sustainable Development: An Interdisciplinary Study from North-Eastern India*. Man and the Biosphere Series, Vol. 10. Paris: UNESCO.

Ramakrishnan, P.S. and O.P. Toky
1982 Soil Nutrient Status of Hill Agro-ecosystems and Recovery Pattern after Slash and Burn Agriculture. *Plant and Soil* 60:41-64.

Rappaport, Roy
1967 *Pigs for the Ancestors: Ritual in the Ecology of a New Guinea People*. New Haven: Yale University Press.

Reichel-Dolmatoff, Gerardo
1985 Tapir Avoidance in the Colombian Northwest Amazon. In *Animal Myths and Metaphors in South America*, G. Urton (ed.), pp. 107-143. Salt Lake City: University of Utah Press.

Ribeiro, Berta
1995 *Os Índios das Águas Pretas*. São Paulo: Companhia das Letras - Editora da Universidade de São Paulo.

Rival, Laura
2000 Domestication as a Historical and Symbolic Process: Wild Gardens and Cultivated Forests in the Ecuadorian Amazon. In *Advances in Historical Ecology*, William Balée (ed.), pp. 232-250. New York: Columbia University Press.

Riviere, Peter
1984 *Individual and Society in Guiana*. Cambridge: Cambridge University Press.

Rode, A.A.
1962 Soil Science (Pochvovedeniye). (A. Gourevich, translator) Israel Prog. For Sci. Trans., Jerusalem. Washington: U.S. Department of Commerce.

Roosevelt, Anna C.
1998 Ancient and Modern Hunter-Gatherers of Lowland South America: An Evolutionary Problem. In *Advances in Historical Ecology*, William Balée (ed.), pp. 190-212. New York: Columbia University Press.
1992 Arqueologia Amazônica. In *História dos Índios no Brasil*, pp. 53-86. São Paulo: Companhia das Letras.

1980 Parmana: Prehistoric Maize and Manioc Subsistence Along the Amazon and *Orinoco*. New York: Academic Press.

Roosevelt, Anna C. et al.
1996 Paleoindian Cave Dwellers in the Amazon: The Peopling of the Americas. *Science* 272:373-384.

Rose Innes, R.
1972 Fire in West African Vegetation. In Proceedings, 11th Annual Tall Timbers Fire Ecology Conference, pp. 147-173. Tallahasse, Florida.

Ruddle, K.
1974 *The Yukpa Cultivation System: A Study of Shifting Cultivation in Colombia and Venezuela*. Berkeley: University of California Press.

Rudel, Thomas K. and Horowitz, Bruce
1993 *Tropical Deforestation: Small Farmers and Land Clearing in the Ecuadorian Amazon*. New York: Columbia University Press.

Runge, E.C.A.
1973 Soil Development Sequences and Energy Models. *Soil Science* 115(3):183-193.

Ruthenberg, Hans
1980 *Farming Systems in the Tropics*. Oxford: Clarendon Press.

Salgado Vieira, Lúcio
1988 *Manual da Ciência do Solo* (2nd ed.). São Paulo: Editora Agronômica Ceres Ltda.

Salgado Vieira, L. and J.P.S. Oliveira Filho
1962 As Caatingas do Rio Negro. *Boletím Técnico IAN* 42:1-32.

Sanchez, P.A.
1976 *Properties and Management of Soils in the Tropics*. New York: John Wiley and Sons.

Sanchez, Pedro A., Dale E. Bandy, J. Hugo Villachica, and John J. Nicholaides
1982 Amazon Basin Soils: Management for Continuous Crop Production. *Science* 216:821-827.

Schmink, Marianne and Charles H. Wood
1992 *Contested Frontiers in Amazonia*. New York: Columbia University Press.

Simonson, R.W.
1959 Outline of a Generalized Theory of Soil Genesis. *Soil Sci. Soc. Am. Proc.* 23:152-156.

Sioli, H. (ed.)
1984 *The Amazon: Limnology and Landscape Ecology of a Mighty Tropical River Basin*. Dordrecht: Dr. W. Junk.

Smith, Nigel
1980 Anthrosols and Human Carrying Capacity inAmazonia. *Annals of the Association of American Geographers* 70:553-566.

Smole, W.J.
1993*The Yanomama Indians: A Cultural Geography*. Austin: University of Texas Press.

Sombroeck, William
1966 *Amazon Soils: A Reconnaissance of the Soils of the Brazilian Amazon Region*. Wageningen: Center for Agricultural Publications and Documentation.

Spaargaren, O.C. (ed.)
1994 *World Reference Base for Soil Resources*. Rome: Wageningen.

Steward, Julian H.
1949 South American Cultures: An Interpretive Summary. Washington: Bureau of American Ethnology. *Bulletin* 143(5):669-772.
1948 The Tropical Forest Tribes. In: *Handbook of South American Indians*, vol. 3. Bulletin No. 143, J. Steward (ed.). Washington, D.C.: Bureau of American Ethnology, Smithsonian Institution.

Stocks, Anthony
1983 Cocamilla Fishing: Patch Modification and Environmental Buffering in the Amazon. In *Adaptive Responses of a Native Amazonians,* ed. Raymond B. Hames and William T. Vickers, pp. 239-267. New York: Academic Press.

Thompson, J.B.
1989 The Theory of Structuration. In *Social Theory of Modern Societies: Anthony Giddens and Critics*, D. Held and J.B. Thompson (eds.), pp. 56-76. Cambridge: Cambridge University Press.

Uhl, Christopher et. al.
1990 Studies of Ecosystem Response to Natural and Anthropogenic Disturbances Provide Guidelines for Designing Sustainable Land-Use Systems in Amazonia. In *Alternatives to Deforestation: Steps Toward Sustainable Use of the Amazon Rain Forest*, Anthony B. Anderson (ed). New York: Colombia University Press.

van Raij, Bernardo
1991 *Fertilidade do Solo e Adubação*. São Paulo: Editora Agronômica Ceres Ltda.

Vásquez de Espinosa, Antonio
1946 *Compendio y Descripción de las Indias Occidentales* [1630]. Washington: Smithsonian Miscellaneous Collections, Vol. 108.

Vayda, Andrew P.
1974 Warfare in Ecological Perspective. *Annual Review of Ecology and Systematics* 5:183-193.

Viveiros De Castro, Eduardo
1992 *From the Enemy's Point of View*. Chicago: The University of Chicago Press.

Wagley, C.
1977 *Welcome of Tears: The Tapirape Indians of Central Brazil*. New York: Oxford University Press.

