Amazonian Dark Earths: Wim Sombroek's Vision

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Logo on back cover: Symbol of the Terra Preta Nova group designed by Wim Sombroek.
Picture on front cover: Wim examining a house garden on the Rio Negro, July 2002.

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Dr Wim G. Sombroek

He had a passion for land as we know
Fueled by the Amazon where jungles grow
A flame that didn't flicker or even go out
His last endeavour Terra Preta still to shout[1]

Wim Sombroek joined the International Soil Museum in Wageningen as a Director in 1978. Long before that, we knew him as a respected soil scientist, who obtained a Ph.D. in Wageningen for his thesis on the Amazon soils, and had carried out extensive soil surveys in Kenya. These illustrated his enthusiasm for field work and for building upon these primary data – the basis for the establishment of the International Soil Museum as a link with the Soil Map of the World project carried out at FAO in Rome.

We remember his many new ideas to make our institution more widely known under the new banner of International Soil Reference and Information Centre (ISRIC). He had an enormous drive to implement new projects. It was a wise decision to accept the task of Secretary-General of the then International Soil Science Society (ISSS), now International Union of Soil Sciences (IUSS). Through this combination of functions over twelve years, he was able to carry out innovative ISSS activities at ISRIC, and play a prominent role internationally, in particular directed to the needs of developing countries.

Wim initiated activities in the further development of a world soil classification system, which finally resulted in the *World Reference Base for Soil Resources* (WRB); the Laboratory Exchange project (LABEX) to improve the performance of soil laboratories in developing countries, in which more than 100 labs participated; the *National Soil Reference Collection* (NASREC) project to develop national soil profile collections in more than 30 countries; and not least the *Soil and Terrain digital database program* (SOTER), which started in 1986 and has carried the initiative of the FAO-Unesco Soil Map of the World through to the twenty-first century,

[1] Excerpt from a poem entitled "Thanks, Wim!" by Richard W. Arnold.

and the framework of the *World Inventory of potential Soil Emissions* (WISE) a unique soil data set that is still used by many researchers.

Wim left ISRIC to become Director of the Land and Water Development Division of FAO, where he was also active in land use issues related to climate change in the framework of the International Panel of Climate Change. His ties with ISRIC were not severed and, after his tenure in Rome, he returned to the Amazon where his heart was, but one foot in an office at ISRIC. He worked on the economic zoning of the Brazilian Amazon, to safeguard parts of this huge but threatened forested region as protected reserves, and develop economical viable systems of sustainable land use.

Thirty years after his thesis, in which he discussed the importance of the *Terra Preta*, he showed the relevance of this pre-Colombian agricultural technique for the development of enhanced carbon sequestration in agricultural land – the *Terra Preta Nova*.

The Terra Preta network has developed enormously in recent years, and includes more than 100 scientists. Two books on the Terra Preta have been published in the meantime, and a symposium on these soils during the 18th World Congress of Soil Science in 2006 was dedicated to his memory.

We, at ISRIC and within the IUSS, are proud that Dr. Wim G. Sombroek has been our Director and friend, and that the work he initiated continues and develops – in the field, in laboratories, institutes and museums, carried out by dedicated researchers in so many disciplines.

On behalf of retired and present ISRIC staff members,

Hans van Baren

Thanks, Wim!

Each of us has a story to tell this day
Of meeting Wim Sombroek along the way
He touched our lives in ways oft untold
And helped us become ‘champions with gold’

He had a passion for land as we know
Fueled by the Amazon where jungles grow
A flame that didn’t flicker or even go out
His last endeavour Terra Preta still to shout

What made this man a man to remember?
Dedication from January to December?
Ready zeal to impart his vast knowledge
To those who never had seen a college?

Perhaps it was the breath of his interests keen
Archaeology nearby, within, without – to be seen
And wild orchids gardened in an exotic place
In his green house always finding space

Was it not the pillars there at home?
Wife Willemijn and four girls that led him roam
Whose constancy supported his very being
Welcomed his return late in the evening?

What do you recall when you hear his name?
A towering presence with moustache and mane
Blue eyes twinkling through gold-rimmed glasses
A fat little notebook shock full of addresses

Or may be the pause as he ‘rolled’ his own
Smoke rising gently as softly it was blown
Or the patient way he slightly leaned over
Catching our phrases like blossoms of clover

I, too, have a special way to recall –
Several clusters of Dutch bulbs one fall
He planted along my garden maze
Now each spring he brightens my gaze

I hear his laughter, feel his handshake
I treasure the moments we dared to take
To dream our dreams, to vision the future
Returning to Pedology, our souls to nurture

Are we mourning – never; rejoicing – ah, yes, ever
Along with insights, strength, and wisdom so clever
There was gentleness, love, and tenderness, too
Wim Sombroek, our hearts give thanks to you.

