1 Towards an Understanding of Amazonian Dark Earths

William I. Woods[1] and Bruno Glaser[2]

1.1 Anthrosols and Amazonia

By way of introduction to the topic and to provide a basis for the context of this volume, we provide the following short discussion. During the last century, a number of researchers looked seriously at development scenarios for various parts of the world and attributed great importance to natural soils and their management or mismanagement. In the case of Amazonia, the extremely poor soils present were cited as the fundamental cause for lack of cultural attainment. In general, soils were used deterministically as an explanatory mechanism when they presumably suited a preconceived notion of development or decline, but little in-depth study was undertaken regarding which soils were actually present on the microscale and how these had been affected by different management strategies over time.

Soils, along with energy from the sun, water, and the cultivated plants themselves, constitute the major environmental resources for agricultural societies and are, therefore, critical to discussions of sustainability. In the Amazon region, often depicted as a “Counterfeit Paradise” or “Green Hell,” the highly weathered, very acidic soils of the *terra firme* (upland settings) are thought of as extremely forbidding. With few available nutrients and having extremely high aluminum concentrations, one could not imagine a worse regime for productive agriculture, particularly when associated with nucleation of population. Indeed, even in the *várzea* (floodplains) with somewhat better soils, crop production has been seen as a risky endeavor because of the unpredictability of the flood regime.

However, it is a matter of scale when dealing with humans and the environment; and for soils, this is particularly true. Continental or regional depictions simply are not appropriate. Rather, one needs to look at the microscale and here one finds great variety in and enormous pre-Columbian modifications to the soil landscape and unexpected answers to questions of sustainability. Most Amazonian soils have been modified and manipulated, intentionally and unintentionally, directly and indirectly, negatively and posi-

[1] Department of Geography, Southern Illinois University Edwardsville, Edwardsville, Illinois 62026, USA
[2] Institute of Soil Science and Soil Geography, University of Bayreuth, 95440 Bayreuth, Germany

tively by the combined activities of the region's aboriginal inhabitants over time.

When dealing with humans and their effects on the land, enormous complications come into play due to the extreme heterogeneity of the types, amounts, and distribution of inputs and withdrawals over time. Anthropogenic soils exhibit these problems in excess at all scales of inquiry and tend to form a continuum of expression within any given micro-habitat. The reality of our aboriginal farmers, their basic decisions, and the majority of outcomes were at the level of the individual and his or her family and household. The point of articulation with the environment at this scale was narrow, mainly including only the limited zone of exploitation surrounding the place of habitation. The result was an extremely heterogeneous mix of adaptive modifications whose resulting soils vary in the extreme.

One tends to associate land degradation with tropical soil use, particularly in Amazonia, where numerous instances from localized deflation and nutri-

Fig. 1.1a. Typical profiles of Latosol

ent depletion have been documented. However, questions have been raised about this overly dismal viewpoint and it has been proposed that complex societies with large, sedentary populations were present for at least a millennium before European contact. Early explorers described dense villages extending for kilometers along river bluff edge settings with roadways linking these to settlements in the interior. Often associated with the presumed village locations are soils termed "Indian black earth," or *terra preta* (Fig. 1.1). The heightened fertility status of these soils, generically termed "dark earths" herein, has long been recognized by the indigenous inhabitants of the region, as well as by current colonists. Throughout Amazonia, dark earths occur in a variety of landscape contexts, in circumscribed patches ranging in size from less than 1 ha to many square kilometers. The most nutrient-demanding crops are often planted on dark earth sites. When not cleared for agriculture, a distinctive vegetation structure and species composition are recognized, and the unique and abundant assemblage of useful wild and semi-domesticated plant species occurring on them is exploited.

Fig. 1.1b. Typical profiles of *terra preta* soils

Currently, most researchers believe that these soils formed in cultural deposits created through the accretion of waste and occupation debris around habitation areas. The great enrichment of essential plant nutrients such as phosphorus, calcium, and potassium found in many of these soils certainly supports such a conclusion. Theories about the anthropogenic origins of the dark earths also include a burning scenario, whether from fires within the habitation area or from those used to clear forest for fields and clear fields of choking weedy growth. Fire contributes charcoal and ash, which increase soil pH, thereby suppressing aluminum activity toxic to plant roots and soil microbiota. The consequent increase in microbiological activity adds colloidally sized organic decomposition products to the soil matrix. These, along with the by-products of incomplete combustion, provide charged surfaces largely absent in the local soils and increase nutrient retention capacity, setting up a synergistic cycle of continued fertility.