Whitehead, Neil
1993 Ethnic Transformation and Historical Discontinuity in Native Amazonia and Guayana, 1500-1900. *L'Homme* 126-128, XXXIII(2-4):285-305.

Wight, Colin
1998 They Shoot Dead Horses, Don't They? Locating Agency in the Agent-Structure Problematique. *European Journal of International Relations* 5(1):109-142.

Wilk, Richard R.
1991 Household Ecology: Decision-Making and Resource Flows. In *The Ecosystem Approach to Anthropology: From Concept to Practice*, Emilio Moran (ed.), pp. 323-356. Ann Arbor: University of Michigan Press.

Williams, C.N.
1975 *The Agronomy of the Major Tropical Crops*. Oxford: Oxford University Press.

Williamson, James A.
1923 *English Colonies in Guiana and on the Amazon 1604-1668*. Oxford: Clarendon Press.

Wilmott, Robert
1977 Structure, Culture and Agency: Rejecting the Current Orthodoxy of Organisation Theory. *Journal for the Theory of Social Behavior* 27:1(93-123).

Wilson, J. Bastow and Warren McG. King
1994 Human-Mediated Vegetation Switches as Processes in Landscape Ecology. *Landscape Ecology* 10(4):191-196.

Winterhalder, Bruce
1995 Concepts in Historical Ecology: The View From Evolutionary Theory. In *Historical Ecology: Cultural Knowledge and Changing Landscapes*, Carole Crumley (ed.), pp. 17-42. Santa Fe: School for American Research Press.

Wood, Charles H. and John Wilson
1984 The Magnitude of Migration to the Brazilian Frontier. In *Frontier Expansion in Amazonia*, Marianne Schmink and Charles H. Wood (eds), pp. 142-152. Gainesville: University of Florida Press.

Woods, W.I.
1995 Comments on the Black Earths of Amazonia. F. Andrew (Editor), *Schoolmaster Papers and Proceedings of the Applied Geography Conferences* 18:159-165.

Woods, William I., Joseph M. McCann and Donald W. Meyer
2000 Amazonian Dark Earth Analysis: State of Knowledge and Directions for Future Research. *Papers and Proceedings of the Applied Geography Conferences* 23:114-121.
1998 The Living Soils of Amazonia. Manuscript onfile, Department of Georgraphy, Southern Illinois University, Edwardsville.

Woods, W.I. and J.M. McCann
1999 The Anthropogenic Origin and Persistence of Amazonian Dark Earths. *The Yearbook of the Conference of Latin Americanist Geographers* 25:7-14.

Wright, Robin
1992 História Indígena do Noroeste da Amazônia: Hipóteses, Questões e Perspectivas. In *História dos Índios no Brasil*, pp. 253-266. São Paulo: Companhia das Letras.

Young, A.
1997 *Agroforestry for Soil Management*. CAB International, New York.

Zech, W., L. Haumaier and R. Hempfling
1990 Ecological Aspects of Soil Organic Matter in Tropical Land Use. In *Humic Substances in Soil and Crop Sciences: Selected Readings,* P. MacCarthy, C.E. Clapp, R.L. Malcolm and P.R. Bloom (eds.). American Society of Agronomy and the Soil Science Society of America, Madison, pp. 187-202.

Appendix A:

Soil Fertility Assays

The following laboratory analyses were carried out on soil samples collected from the study region for fertility and pedological analyses:

Measure	Method
pH	Electrode determination in water
Plant-Available Phosphorus (PO_3^-)	Mehlich II
Exchangeable Potassium (K^+)	Mehlich II
Exchangeable Sodium (Na^+)	Mehlich II
Exchangeable Magnesium (Mg^{++})	Official EMBRAPA method
Exchangeable Calcium (Ca^{++})	Official EMBRAPA method
Exchangeable Aluminum (Al^{+++})	Official EMBRAPA method
Total C	LECO analyzer, C analyzer
Total N	LECO analyzer
Effective Cation Exchange Capacity	Standard calculation
Base Saturation	Standard calculation
Soil Texture	Official EMBRAPA method

A description of these methods follows:

Soil pH (pH_{water}, pH_{KCl}) was determined using a 1:2.5 soil-to-solution ratio (deionized water and 1M KCl, respectively) and electrode determination.

Plant-available phosphorus (AP) was determined by the Mehlich II method (CITE), with a 0.025 N H_2SO_4 and 0.05 N HCl extractant. The determination was done colorimetrically, using ammonium molibdate and ascorbic acid for color development and standard P solutions for interpretation.

Exchangeable potassium (EK) ***and sodium*** (AN) were determined with a 0.025 N H_2SO_4 and 0.05 N HCl extractant. Determination was carried out using a flame photometer and standard solutions for interpretation.

Exchangeable magnesium (EM), ***calcium*** (EC) ***and aluminum*** (EA) were determined using a 1 N KCl extractant. For Al determination, a Bromotimol Blue indicator at 0.1% was used, followed by a 0.025 N NaOH titration. For Ca and Mg determination, 10 ml of 0.1 % La_2O^3 was added to 1 ml of soil solution, and readings taken on a ....

Total carbon (TC) ***and nitrogen*** (TN) were determined using a LECO. Supplementary TC readings were carried out on a Carbon analyzer.

Soil texture was determined …

Effective Cation Exchange Capacity (ECEC) was calculated by taking the sum of exchangeable cations, as indicated in the following equation:

ECEC = (Ca + Mg + K + Na)

Base Saturation (BS) was determined by calculating the percentage of the ECEC resulting from the sum total of exchangeable cations, as indicated in the following equation:

BS = 100 x [(Ca + Mg + K + Na)/(Ca + Mg + K + Na + Al)]

References Cited

Bowman, R.A.
1988 A Rapid Method to Determine Total Phosphorus in Soils. *Soil Science Society of America Journal* 52:1301-1304.