Richard W. Arnold 1-15-04

A Few Words About Wim Sombroek

The first time I met Wim Sombroek was actually the second time I met him, though I didn't realize it till later. I also didn't realize that in both cases Wim was doing something he had been doing his whole life: trying to attract the world's attention to soil, and to soil science. I am a journalist, and both times I was introduced to Wim I had a notebook and pen in my hand and wanted to talk to him about his research on *terra preta do índio* – anomalously rich, charcoal-thick soils, created by native peoples in the Amazon Basin. Eventually we became friendly and I learned how many and various his interests were. But it was only after he passed away that I fully grasped what he was trying to accomplish. He wanted to change and expand the discipline of soil science itself, with *terra preta* as a hortatory example.

This second time when I met Wim (or, as I thought, the first time) was at a *terra preta* conference at a hotel in Manaus. Someone I was talking to pointed at a silver-haired man with an impressive moustache who was nursing a beer at a table in the lobby bar. "That's Wim Sombroek," I was told. "You ought to talk to him." I went over and introduced myself. One thing led to another, and many hours later we were drinking beer with a large group in another part of Manaus. I asked how long he had been interested in *terra preta*. "A few years," he said, or something to that effect. The amused glint in his blue eyes suggested to me that he was understating the case, an impression that was confirmed when he told me about the soils at his parents' home in the rural Netherlands.

He was ten years old during the Hongerwinter — the Dutch famine of 1944–45, in which more than 10,000 people died. Sombroek's family survived on the harvest from a tiny plot of *plaggen* soil: land enriched by generations of careful fertilization. His parents further improved their land, he told me, by scattering the ash and cinders from their home fireplaces. In the 1950s, Wim went to Brazil and encountered more charcoal-filled earth: *terra preta*. Naturally, it reminded him of the *plaggen* in his parents' yard, and he paid attention. His book, *Amazon Soils*, included the first sustained study of *terra preta* and a map of its distribution along the lower Rio Tapajós.[1]

[1] Sombroek WG (1966) Amazon Soils: A Reconnaissance of the Soils of the Brazilian Amazon Region. Wageningen, the Netherlands: Center for Agricultural Publications and Documentation (map on p. 175).

As Wim told this story I suddenly realized that I had met him almost a decade before, in the early 1990s. At that time two groups of researchers were embroiled in a lengthy fight over the extent and cost of soil degradation. One side, led by entomologist David Pimentel, of Cornell University, charged that "nearly one-third of the world's arable land has been lost by erosion" since the 1950s. Soil loss, Pimentel and his collaborators said in 1995, already cost the world "$400 billion per year, or more than $70 per person per year."[2] The other side, often identified with economist Pierre R. Crosson of the Washington environmental-research group Resources for the Future, responded that Pimentel's figures had "such thin underpinnings that [they] cannot be taken seriously." The annual toll of erosion-induced on-farm productivity losses in the United States was, in Crosson's estimation, no more than $600 million.[3] (Off-farm costs might well be higher, he said, but neither Pimentel nor he had tried to assess them.)[4] The debate spilled outside academia – Crosson, as I recall, once found himself on National Public Radio, trying to explain the Universal Soil Loss Equation to a bewildered interviewer.

For a long time, one of the more striking features of the debate was the near-absence of soil scientists themselves from the discussion. Indeed, almost 20 years passed between the time soil-degradation fears first stirred alarm and the first published estimates of global soil degradation. In 1990, the International Soil Reference and Information Center (ISRIC) in Wageningen, the Netherlands, finally filled the gap, releasing the Global Assessment of Soil Degradation. This major effort was undertaken at the initiative of Wim Sombroek, then ISRIC's director (and, simultaneously, Secretary General of the International Society of Soil Science).[5]

When I learned about GLASOD, as the assessment was called, I contacted Wim. We met when he came to the United States for, I believe, a meeting in Washington, D.C. GLASOD, he told me, was a first step toward answering an urgent question in soil science — the size, location and character of degraded soils around the world. But the assessment also had a second purpose. All soil scientists know that, as Will Durant said, "Ultimately every civilization is based upon the soil."[6] But all

[2] See, e.g., Pimentel D et al. (1976) Land degradation: effects on food and energy resources. Science 194:149–55. Pimentel D et al. (1995) Environmental and economic costs of soil erosion and conservation benefits. Science 262:1117–1123 (quotes on 1117, 1120)

[3] See, e.g., Crosson PR (1986) Soil erosion and policy issues. In: Phipps TT, Crosson P and Price KA (eds) Agriculture and the Environment. Washington, DC: Resources for the Future.,pp. 35–73; Crosson PR (1995) Soil erosion estimates and costs. Science 269:461–64 (quote on 461)