1.2 Volume Overview

In the lowland humid portion of the Amazon Basin, intensively weathered nutrient-poor soils such as Oxisols, Ultisols, and Acrisols predominate. Embedded in this landscape of infertile soils are patches of dark earths with huge carbon- and nutrient-rich A horizons providing sustainable land use. The following 14 chapters of this book investigate various aspects of the dark earth phenomenon.

In Chapter 2, Glaser, Zech, and Woods trace the development of scientific knowledge of the dark earths from the first descriptions by observers in the 1870s. Although these early accounts supposed an anthropogenic origin, later discussions presented a variety of geogenic-origin hypotheses. More intensive investigations starting in the 1960s have provided a clearer picture of the widespread distribution of these soils. Analyses of their chemical and physical parameters have shown that the dark earths were formed in situ by the activities of pre-Columbian Indians. Recent work at the molecular level has revealed that the dark earths contain considerable amounts of charring residues which are known to persist in the environment for centuries. However, the specific sources for the nutrient enrichment found in many of these soils are still unclear. These authors conclude that future investigations should focus on the identification of land-use practices of the pre-Columbian population and on the implementation of this knowledge in order to reproduce sites of enriched soils.

Kern, Costa, and Frazão in Chapter 3 also review the scientific background for Amazonian dark earth studies and similarly come to the conclusion that these soils are the product of aboriginal settlement activities. They provide geochemical data that identify chemical associations of elements that were added to the soil by past human occupations and represent the geochemical signature for modified regional soils. These data also allow the hypothetical determination of the settlement pattern in a prehistoric site with *terra preta*, as well as its evolution over the centuries. Ongoing research concerns the chemical composition of plants like palm trees and manioc, mostly to detect the origin of the high values of Zn and Mn which occur in the *terra preta*. It is already known that ceramics present in archaeological black earth (ABE) contain very high contents of some chemical elements.

German in Chapter 4 outlines a method for the geographical characterization of Amazonian dark earths. The method is employed to map and characterize sites on the Rio Negro, where the environment has been portrayed as a constraint to human subsistence and sedentary occupation. The degree of anthropogenic soil modification is estimated from total phosphorus content, epipedon depth, and soil color. Findings show that human settlements over time were concentrated along major waterways, at the headwaters of smaller tributaries, and at the confluence of two rivers. Rather than corresponding to distributions of a single "limiting" resource, settlement areas are shown to provide a number of advantages to human inhabitants, including access to multiple resources, political-economic control and defense.

In contrast to the Brazilian Amazon, few *terra preta* sites have yet been identified in the Upper Amazon. In Chapter 5, Coomes describes the characteristics and human uses of a site on a relic meander island complex in the Amazon River lowlands of northeastern Peru. Local residents refer to the site as the '*yarinales*' (after the presence of the ivory nut or *yarina* palm). The soils of the *yarinales* are distinct from those of the Amazon River floodplain and the Ultisols of the *terra firme*, by elevated phosphorus concentrations, dark color, and high sand content. Pot sherds and stone implements suggest prehistoric occupation of the site. Since the late nineteenth century, farmers have practiced one of the most productive and profitable forms of lowland swidden-fallow agroforestry yet described for the Amazon Basin. Crop–fallow cycles are tailored to the elevation of the land relative to periodic floodwaters. Residents also rely on the *yarinales* for the extraction of non-timber forest products as well as medicinal plants and for hunting. The common occurrence of relic riverine features in the Peruvian Amazon suggests that similar sites of high agricultural potential are to be found in the Upper Amazon.

Prehistoric migrations out of the central Amazon may have been motivated by a population explosion made possible by dark earth technology. In Chapter 6, Myers analyzes sites from the Upper Amazon to determine (1) if dark earth technology accompanied immigrants from the central Amazon, and (2) if there was an indigenous development of dark earth technology. His analysis reveals that immigrants were not frequently associated with dark earth sites and that dark earth sites are sometimes associated with indigenous peoples. Thus it seems unlikely that black earth technology was the key innovation that permitted population growth and the subsequent diaspora from the central Amazon to its principal tributaries.

Ruivo, Cunha, and Kern studied the mineral, elemental chemical, and organic components of soils from five sites located in the Ferreira Penna Sci-