Appendix B:

ETHNOPEDOLOGICAL DATA

I. Ethnopedological Knowledge

Table B-1. Ethnopedological Knowledge: Soil Class Attributes

Domain Characteristics:	**% of Individuals, *T. Preta***				**% of Individuals, *T. Comum***			
	No	**Yes**	**Some-times**	**Some-what**	**No**	**Yes**	**Some-times**	**Some-what**
Clayey	83.3	8.3	8.3	0.0	30.0	30.0	40.0	0.0
Sandy	33.3	50.0	16.7	0.0	40.0	10.0	40.0	10.0
Black	0.0	100.0	0.0	0.0	100.0	0.0	0.0	0.0
Yellow	100.0	0.0	0.0	0.0	0.0	25.0	0.0	75.0
Red	100.0	0.0	0.0	0.0	0.0	75.0	0.0	25.0
Weak	91.7	8.3	0.0	0.0	10.0	40.0	20.0	30.0
Strong	8.3	83.3	8.3	0.0	60.0	10.0	20.0	10.0
Strong (worked)	50.0	8.3	8.3	33.3	90.0	0.0	10.0	0.0
Weak (worked)	25.0	41.7	16.7	16.7	10.0	80.0	10.0	0.0
Raw	58.3	41.7	0.0	0.0	0.0	100.0	0.0	0.0
Burnt	41.7	58.3	0.0	0.0	100.0	0.0	0.0	0.0
Sticky	58.3	16.7	25.0	0.0	40.0	20.0	40.0	0.0
Loose	8.3	66.7	25.0	0.0	30.0	20.0	30.0	20.0
Dry	50.0	33.3	8.3	8.3	30.0	40.0	20.0	10.0
Retains moisture	33.3	50.0	8.3	8.3	20.0	40.0	40.0	0.0
Shallow	25.0	50.0	8.3	8.3	80.0	10.0	10.0	0.0
Deep	58.3	25.0	8.3	0.0	10.0	80.0	10.0	0.0
Changes with depth	25.0	75.0	0.0	0.0	60.0	20.0	20.0	0.0
Hot	25.0	50.0	16.7	8.3	20.0	40.0	20.0	10.0
Cold	58.3	16.7	16.7	8.3	50.0	20.0	20.0	0.0
Thick	58.3	25.0	16.7	0.0	20.0	40.0	40.0	0.0
Soft/light	8.3	75.0	16.7	0.0	40.0	20.0	40.0	0.0
Hard	83.3	0.0	16.7	0.0	40.0	20.0	40.0	0.0
Fibrous/matted	91.7	0.0	0.0	0.0	20.0	40.0	20.0	0.0
Wild	50.0	8.3	0.0	0.0	40.0	10.0	10.0	0.0
Fertilized	8.3	91.7	0.0	0.0	90.0	0.0	0.0	10.0
Natural	25.0	75.0	0.0	0.0	0.0	100.0	0.0	0.0
Friable	8.3	75.0	16.7	0.0	30.0	10.0	50.0	0.0
Sticks	58.3	16.7	25.0	0.0	30.0	10.0	60.0	0.0
Slippery/smooth	75.0	16.7	8.3	0.0	30.0	20.0	50.0	0.0
Produces everything	16.7	83.3	0.0	0.0	80.0	0.0	10.0	10.0
Rocky	50.0	8.3	33.3	8.3	30.0	10.0	60.0	0.0
Heavy	25.0	66.7	8.3	0.0	20.0	20.0	40.0	20.0
Does Soil X 'have life'?	0.0	91.7	0.0	8.3	0.0	90.0	0.0	10.0
Does water infiltrate quickly on Soil X?	0.0	75.0	16.7	8.3	20.0	30.0	30.0	20.0
Does Soil X maintain its humidity?	50.0	33.3	0.0	16.7	40.0	40.0	0.0	10.0
Dries quickly?	8.3	58.3	16.7	0.0	20.0	30.0	20.0	20.0
Does the night's dew moisten Soil X?	33.3	58.3	0.0	8.3	20.0	30.0	10.0	40.0
Does the night's dew cool Soil X?	8.3	66.7	0.0	8.3	10.0	60.0	0.0	10.0

Table B-2. Ethnopedological Knowledge: Management and Production Characteristics

Questions:	**% of Individuals, *T. Preta***				**% of Individuals, *T. Comum***			
	No	**Yes**	**Some-times**	**Some-what**	**No**	**Yes**	**Some-times**	**Some-what**
Does Soil X require much labor?	8.3	91.7	0.0	0.0	50.0	0.0	20.0	30.0
Does Soil X produce much 'abundance'?	0.0	83.3	16.7	0.0	50.0	10.0	20.0	20.0
Is it labor-intensive to weed Soil X?	8.3	83.3	0.0	8.3	60.0	20.0	10.0	0.0
…on Soil X that was mature forest?	8.3	8.3	0.0	8.3	100.0	0.0	0.0	0.0
…on Soil X that was fallowed?	8.3	91.7	0.0	0.0	20.0	50.0	10.0	20.0
Is it labor-intensive to slash [the vegetation on] Soil X?	0.0	83.3	0.0	8.3	50.0	0.0	20.0	10.0
Is it labor-intensive to fell the forest on Soil X?	75.0	8.3	0.0	0.0	0.0	90.0	0.0	10.0
Are there differences in soil strength within a Soil X swidden?	50.0	41.7	8.3	0.0	10.0	90.0	0.0	0.0
Are crops on Soil X seasonal?	25.0	66.7	0.0	0.0	40.0	60.0	0.0	0.0
Do crops grow quickly on Soil X?	0.0	83.3	8.3	8.3	80.0	10.0	0.0	10.0
Are there many pests/diseases on Soil X?	16.7	58.3	25.0	0.0	50.0	30.0	20.0	0.0
Does Soil X have problems with the 'strong look'/evil eye?	16.7	75.0	8.3	0.0	40.0	40.0	20.0	0.0
On Soil X, is it necessary to plant with the moon?	41.7	58.3	0.0	0.0	30.0	60.0	0.0	0.0
Is it necessary to use the 'coivara' with Soil X?	16.7	58.3	16.7	0.0	10.0	60.0	20.0	0.0
Is it necessary to use the burn on Soil X?	16.7	66.7	8.3	0.0	0.0	90.0	0.0	0.0
Can you burn Soil X in the winter?	25.0	33.3	25.0	8.3	70.0	10.0	10.0	0.0
Does raw Soil X produce well?	50.0	33.3	0.0	8.3	90.0	10.0	0.0	0.0
Does burnt Soil X do well?	8.3	83.3	0.0	0.0	0.0	90.0	10.0	0.0
Does Soil X maintain its strength after the burn?	8.3	83.3	0.0	8.3	20.0	40.0	0.0	40.0
Does Soil X fully recuperate through fallowing?	0.0	91.7	0.0	8.3	20.0	50.0	20.0	0.0
When Soil X 'weakens', does it always produce?	16.7	50.0	16.7	16.7	50.0	30.0	10.0	10.0
When Soil X 'weakens', does it recuperate quickly?	8.3	83.3	0.0	8.3	90.0	0.0	0.0	10.0
Does Soil X tire quickly?	50.0	25.0	8.3	16.7	20.0	60.0	20.0	0.0
Does Soil X economize fertilizer?	0.0	66.7	0.0	0.0	20.0	20.0	0.0	10.0
Does Soil X produce many weeds/'close' quickly?	8.3	91.7	0.0	0.0	40.0	10.0	40.0	0.0