[4] Crosson PR (2003) The Economics of Soil Erosion and Maintaining Soil Biodiversity. Discussion paper for OECD Expert Meeting on Soil Erosion and Soil Biodiversity Indicators, Rome (unpublished manuscript)

[5] Sombroek WG (1985) Establishment of an International Soil and Land Resources Information Base. Discussion Paper for the ISSS Working Group on Digital Mapping of Global Soil Resources. Wageningen: ISRIC (unpublished manuscript); Oldeman LR, Hakkeling RTA and Sombroek WG (1990) World Map of the Status of Human-Induced Soil Degradation. Wageningen: ISRIC/UNEP

[6] Quoted in Preston RJ (1939) Soil erosion. The significance of the problem and its attempted control. Journal of Geography 38:308. See also the widely cited Howard A 1940. An Agricultural Testament. London: Oxford

too often, Wim said, they act as handmaidens to agronomy and crop science, rather than environmental scientists who should use their specialized knowledge about a critically important resource to work with ecologists, economists, and political scientists to help humankind through these ecologically parlous times.[7] GLASOD was an attempt to show "policy-makers and decision-makers" how soil science could inform the fight against "declining food productivity by conserving and restoring our natural resources."[8]

Ultimately, Wim told me in Washington, he had been disappointed by GLASOD's lack of larger impact, as well as ISRIC's failure to improve on it.[9] But even as he was finishing GLASOD he was turning his attention to another means of elevating the profile of soil science: *terra preta* — or Amazonian Dark Earth,[10] as it has been renamed. Found in patches along almost all of the major rivers in the Amazon basin, Amazonian Dark Earth is, unlike typical tropical soils, rich with phosphorus, nitrogen, zinc, and magnesium. More important, it is full of carbon – as much as 70 times the level of neighboring soils—in the form of "bio-char," a charcoal-like residue created when organic matter is burned at a low temperature.[11]

As far back as the 1960s, Wim had wondered whether scientists could reconstruct the techniques by which Indians had made *terra preta* in the past. If so, he now argued, contemporary tropical farmers might create their own *terra preta — terra preta nova*, as he dubbed it — to help forestall soil degradation. Because soil degradation is an enormous limiting factor in tropical agriculture, *terra preta nova* could not only boost yields but also reduce the amount of tropical forest that had to be cleared for farms. Much as the Green Revolution dramatically improved the developing world's crops, resilient *terra preta nova* could unleash a "black revolution" for the developing world's soil.[12]

In addition, Wim argued, manufacturing large swathes of Amazonian dark earth would require so much biochar that these regions would act as enormous carbon

[7] This is not a new complaint. See, e.g., Kellogg CE (1961) A challenge to American soil scientists: On the occasion of the 25th anniversary of the soil science society of America. Soil Science Society of America Proceedings 25:419–23

[8] Oldeman LR, Hakkeling RTA, Sombroek WG (1991) World Map of the Status of Human-Induced Soil Degradation: An Explanatory Note. Den Haag: CIP-Gegevens Koninklijke Bibliotheek, 2nd ed.: 21

[9] GLASOD is not even mentioned in Pimentel et al. (1995), a widely publicized study in a major journal that appeared just 5 years afterward

[10] This term was coined by Woods and McCann to encompass the wide range of variability of dark anthropogenic soils in Amazonia [Woods WI, McCann JM (1999) The anthropogenic origin and persistence of Amazonian dark earths. The Yearbook of the Conference of Latin American Geographers 25:7–14]

[11] Lehmann, J, Kern DC, Glaser B, Woods WI (eds). 2003. Amazonian Dark Earths: Origin, Properties, Management. Dordrecht: Kluwer; Glaser, B, and Woods WI (eds) 2004. Amazonian Dark Earths: Explorations in Space and Time. Berlin: Springer.

[12] I take the phrase "black revolution" from Marris, E 2006. Black is the new green. Nature 442:624–26.

sinks, counteracting global warming.[13] In theory, the potential for carbon storage is huge: according to a 2006 estimate in the journal *Mitigation and Adaptation Strategies for Global Change*, more carbon could be stored in *terra preta nova* every year than is released by the entire world's fossil-fuel use, at least at current levels of consumption.[14]

The possibilities of Amazonian dark earth obviously thrilled Wim. In Manaus, I was not the only person to be startled during the conference tour of *terra preta* sites when the former Secretary General of the International Society of Soil Science scrambled into archaeological trenches and began taking measurements with his soil-color chart. But what I only realized later, talking to Wim, is that he hoped that the *Terra Preta Nova* project would, even more than GLASOD, serve as an example of how soil science might reorient itself.