Table B-3. Ethnopedological Knowledge: Multiple Choice Management Behavior

	Terra Preta				Terra Comúm/Amarela			
Multiple Choice Management Questions:	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**
1) For Soil X to produce more, after weeding you should:	8.33	50.00	41.67	0.00	10.00	40.00	50.00	0.00
2) To maintain the 'strength' of Soil X, after weeding you should:	8.33	8.33	83.33	0.00	10.00	20.00	70.00	0.00
3) For Soil X to produce more, when it begins to 'weaken' you should:	33.33	16.67	41.67	8.33	80.00	10.00	10.00	0.00
4) To maintain the 'strength' of Soil X, when it begins to 'weaken' you should:	50.00	29.17	8.33	12.50	90.00	0.00	0.00	10.00
5) When you abandon a swidden on Soil X, it is because:	50.00	16.67	33.33	0.00	85.00	5.00	10.00	0.00
6) For Soil X to produce more, after felling the forest you should:	72.73	27.27	0.00	0.00	50.00	50.00	0.00	0.00
7) To maintain the 'strength' of Soil X, after felling the forest you should:	45.00	25.00	30.00	0.00	44.44	22.22	33.33	0.00
Averages:	*38.25*	*24.73*	*34.05*	*2.98*	*52.78*	*21.03*	*24.76*	*1.43*
Ranking: Which soil 'improves livelihood' the most?	1.00				2.00			
Open-ended Question: Fallow vegetation on Soil X 'closes in' after how many years?	1.83				3.61			

Key:

Qts. 1,2. A= remove all residues from the swidden, B= burn residues, C= weed and leave residues in place.

Qts. 3,4. A= let the fallow vegetation grow high, B= let the fallow vegetation grow a bit and then burn it, C= use chemical fertilizer, D= use organic fertilizer.

Qt. 5. A= the soil was 'tired', B= it 'closed in' a lot (too many weeds), C= other reason.

Qts. 6,7. A= burn and plant, B= burn, let the fallow vegetation grow, burn again and plant, C= remove the large slash and plant without burning?

II. Soil Classification Data

Table B-4. Saliency of Distinct Soil Classes and Descriptors, Lower Negro and Urubú Rivers

Level One Term [basis for level 2 differentiation]	**Level Two Term**	**Individuals** #	%
Terra Preta		***12***	***100***
[texture]	Areiusca Barrenta	5 5	42 42
[color]	Legítima/Mais Preta Misturada/Avermelhada/Arroxeada Barro Preto	3 3 1	25 25 8
Barro Vermelho/Roxo		7	92
[friability]	Escaldado/Maçapé Macío	2 2	25 25
[color]	Branquecento Bem vermelha	1 1	8 8
Terra Amarela/Vermelha		6	50
[texture/prototype]	Areiusca Legítima/Barrenta	3 3	25 25
Terra Areiusca		4	33
	None	-	
Terra da Várzea		3	25
	None	-	
Terra Comúm		2	17
[texture/prototype]	Barrenta Areiusca Avermelhada meia solta/legítima	2 2 1	17 17 8
Terra Roxa		2	17
	None	-	
Terra Barrenta		1	8
[color]	Bem vermelha Meia escura ou suja Misturada com areia	1 1 1	8 8 8

[a] The terminology and level of differentiation of Black Earth are identified in italicized bold type to demonstrate the most important distinctions between conceptualizations of this soil class in each region.

Table B-5. Saliency of Distinct Soil Classes and Descriptors, Santa Isabel Region (Rio Negro)

Level One Term [basis for level 2 differentiation]	**Level Two Term**	**Individuals** #	%
Iví Pixuna/Areia Preta (Black Earth/Sand)		***4***	***50***
[color/protoypicality – 3[a]]	Legítima/Mais Preta Misturada/Avermelhada/Arroxeada	3 3	38 38
Iví Cuí/Praia		7	88
[color – 3]	**Iví Pixuna** Iví Murutinga/Branca Amarela/Avermelhada	***3*** 3 2	***38*** 38 25
Tuyuka/Barro		5	63
[color - 2]	Roxeado Amarelado Vermelho Barro meio preto	1 1 2 1	13 13 25 13
[texture - 1]	Barro puro Barro misturado com areia	1 1	13 13
Iví Tauá		5	63
	None		
Barro Branco		2	25
	None		

[a] Numbers refer to the number of individuals who differentiate on the basis of bracketed criteria.

Table B-6. Saliency of Distinct Soil Classes and Descriptors, Rio Canoas

Level One Term [basis for level 2 differentiation]	A. Level Two Term	**Individuals** #	%
Terra Preta		***3***	***100***
[texture – 3]	Barrenta/Barro Preto Areiusca/Areia Preta	3 3	100 100
Barro Amarelo		3	100
[none]		3	67
Areia Branca		2	67
[none]		2	67
Terra Escura/Marróm		1	33
[none]		1	33
Barro Branco		1	33
[none]		1	13

Appendix C:

BOTANICAL DATA

Table C1. Raw Botanical Data, Terra Preta Swiddens

Crop	Class	Terra Preta # Inds.	% Inds.	# Swiddens	% Swiddens	# Plants	% Plants
Totals:		*8*	*100*	*43*	*100*	*6624*	*100*
Abiu	F	0	0.0	0	0.0	0	0.0
Avocado	F	1	12.5	2	4.7	8	0.1
Bamboo	U	1	12.5	1	2.3	7	0.1
Banana	F	2	25.0	2	4.7	8	0.1
Bell Pepper	V	3	37.5	4	9.3	577	8.7
Bitter Manioc	T	4	50.0	18	41.9	2002	30.2
"Black Palm"	U	1	12.5	3	7.0	8	0.1
Caiaué	F	3	37.5	9	20.9	41	0.6
Canapum	EI	5	62.5	10	23.3	68	1.0
Carajiru	U	0	0.0	0	0.0	0	0.0
Carirú	EI	3	37.5	11	25.6	172	2.6
Cashew	F	1	12.5	1	2.3	3	0.0
Cecropia spp.	I	4	50.0	14	32.6	404	6.1
Chili Pepper	V	5	62.5	7	16.3	260	3.9
Cucumber	V	2	25.0	6	14.0	253	3.8
Cupuaçú	F	1	12.5	2	4.7	45	0.7
French Cashew	F	1	12.5	1	2.3	9	0.1
Ginger Root	T	1	12.5	1	2.3	7	0.1
Graminea (pasture)	U	0	0.0	0	0.0	0	0.0
Guava	F	4	50.0	10	23.3	167	2.5
Hot Pepper (*Malegetão*)	V	1	12.5	1	2.3	2	0.0
Hot Pepper (*Murupi*)	V	1	12.5	1	2.3	34	0.5
Inga	EI	3	37.5	9	20.9	41	0.6
Jambro	F	1	12.5	1	2.3	9	0.1
Japona	U	1	12.5	1	2.3	7	0.1
Jurubeba	EI	1	12.5	6	14.0	33	0.5
Lemon	F	0	0.0	0	0.0	0	0.0
Lemon Grass	EG	0	0.0	0	0.0	0	0.0
Maize	G	5	62.5	19	44.2	612	9.2
Marí	F	0	0.0	0	0.0	0	0.0
Meter Bean	V	1	12.5	1	2.3	26	0.4
Okra	V	3	37.5	3	7.0	21	0.3
Papaya	F	6	75.0	16	37.2	419	6.3
Paprika	F	0	0.0	0	0.0	0	0.0
Pineapple (*Abacaxi*)	F	0	0.0	0	0.0	0	0.0
Pineapple (*Anana*)	F	2	25.0	3	7.0	21	0.3
Pumpkin	V	6	75.0	10	23.3	67	1.0
Red Bean	G	4	50.0	9	20.9	160	2.4
Soursop	F	0	0.0	0	0.0	0	0.0

Star Nut Palm	F	6	75.0	23	53.5	404	6.1
Sucuba	U	2	25.0	2	4.7	5	62.5
Sugar Cane	EG	1	12.5	1	2.3	35	0.5
Sweet Manioc	T	2	25.0	2	4.7	96	1.4
Sweet Potato	T	3	37.5	4	9.3	23	0.3
Tomato	V	3	37.5	3	7.0	102	1.5
Watermelon	V	4	50.0	5	11.6	39	0.6
West Indian Gerkin	V	6	75.0	17	39.5	353	5.3
"White Palm"	U	3	37.5	3	7.0	8	0.1
Yam	T	2	25.0	7	16.3	41	0.6

Crop Classes:

F = Fruit Trees

T = Tuber Crops

V = Vegetable Crops

VE = Voluntary Edibles

G = Grain Crops

EG = Edible Grasses

U = Non-edible Utilitarian

I = Non-useful Invasives

Table C2. Raw Botanical Data, Latosol Swiddens

Crop	Class	Latosol # Inds.	% Inds.	# Swiddens	% Swiddens	# Plants	% Plants
Totals:		*9*	*100*	*25*	*100*	*4372*	*100*
Abiu	F	1	11.1	1	4.0	1	0.023
Avocado	F	2	22.2	3	12.0	14	0.3
Bamboo	U	0	0.0	0	0.0	0	0.0
Banana	F	4	44.4	11	44.0	22	0.5
Bell Pepper	V	0	0.0	0	0.0	0	0.0
Bitter Manioc	T	9	100.0	23	92.0	3389	77.5
"Black Palm"	U	0	0.0	0	0.0	0	0.0
Caiaué	F	0	0.0	0	0.0	0	0.0
Canapum	EI	0	0.0	0	0.0	0	0.0
Carajiru	U	1	11.1	1	4.0	6	0.1
Carirú	EI	0	0.0	0	0.0	0	0.0
Cashew	F	3	33.3	3	12.0	15	0.3
Cecropia spp.	I	9	100.0	20	80.0	369	8.4
Chili Pepper	V	1	11.1	2	8.0	16	0.4
Cucumber	V	0	0.0	0	0.0	0	0.0
Cupuaçú	F	3	33.3	5	20.0	56	1.3
French Cashew	F	0	0.0	0	0.0	0	0.0
Ginger Root	T	1	11.1	1	4.0	1	0.0
Graminea (pasture)	U	1	11.1	1	4.0	11	0.3
Guava	F	0	0.0	0	0.0	0	0.0
Hot Pepper (*Malegetão*)	V	0	0.0	0	0.0	0	0.0
Hot Pepper (*Murupi*)	V	0	0.0	0	0.0	0	0.0
Inga	EI	1	11.1	1	4.0	3	0.1
Jambro	F	0	0.0	0	0.0	0	0.0
Japona	U	0	0.0	0	0.0	0	0.0
Jurubeba	EI	5	55.6	9	36.0	73	1.7
Lemon	F	1	11.1	1	4.0	6	0.1
Lemon Grass	EG	1	11.1	1	4.0	11	0.3
Maize	G	0	0.0	0	0.0	0	0.0
Marí	F	2	22.2	2	8.0	12	0.3
Meter Bean	V	0	0.0	0	0.0	0	0.0
Okra	V	0	0.0	0	0.0	0	0.0
Papaya	F	1	11.1	1	4.0	3	0.1
Paprika	F	1	11.1	1	4.0	25	0.6
Pineapple (*Abacaxi*)	F	4	44.4	4	16.0	23	0.5
Pineapple (*Anana*)	F	2	22.2	2	8.0	24	0.5
Pumpkin	V	1	11.1	1	4.0	3	0.1
Red Bean	G	0	0.0	0	0.0	0	0.0
Soursop	F	1	11.1	1	4.0	6	0.1

Star Nut Palm	F	7	77.8	14	56.0	116	2.7
Sucuba	U	0	0.0	0	0.0	0	0.0
Sugar Cane	EG	4	44.4	4	16.0	13	0.3
Sweet Manioc	T	1	11.1	1	4.0	79	1.8
Sweet Potato	T	2	22.2	2	8.0	5	0.1
Tomato	V	0	0.0	0	0.0	0	0.0
Watermelon	V	0	0.0	0	0.0	0	0.0
West Indian Gerkin	V	2	22.2	2	8.0	10	0.2
"White Palm"	U	4	44.4	5	20.0	36	0.8
Yam	T	3	33.3	6	24.0	25	0.6

Crop Classes:

F = Fruit Trees

T = Tuber Crops

V = Vegetable Crops

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U = Non-edible Utilitarian

I = Non-useful Invasives

Appendix D:

Pedological Data

I. Horizon Descriptions

Figure D-1. Terra Preta, Negro River: Humic Anthropogenic Latosol and Latosol Horizons[1]

Pedon 1: Humic Anthropogenic Latosol

Location: Pedon located on the edge/summit of a plateau on the main channel of the Negro River, among fallow vegetation of palm (Caiaué) and other fruit trees and herbaceous species.

Landform: Summit **Elevation**: ± 25m above low-water **Slope**: ± 0

Physiography: Terra firme plateau.

Mean Annual Temperature: **Drainage**: Well-drained

Land Use: Fallow (once used for vegetable crops).

Soil Description:

A- 0 to 28 cm; black (7.5YR 2.5/1 or darker) ; medium very fine to medium subangular blocky structures; friable to firm; few medium, and common fine to very fine roots; common medium-sized pores; cleary wavy boundary. Anthropic epipedon with presence of potsherds.

A/Bo- 28 to 82 cm; distinctive orange (7.5YR 6/8) and brown (10YR 2-3/3) matrix with significant mixing (10YR 4/3); medium to strong very fine to medium angular blocky structures; friable to firm; very few fine roots; many thick organic (10YR 4/3) ped coatings and root linings (contributes to the matrix itself by coloring ped cores, and represents 60 to 30% of matrix with depth); abrupt intermittent boundary.
Bo- 82 to 100+ cm; yellowish organge (7.5YR 5/8) ; weak to medium, fine and medium-sized subangular blocky structures; friable to firm; very few thin organic (7.5YR 5/4) ped coatings; unknown boundary.

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[1] The location of these two pedons was determined by the predominance of Black Earth on riverine plateaus in the study region, requiring that the comparison be made with a Latosol on the back edge of the site. These two horizons are more comparable than one made between Black Earth and a low-lying, sandier non-anthropogenic soil on the river's edge.

Comments:

1) While the entire AB horizon is characterized by patchiness (intermittent gradations), with a gradual lessening of the dark proportion of the matrix with depth, this patchiness shows an abrupt transition at 82 cm, distinctly marking the B horizon transition.

Pedon 2: Red-Yellow Latosol

Location: Pedon located at a 10-minute walking distance from the right margin of the Negro River, where influence of Black Earth site terminates. Back edge of terra firme summit that extends to the Black Earth site. Manioc swidden.

Landform: Summit **Elevation**: ± 30m above igarapé at low-water **Slope**: ± 0

Physiography: Inland terra firme, flat to slightly convex.

Mean Annual Temperature: **Drainage**: Well-drained

Land Use: Manioc swidden.

Soil Description:

Ap- 0 to 18 cm; ? (10YR 3/3) ?; granular with limited weak fine subangular blocky structural components; very friable; common fine and very fine roots; abrupt smooth boundary defined by structural change.

A/B- 18 to 55 cm; ? (10YR 3/4 and 4/4) ? with thin clay (7.5 YR 5/8) mottles; medium, fine to medium subangular blocky structure; friable; negligible roots; very few thin clay (7.5YR 5/8) mottles; gradual smooth boundary.

Bo- 55 to 100+ cm; ? (7.5YR 5/8) ?; medium, fine to medium subangular blocky structure; firm; negligible roots; common medium organic (10YR 4/4) ped coats (diminishing to very few with depth); unknown boundary.

Comments:

1) “Mottles” identified in the B horizon, perhaps predominant in pre-agricultural times, appear to be residual rather than infiltrating from superadjacent horizon.

2) Transition from Ap to A/B horizons most marked by structural change, and from A/B to B by a change in color.

Figure D-2. Upper Urubú River: Humic Anthropogenic Latosol and Latosol Horizons

Pedon 3: Humic Anthropogenic Latosol

Location: Pedon located on a high plateau on the right margin of the Urubú River, in front-center of cultivated Terra Preta, among early successional species.

Landform: Summit **Elevation**: ± 20m above low-water **Slope**: ± 0

Physiography: Terra firme bluff edge.

Mean Annual Temperature: **Drainage**: Well-drained

Land Use: Agriculture: manioc, maize, beans, squash, pineapple.

Soil Description:

A- 0 to 72 cm; black (gley 2.5/N) loam to sandy loam; weak medium subangular blocky structure; very friable; many fine and few medium roots; clear smooth boundary. Anthropic epipedon with very few potsherds.

AB- 72 to 102 cm; greyish yellow (2.5 Y 4/2) loamy sand; weak medium subangular blocky and granular structures; friable; few medium roots; very few thin organic (gley 2.5/N) ped coatings; clear wavy boundary. Transitional anthropic horizon with no potsherds.

Bo- 102+ cm; yellow (7.5YR 6/8) clay; medium medium subangular blocky structure; friable; few medium roots; common thin organic (2.5Y 5/3) ped coatings; boundary unknown.

Comments:

1) Coloring as “gley” a reflection of anthropic influences, not gleying as a hydrologic process.

Pedon 4: Red-Yellow Latosol

Location: Left margin of Rio Urubú approximately 10 minutes upstream from Pedon 16. Pedon located on embankment facing riverfront, among cultivated fruit species.

Landform: Backslope **Elevation**: ± 8m above low-water **Slope**: ± 3%

Physiography: Terra firme slope.

Mean Annual Temperature: **Drainage**: Well-drained

Land Use: Incipient agriculture: fruit trees, sweet and bitter manioc.

Soil Description:

A – Absent[2]

B1- 0 to 50 cm; brownish-yellow (10YR 6/6) silty clay; medium medium subangular blocky structure; friable; few fine and coarse roots; few fine pores; clear smooth boundary.

B2- 50 to 100+ cm; reddish-yellow (10YR 7/8) silty clay; weak to medium fine subangular blocky structure; friable; conspicuous absence of roots and pores; boundary unknown.

II. Pedological Characterizations of Soil Profile

The following tables include data from pedological (chemical, morphological) characterizations of soil profiles from Phase One (lower Negro, middle Urubú) and Phase Two (Santa Isabel, Canoas River and intensively farmed sites near Manaus) research sites. Average values of common soil chemical and physical parameters are first presented by soil horizon (Tables D-1 through D-3).

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[2] The A horizon (a shallow organic layer existing under forest vegetation), characteristic for Latosols, was absent on this soil, thereby obscuring the depth difference between the two epipedons. This greater depth of the A horizon in this Latosol should not be taken as characteristic of other pedons.