Between 1992 and 2004, enrollment in North American soil-science graduate programs fell by about 40%; Europe apparently experienced similar declines. The drop occurred despite "a continuous increase of the interest manifested by the scientific community in soils-related issues," at least as measured by scientific publications in the field.[15] Amazingly, it occurred despite the enormous global boom in organic farming, with its emphasis on protecting the soil. One common explanation for the decline is the tendency of soil-science schools to treat soil science, in isolation, as a vehicle to increase crop production, even though students increasingly view soil through the lenses of environmental and social sciences. To Wim's way of thinking, the *Terra Preta Nova* project was an example of the way to go.

Wim's hopes will not be easy to fulfill. It has become increasingly clear that much of the resilience in Amazonian dark earth derives from its ability to support soil ecosystems; the microbiota of *terra preta* are both more numerous and more diverse than that of surrounding areas.[16] Unfortunately, identifying precisely what is living in these soils will be difficult. As is well known, researchers can cultivate only a small fraction of rhizospheric species in petri dishes. Equally important, nobody knows how much carbon can be stored in soil. Preliminary studies suggest

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[13] Sombroek WG 1992. Biomass and carbon storage in the Amazon ecosystems. Interciência 17:269–72; Sombroek

WG, Ruivo ML, Fearnside PM, Glaser B, Lehmann J (2003) Amazonian Dark Earths as carbon stores and sinks. In: Lehmann, J, Kern DC, Glaser B, Woods WI (eds). 2003. Amazonian Dark Earths: Origin, Properties, Management. Dordrecht: Kluwer, pp 125–139

[14] Lehmann J, Gaunt J, and Rondon M (2006) Bio-char sequestration in terrestrial ecosystems: A review. Mitigation and Adaptation Strategies for Global Change 11:403-27. Lehmann, Gaunt and Rondon predicate their estimates on a sharp rise in biofuel use, with the biofuels being produced by processes that generate bio-char.

[15] Baveye P, et al. (2006) Whither goes soil science in the United States and Canada? Soil Science 171:501–18 (quote on 506).

[16] Ruivo ML, Cunha ES, Kern DC (2004) Organic matter in archaeological black earths and yellow latosol in the Caxiuanã, Amazônia, Brasil. In: Amazonian Dark Earth: Explorations in Space and Time. Berlin: Springer, pp. 95–108.

that at least in some soils' soil-carbon content may not increase linearly with carbon inputs but reach some limiting value.[17]

But in another sense Wim's dream has already been realized. The *Terra Preta Nova* project, with its vision of the soil as a key element in our common future, has attracted enormous public attention to soil science. On a professional level, the scientific collaboration links soil scientists, archaeologists, geographers, microbiologists, engineers, ecologists, economists, and atmospheric scientists around the world in a common project that promises to reveal much about the workings of soil, may have an enormous impact on agriculture and could even play a role in climate change. This book, and all it represents, is more than a tribute to Wim Sombroek's legacy—it is a way forward.

Charles C. Mann

[17] Stewart CE, et al. (2007) Soil carbon saturation: Concept, evidence and evaluation. Biogeochemistry 86:19–31.

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Chapter 1
Amazonian Dark Earths: The First Century of Reports

WI Woods and WM Denevan

1.1 Introduction

Amazonian dark earths are anthropogenic soils called *terra preta de índio* in Brazil, created by indigenous people hundreds, even thousands, of years ago (Smith 1980; Woods and McCann 1999). *Terra preta* proper is a black soil, associated with long-enduring Indian settlement sites and is filled with ceramics and other cultural debris. Brownish colored *terra mulata*, on the other hand, is much more extensive, generally surrounds the black midden soils, contains few artifacts, and apparently is the result of semi-intensive cultivation over long periods. Both forms are much more fertile than the surrounding highly weathered soils, mostly Ferralsols and Acrisols, and have generally sustained this fertility to the present despite the tropical climate and despite frequent or periodic cultivation. This fertility probably is because of high carbon content, which retains nutrients and moisture, and an associated high and persistent microbial activity.

The high concentrations of pyrogenic carbon in *terra preta* come mainly from charcoal from cooking and processing fires and settlement refuse burning, and in *terra mulata* the carbon probably comes from in-field burning of organic debris. Low intensity "cool" burning, what has been called slash-and-char, resulting in incomplete combustion, can produce carbon in high quantity which can persist in soil for thousands of years. Dated carbon in dark earths is as old as 450 BC (Hilbert 1968; Petersen et al. 2001:100). In contrast, slash and burn shifting cultivation fires today tend to be "hot" fires, set at the end of the dry season, which produce large releases of carbon dioxide to the atmosphere and more ash of brief persistence than charcoal.

Denevan (2001:116–119) has argued that in pre-Columbian times the use of stone axes made long-fallow shifting cultivation very inefficient, and as result probably uncommon until the European introduction of metal axes. Previously, soil fertility must have been maintained and improved by frequent composting, mulching, and in-field burning, making semi-permanent cultivation possible with only brief fallowing. Over time these activities could have produced fertile, self-sustaining dark earths.