Next, I estimated the divergence of Black Earths from background soils to assess the relative plasticity of diverse chemical and physical parameters associated with anthropogenic soil modification. I did this by generating several measures of divergence ("Percentage Divergence" of averages, maxima and minima) for each soil parameter, and other measures of proximity ("Range Overlap") and distance ("Range Exclusion"). Results are tabulated in Tables D-4 through D-6. For each region, naturally-forming soils are employed as the reference points from which Black Earth values deviate.

Table D-1. Pedological Comparison between Non-Anthropogenic Soils (Ultisol/Oxisol) and Indian Black Earth, Negro and Urubú Rivers: Horizon Averages[1]

Soil	Hor.	Granulométrica Composition				pH	P_2O_5	Exchange Complex				
		Coarse Sand	Fine Sand	Silt	Total Clay		($mg \cdot dm^3$)	($cmol/dm^3$) Ca^{++}	Mg^{++}	($mg \cdot dm^3$) K^+	Na^+	($cmol/dm^3$) Al^{+++}
Ultisol/ Oxisol	A	27.95	9.91	18.22	42.83	4.27	3.61	0.11	0.10	17.40	4.50	2.34
	AB	21.89	9.03	19.52	50.36	4.34	1.67	0.03	0.03	8.00	2.50	1.72
	B_1	21.19	13.04	13.25	52.52	4.28	2.07	0.05	0.06	9.00	2.50	1.62
	B_2	7.80	2.43	18.52	71.25	4.49	0.67	0.01	0.01	4.00	2.00	0.93
TPI	A	45.18	13.75	14.90	21.17	5.55	68.63	5.41	0.66	16.25	10.25	0.47
	AB	38.49	12.75	11.69	37.07	5.16	37.37	1.63	0.22	4.75	2.50	0.72
	B_1	33.41	10.48	11.14	44.98	4.98	41.88	0.70	0.13	2.75	1.50	0.61
	B_2	27.09	8.15	14.11	50.42	4.81	39.24	0.45	0.07	2.00	1.00	0.83
Transition	A	40.53	19.74	14.89	24.85	4.58	6.02	0.58	0.23	19.00	3.00	1.64
	B_1	33.06	18.45	15.52	32.98	4.44	3.01	0.14	0.04	6.00	2.00	1.60
	B_2	28.79	16.70	12.36	42.15	4.51	2.34	0.04	0.02	4.00	1.00	1.32

[1] Values based on averages. This averaging makes little sense in the real world, in that averaged soil horizons are not the same depth. However, it provides an idea of average differences between Black Earth and naturally-forming Ultisols and Oxisols, and therefore provides information central to the focus of this chapter.

Table D-1. (Continued)

Soil	Hor.	Total C (%)	Total N (%)	Base Sat. (%)	ECEC (meq/100g)
Ultisol/ Oxisol	A	4.48	0.13	10.75	2.74
	AB	1.92	0.06	5.51	1.85
	B_1	1.09	0.05	6.27	1.60
	B_2	n/a	n/a	4.03	0.97
TPI	A	3.23	0.10	85.52	6.63
	AB	1.46	0.05	64.16	2.59
	B_1	0.62	0.03	49.99	1.48
	B_2	n/a	n/a	38.86	1.35
Transition	A	2.49	0.08	32.02	2.51
	B_1	n/a	n/a	10.05	1.80
	B_2	n/a	n/a	4.75	1.39

Table D-2. Pedological Comparison between Naturally-Forming Soils (Oxisol/Podzol) and Indian Black Earth, Santa Isabel Region: Horizon Averages

Soil	**Hor.**	**Granulométrica Composition**				**pH**	**P_2O_5**	**Exchange Complex**				
		Coarse Sand	Fine Sand	Silt	Total Clay		($mg \cdot dm^3$)	($cmol/dm^3$) Ca^{++}	Mg^{++}	($mg \cdot dm^3$) K^{+}	Na^{+}	($cmol/dm^3$) Al^{+++}
Podzol	A	40.32	25.87	19.55	14.26	5.29	343.84	3.70	0.16	26.57	15.14	0.94
(Santa	AB	43.22	27.49	17.29	12.00	5.31	318.75	1.01	0.03	8.50	14.25	1.23
Isabel)	B_1	32.92	23.10	18.80	25.18	5.18	303.27	0.04	0.02	4.67	14.33	1.72
TPI	A	39.33	22.68	18.92	19.07	4.42	78.31	0.26	0.07	23.33	10.25	2.02
(Santa	AB	30.29	22.40	17.67	29.64	4.54	24.46	0.05	0.03	8.80	2.50	2.24
Isabel)	B_1	24.88	21.53	15.81	37.78	4.58	23.75	0.02	0.01	4.67	1.50	2.00

[1] Values again based on averages.

Table D-3. Pedological Comparison between Non-Anthropogenic Soils and Indian Black Earth, Rio Canoas Region: Horizon Averages[1]

- Data Pending -

Table D-4. Quantitative Measures of Subsistence Plasticity: Assessing the Pedochemical Divergence of Anthropogenic Black Earth from Non-Anthropogenic Soils of the Central Study Region