Dark earths may occupy 0.1% to 0.3%, or 6,000 to 18,000 km^2, of forested lowland Amazonia (Sombroek and Carvalho 2002:130). Because their densities vary

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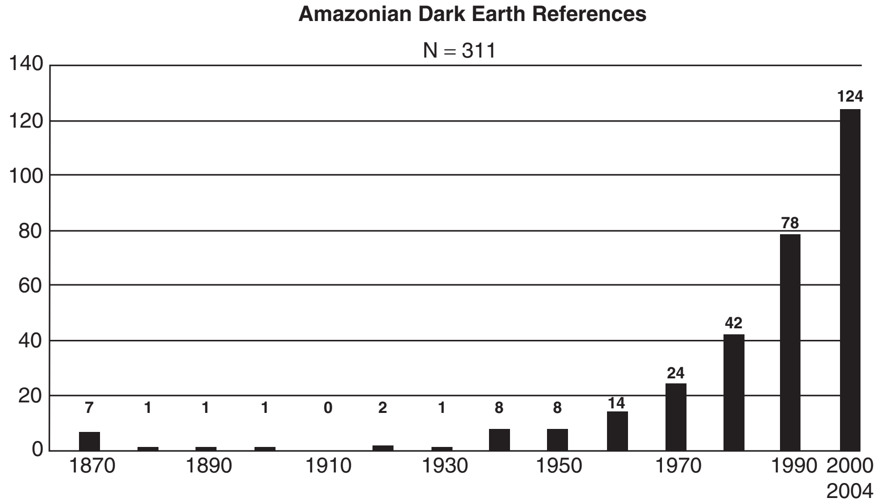

Fig. 1.1 Amazonian dark earth references by decades, 1870–2004 (n = 311)

greatly within subregions and almost no systematic survey has been accomplished within Amazonia, variations in density projections of an order of magnitude are to be expected. The dark earths occur in a variety of climatic, geologic, and topographic situations, both along river bluffs and in the interior, with depths sometimes exceeding 2.0 m. Individual patches range from 1 ha or so to several hundred hectares.

It has only been since about 1980 (Fig. 1.1) that these soils have received intensive scholarly attention. Recent research has been multidisciplinary and international, especially by soil scientists, archaeologists, and geographers from Brazil, Colombia, Germany, and the United States. Independent work in these disciplines and countries came together in three international conferences in 2001–2002 in Benicassim in Spain (CLAG) and in Rio de Janeiro and Manaus in Brazil, resulting in two important collections of *Amazonian Dark Earths* papers (Lehmann et al. 2003; Glaser and Woods 2004). The topic is now of major scientific interest, of relevance both to prehistory and to agricultural development and global climate change today; hence the value of this historical survey.

When Woods began seriously looking at the phenomenon of the Amazonian dark earths in the early 1990s, a first step of course was to acquire as much of the previous literature as possible, review it, and begin a bibliography. Subsequently the bibliography has grown and has become a resource in itself that could be queried for substantive data on the development of and trends in dark earth studies. Toward that end he sent out a draft compilation to over three dozen other interested researchers asking them for comments, corrections, and additions, and he asked them to pass the bibliography on to others who might be able to contribute. Many responded, and the result reflects the combined efforts of numerous individuals.

1.2 The Bibliography

The bibliography through 2004 contains 311 items. All have been examined to determine that they have specific references to dark earths. Not included are newspaper stories, unpublished reports, letters, notes, and abstracts. Included are theses and dissertations and expanded abstracts published in conference proceedings. There are some additional unchecked references that may be included in future revisions of the bibliography. Undoubtedly there are other items, but we believe that these are few. This document is intended to be a work in progress which will be continually updated and distributed to interested parties (copies are available from William Woods, wwoods@ku.edu). Following are some general comments and then a review of early observations and studies.

An overwhelming proportion of the entries are relatively recent (Fig. 1.1). Since the 1960s there has been roughly a doubling in new entries every decade. Indeed, 202% or 65% of the entries have been published since 1990 and 124% or 40% since 2000. About two thirds of the entries are in English, 21% in Portuguese, 5% each in Spanish or German, and less than 2% in French. We should note that many of the Brazilians, Germans, and Colombians often have been publishing in English for over 20 years, so these figures do not truly reflect the linguistic origin of the authors. For example, the majority of the 55 authors and co-authors of the two recently published *Amazonian Dark Earths* volumes are non-native English speakers, and of the four editors Woods is the only one whose native language is English. Finally, 19 of the entries are either theses or dissertations from universities in Germany, Brazil, the United States, the Netherlands, Canada, and Great Britain.

The full bibliography is too long to include here. Thus in “The Bibliography, 1874–1977” that follows, we only list items for the period during which the initial discoveries and studies were made (61 items). The period of modern scientific research properly begins in 1978–1980, although one might be able to argue that both Katzer (1903) and Sombroek (1966) could well fit into the modern scientific period. Most of the publications on Amazonian dark earths from 1980 to 2004 are either in Lehmann et al. (2003) and Glaser and Woods (2004) or are listed in the bibliographies in those collections. The bibliography here through 1977 does not include some publications in which the information about dark earths is not substantial, with the exception of the earliest reports.

1.3 Initial Discoveries and Early Studies

All the entries are dated since 1874. This is extremely curious, since there are numerous explorers’, travelers’, and scientific reports about Amazonia beginning in the sixteenth century, and one would have expected that someone would have noted, if only in passing, so common and distinctive a phenomenon. However, searches of the literature and archives by numerous people have come up empty. The common settlement place name “*Terra Preta*” isn’t even mentioned. Soils in general are rarely referred to, and when they are it is in dubious sources such as the 1809 geography by Jedidiah Morse who merely says that "The soils are extremely fertile …" in Amazonia (p. 242). Perhaps this lack of interest in aboriginal resources stems from the Eurocentric view of the economic superiority of Old World technologies coupled with the prevailing idea of Amazonia as an unsullied wilderness. Not all shared this viewpoint including von Humboldt who admired the achievements of both the pre- and post-colonial Indians and said that "Every tropical forest is not primeval forest" in the neotropics (1869:193).

Ignorance of *terra preta* changed as an indirect result of the ending of the American Civil War. Many in the South decided to migrate to Latin America rather than to be re-Unionized (Dawsey and Dawsey 1995). The leader of one such group, Lansford Hastings, surveyed the Amazon Valley from Santarém to Manaus in 1866 and decided to establish a colony on the Belterra Plateau south of the city of Santarém. Selection of some of the richest dark earth lands in the lower Amazon could not have been a coincidence, but had to have resulted from local knowledge. Enormous dark earth sites at Panema, Diamantina, Taperinha, and Marurú all became plantations for the so-called "Confederados" in 1867 or shortly thereafter.

The first to note this correspondence in print was the geologist Charles Hartt (1840–1878) in his publications (1874a:227; 1874b:36–37; 1885:3, 12–16) describing the lower Tapajós based on his work there in 1870 and 1871, including excavations of the famous Taperinha site.[1] Both Hartt and his assistant Herbert H. Smith (1851–1919) in his book *Brazil: The Amazons and the Coast* (1979a) and in an article "An American Home on the Amazons" (1879b) clearly made the connection between the dark earths and prior Indian villages. Hartt (1874b:5, 7) used the term "kitchen middens" to describe these soils. He was the first to report modern Indian cultivation of *terra preta* (Hartt 1885:13). Smith (1879a:145, 168) said that "Strewn over it everywhere we find fragments of Indian pottery … the bluff-land owes its richness to the refuse of a thousand kitchens for maybe a thousand years." The British geologist C. Barrington Brown (1839–1917) made similar observations at about the same time when describing the black soils along the New River in Guyana: "In two places also, in the forest, were the sites of ancient villages, marked by a deep black soil mixed with broken pottery" (Brown 1876:339); and on the bluffs along the Amazon near Óbidos: "undoubtedly of artificial origin … highly prized as agricultural grounds, owing to their fertility; and they bear the name of "Terras pretas" (black earths)" (Brown and Lidstone 1878:270–271). In this publication Brown and Lidstone were apparently the first to use the term *terra preta* ("*terras pretas*") in print.

[1] Hartt's history has recently been described by Brice and Figueirôa (2003), who call him "one of he great explorer-geologists of the nineteenth century." He initially went to Amazonia in 1865–1866 with Louis Agassiz on the Thayer Expedition. (Agassiz in his famous book *A Journey in Brazil* [1868] makes no mention of dark earth during his travels between Belém and Tefé.) A respected scholar, Hartt was a correspondent with Charles Darwin. He founded the Geological Commission of Brazil in 1875. He was a professor of geology at Cornell University from 1868 to 1878, when not on leave in Brazil. Interestingly, Cornell is now one of the centers of Amazonian dark earths research, under soil scientist Johannes Lehmann. Hartt died in Rio de Janeiro in 1878 at the age of only 37 after contracting yellow fever in Amazonia.