Horizon		**Depth**	**Ca++**	**Mg++**	**Al+++**	**pH**	**K+**	**Base Sat.**	**ECEC**	**Avail. P**	**Total C**	**Total N**
H1	% divergence of averages	87.0	4673.5	552.7	-80.9	30.7	-9.7	695.5	142.1	1711.0	-27.8	-20.8
H2	% divergence of averages	-1.4	5146.0	532.4	-58.7	18.1	-46.0	1064.4	40.2	2049.0	-24.2	-23.1
H3	% divergence of averages	-10.6	1481.6	175.7	-54.2	14.0	-52.4	698.0	7.6	3407.1	-43.7	-29.7
H4	% divergence of averages	-20.5	4366.7	566.7	-11.0	7.1	-50.0	864.6	39.5	5766.7		
	Maximum divergence:	**87.0**	**5146.0**	**566.7**	**80.9**	**30.7**	**52.4**	**1064.4**	**142.1**	**5766.7**	**43.7**	**29.7**
H1	% divergence of maxima	260.0	2200.0	640.0	-54.5	36.4	30.8	273.5	172.3	2350.0	-57.4	-45.0
H2	% divergence of maxima	8.0	6266.7	860.0	-33.3	25.9	-37.5	891.1	66.4	2900.0	-21.6	-17.9
H3	% divergence of maxima	24.6	472.7	100.0	-58.4	19.8	-77.8	379.8	8.8	5975.0	-23.6	-14.4
H4	% divergence of maxima	13.6	5600.0	1300.0	24.2	10.0	-50.0	890.4	93.7	15900.0		
	Maximum divergence:	**260.0**	**6266.7**	**1300.0**	**58.4**	**36.4**	**77.8**	**891.1**	**172.3**	**15900.0**	**57.4**	**45.0**
H1	% divergence of minima	50.0	4300.0	-100.0	-100.0	19.1	-50.0	732.1	41.1	266.7	-6.8	-9.5
H2	% divergence of minima	70.0	1300.0	0.0	-93.7	7.0	-66.7	223.7	32.4	600.0	-44.6	-30.1
H3	% divergence of minima	-10.0	1600.0	0.0	-87.4	9.7	0.0	471.7	18.2	700.0	-63.8	-45.0
H4	% divergence of minima	-54.5	3700.0	100.0	-30.3	3.1	-50.0	849.7	11.3	700.0		
	Maximum divergence:	**70.0**	**4300.0**	**100.0**	**100.0**	**19.1**	**66.7**	**849.7**	**41.1**	**700.0**	**63.8**	**45.0**
H1	% of Range Overlap	12.5	0.0	11.5	1.0	2.0	60.0	0.0	16.3	0.0	18.3	28.2
H2	% of Range Overlap	75.0	0.0	100.0	25.8	11.3	28.6	0.5	36.1	0.0	28.8	12.1
H3	% of Range Overlap	69.8	4.0	48.6	6.3	0.0	12.5	3.8	75.5	0.0	0.0	0.0
H4	% of Range Overlap	n/a	0.0	0.0	n/a	0.0	0.0	0.0		0.0	n/a	n/a
Horizon	**Maximum overlap:**	**75.0**	**4.0**	**100.0**	**25.8**	**11.3**	**60.0**	**3.8**	**75.5**	**0.0**	**28.8**	**28.2**
H1	% of Range Exclusion	0.0	112.8	0.0	0.0	0.0	0.0	60.9	0.00	11.1	0.0	0.0
H2	% of Range Exclusion	0.0	20.5	0.0	0.0	0.0	0.0	0.0	0.00	22.3	0.0	0.0
H3	% of Range Exclusion	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.00	44.4	3.4	4.0
H4	% of Range Exclusion	0.0	0.0	0.0	0.0	0.0	8.3	143.0	2.6	0.0	0.0	0.0
	Maximum exclusion:	**0.0**	**112.8**	**0.0**	**0.0**	**10.0**	**8.3**	**143.0**	**2.6**	**44.4**	**0.0**	**0.0**

Table D-5. Quantitative Measures of Subsistence Plasticity: Assessing the Pedochemical Divergence of Anthropogenic Black Earth from Non-Anthropogenic Soils, Santa Isabel Region

Horizon		**Depth**	**Ca++**	**Mg++**	**Al+++**	**pH (H2O)**	**K+**	**Base Sat.**	**ECEC**	**Avail. P**	**Total C**	**Total N**
H1,URN	% divergence of averages	198.9	3266.2	64.3	-61.8	24.5	47.6	434.3	80.3	8972.2	-34.1	-38.2
H2, URN	% divergence of averages	-3.6	3250.0	0.0	-29.6	21.5	-3.4	547.2	27.1	18219.0	n/a	n/a
H3, URN	% divergence of averages	-53.4	0.0	-58.3	14.9	20.2	-22.2	57.8	15.9	22532.0	n/a	n/a
	Maximum divergence:	**198.9**	**5590.9**	**305.0**	**94.2**	**27.4**	**100.0**	**811.1**	**156.5**	**22532.0**	**34.1**	**38.2**
H1,URN	% divergence of maxima	315.0	3372.5	210.0	-41.1	31.2	38.5	271.7	268.6	12524.3	-33.0	-38.0
H2, URN	% divergence of maxima	-24.0	5916.7	0.0	-22.8	32.6	-12.5	903.7	33.0	16844.7	n/a	n/a
H3, URN	% divergence of maxima	-64.9	-72.7	-84.2	33.6	19.8	-55.6	-22.0	34.4	19212.8	n/a	n/a
	Maximum divergence:	**315.0**	**5916.7**	**240.0**	**96.1**	**32.6**	**92.3**	**903.7**	**268.6**	**19212.8**	**33.0**	**38.0**
H1,URN	% divergence of minima	175.0	800.0	-33.3	-97.9	21.4	100.0	165.9	-41.3	4785.3	-63.3	-58.9
H2, URN	% divergence of minima	100.0	200.0	-50.0	-95.5	16.9	-33.3	193.8	33.9	16665.1	n/a	n/a
H3, URN	% divergence of minima	0.0	100.0	-100.0	-53.8	23.3	0.0	70.5	-49.0	6988.6	n/a	n/a
	Maximum divergence:	**175.0**	**28000.0**	**333.3**	**97.9**	**37.9**	**175.0**	**1867.1**	**237.3**	**25328.1**	**63.3**	**58.9**
H1,URN	% of Range Overlap	0.0	1.6	28.3	14.3	0.0	35.7	14.4	16.1	0.0	42.3	31.6
H2, URN	% of Range Overlap	64.3	0.2	75.0	36.3	0.0	66.7	1.4	46.2	0.0	n/a	n/a
H3, URN	% of Range Overlap	n/a	0.3	10.5	55.1	0.0	37.5	62.3	53.3	0.0	n/a	n/a
	Maximum divergence:	**64.3**	**1.6**	**75.0**	**55.1**	**0.0**	**66.7**	**62.3**	**53.3**	**0.0**	**42.3**	**31.6**
H1,URN	% of Range Exclusion	3.2	0.0	0.0	0.0	5.0	0.0	0.0	0.0	1519.9	0.0	0.0
H2, URN	% of Range Exclusion	0.0	0.0	0.0	0.0	27.5	0.0	0.0	0.0	1810.0	n/a	n/a
H3, URN	% of Range Exclusion	n/a	0.0	0.0	0.0	80.0	0.0	0.0	0.0	744.5	n/a	n/a
	Maximum divergence:	**3.2**	**1338.5**	**0.0**	**53.1**	**83.8**	**0.0**	**295.8**	**66.0**	**8378.7**	**0.0**	**0.0**

Table D-6. Quantitative Measures of Subsistence Plasticity: Assessing the Pedochemical Divergence of Anthropogenic Black Earth from Non-Anthropogenic Soils, Rio Canoas

- Data Pending -