Another early observer of the dark earth phenomenon was the geologist, clergyman, and explorer James Orton (1830–1877) who visited the Santarém area in 1868. The third edition of his book *The Andes and the Amazon* (1875:368) tells us that "The soil is black and very fertile. It beats South Carolina, yielding without culture thirty bushels of rice per acre." No indication was given by Orton that these soils might be anthropogenic. It is curious that neither of Orton's earlier two editions (1870, 1871) of this volume mention the dark earths and, indeed, they say that in the country surrounding Santarém "the soil is poor" (Orton 1870:251). Perhaps Orton's third edition was rewritten and expanded in response to Hartt's evidence to the contrary and his disparaging comments on Orton's earlier reports (Hartt 1872:243).

Hartt, Smith, Brown and Lidstone, Orton, Orville A. Derby (1851–1915), and J. B. Steere (1842–1940) (see below) in the 1870s were all English speaking and most mentioned the Confederados. It would have been natural for them in their travels in the Santarém region to visit the English speaking American colonists and observe their crops of rice, sugar cane, and tobacco on *terra preta* soils. These settlers undoubtedly had learned about the merits of the black earth soils from Indian and Brazilian farmers.

A posthumous monograph by Hartt was published in Brazil in 1885; however, with the exception of a note by Derby in the late 1890s about *terra preta* soils in the Trombetas region (Derby 1897–1898:374), nothing else on the dark earths was forthcoming until 1903 when Friedrich Katzer's (1861–1925) classic volume on the geology of the Amazon region was published in Leipzig. Based on his 3 years of fieldwork (1895–1898), Katzer (1903:64–70) recognized the fertility of these soils in the lower Amazon. He (1903:64, 67) stated that the region's "more distinguished wealth lies in its soil" and estimated that there were over 50,000 ha of *Schwarze Erde* immediately south of Santarém between the Tapajós and the Curuá Una rivers. Subsequent research has confirmed the extensive amount of dark earth there. Katzer conducted pioneering analytical work on these soils, and as a result concluded that they had a completely different origin from the Chernozems he knew in central Europe in that the former were cultural in origin. He found that these soils consisted of an intimate blending of mineral residuum, charred plant materials, and decomposed organics. Three dark earth samples were subjected to loss-on-ignition testing with results indicating high organic matter content, in stark contrast to soils from surrounding locations. Based on his analyses, Katzer suggested that because of their fertility the dark earths were cultivated in ancient times when the region was more or less densely populated, a prescient assertion. His would be the last published chemical analyses of dark earths until Sombroek in 1966.[2]

[2] Upon returning from Brazil in 1898, Katzer focused his research on the geology of Bosnia-Herzegovina and ultimately became the Director of the Geological Institute in Sarajevo. He authored over 140 scientific works, including his major book *Geologie Bosniens und der Hercegovina* published posthumously in 1925 (Ćorić 1999:131). Almost all of Katzer's collections were destroyed with the national museum during the tragic Bosnian war of the 1990s.

Thus, by the end of the nineteenth century several scientists had reported the presence of dark earths at various locations within Amazonia. They made the connection between Indian artifacts within the dark earth soils and an anthropogenic origin. The link between prior burning activities and charcoal as a major feature of these soils was made, and it was established that these soils were highly fertile and productive and probably used for agriculture in the pre-European past. However, very little further progress was made during the first half of the twentieth century.

There were no other publications on the dark earths until the 1920s. One was by the anthropologist William Farabee (1921:156–157), based on a trip to the Santarém area in 1915. On the northern edge of the Belterra Plateau on bluffs overlooking the Amazon he found that black earth marked ancient Indian settlements. The black earth was 1 to 2 ft deep and covered, in some places, as much as 10 acres of surface. In 1927, Steere (p. 24), a professor and traveler from Michigan, reported briefly on 1870 excavations and observations of dark earths on the plateaus to the east and south of Santarém, "…which were, no doubt, sites of ancient towns."

Sponsored by the Ethnographical Museum of Göteborg, Sweden under the direction of Erland Nordenskiöld, between 1923 and 1925 the German-naturalized Brazilian anthropologist Curt Nimuendajú (1883–1945; Curt Unkel before 1922) conducted excavations and surveys of dark earth sites within the lower Tapajós region and adjacent Amazon bluffs. Like Katzer, Nimuendajú (2004:122) believed that the dark earths had developed from Indian habitation activities associated with permanent settlements and that the resultant fertile soils were then used for crop production. He produced a manuscript in 1925 entitled "Die Tapajó" and beginning in 1923 a number of maps showing locations of *terra preta* sites, with relevant publications not until after his death (Nimuendajú 1948:216; 1949; 1952; 1953; 2004). The latter publication is the result of the efforts of several individuals, most notably the editor, Per Stenborg. It consists of comprehensive translations to English with interpretation of Nimuendajú's manuscripts, notes, and correspondence held at the Göteborg Museum. An editor's preface and introductions by Eduardo Góes Neves and Stig Rydén, coupled with further commentary by these individuals, provide the necessary background for placing Nimuendajú's work in its full historical and contemporary scholarly context. A total of 67 figures, 200 plates, and 21 maps illustrate the wealth of the materials collected by Nimuendajú, give accurate representations of his sketches and plans, and provide through historical and modern photographs the settings for his investigations.

The decade of the 1930s is marked only by the 1933 posthumous publication of a Portuguese translation of Katzer's 1903 book. The lack of dark earth publications in the 1920s and 1930s is puzzling. This was the period of the failed Fordlandia rubber-plantation venture, initiated in 1927 along the upstream Tapajós, with most of the production activities subsequently transferred in 1934 downstream to the much better setting at Belterra. Significantly, the Belterra Plateau has an exceptional density of dark earths, and the zone centered on the town of Belterra is especially rich in these soils. However, no special mention seems to have been made of them in the literature or to the fact that rubber trees grow especially well on them (W Sombroek 2002, personal communication, Manaus). In an effort to investigate further the possibility that dark earths were a major factor in the decision to move production, Woods conducted archival research at the Benson Ford Research Center on records relating to Fordlandia and Belterra. This research indicates that the level terrainof the latter and its position at the head of year round access by deep water ships were considered to be much more significant than any differences between thetwo tracts' soil properties.[3] Equally curious is the failure of Marbut and Manifold to mention dark earths in their classic 1927 *Geographical Review* article on the soils of Amazonia. They clearly conducted soil survey and sampling in the heart of the dark earth country, but seem to have ignored the presence of this unique soil.

In the 1940s, 1950s, and 1960s various observers reported and described dark earth soils. However, rather than analytical research, attention was more focused on possible natural origins of the soil, in contrast to the earlier belief that the soil was of human origin (Glaser et al. 2004:10; Myers et al. 2003:23). The Brazilian agronomist Felisberto Camargo (1941) believed that *terra preta* came from volcanic ash. Archaeologist Barbosa de Faria (1944) and pedologists Cunha Franco (1962) and Ítalo Falesi (1965; 1967; 1972; 1974:210–214) argued that *terra preta* was formed by the accumulation of organic material in past lakes and ponds, and that such sites attracted Indian settlement, which explained the cultural midden material present; therefore a mixed natural and anthropogenic origin. Ítalo Falesi (2002, personal communication, Manaus) now believes that these soils resulted from human activity. In 1949 the French geographer Pierre Gourou reviewed various origin theories and concluded that the soil he had observed was probably "archaeological" (1949b:375–379), as did Hilbert (1968). In 1944 an extract from Katzer's 1903 geology book was published in Brazil as "A Terra Preta." This was the first article specifically on *terra preta* and is frequently cited.

The Brazilian-American geographer Hilgard Sternberg described *terra preta* soils in his 1953 dissertation (Universidade do Brasil, presently Universidade Federal do Rio de Janeiro) on Careiro Island east of Manaus, published in 1956 (new edition in 1998, see pp. 107–110)). Sternberg (1960:417, 419) radiocarbon dated ceramics in *terra preta* soil on Careiro in order to determine the antiquity of the migration and stability of Amazon channels. Later, he pointed out that: "It is remarkable that in an environment such as Amazonia, whose potentials have been judged insufficient to support large concentrations of population or stable settlement (Meggers 1954), indigenous settlements should have been so large and persistent" (Sternberg 1975:32–33).

For the 1960s the soil studies by Franco, Falesi, and Hilbert are mentioned above. Falesi (1967) believed that *terra preta* was so common that he recognized it as

[3] An April, 1935 photograph (Benson Ford Research Center #0–7672) of the 121 acre *Hevea brasiliensis* nursery at Belterra shows two men in the foreground standing at the edge of a large level field with pottery sherds lying on the bare black soil literally at their feet. This photograph has been published in Bryan (1997:159).

Fig. 1.2 Wim Sombroek at the Hatahara site, July 2002. (Photograph taken by Johannes Lehmann)

a taxonomic unit. In 1966 Dutch soil scientist Wim Sombroek (Fig. 1.2) based on his earlier dissertation published his classic *Amazon Soils*, which includes descriptions and lab analyses of dark earths on the Belterra Plateau (Sombroek 1966:174–176, 252–256, 261). He made a distinction between black *terra preta* proper derived from village middens and brownish *terra mulata*, a term he introduced to the literature, which be believed "obtained its specific properties from long-lasting cultivation." He was the first to suggest this as far as we know. And he mapped the distribution of dark earths along the bluffs of the lower Rio Tapajós (p. 175). In 1966 he questioned whether it was "economically justifiable," in his words, to create and cultivate such soil today (p. 261). However, more recently, he promoted the idea of developing new dark earth as carbon stores and sinks for intensive cultivation, what he called "*Terra Preta Nova*" (Sombroek and Carvalho 2002; Sombroek et al. 2003:136; Madari, Sombroek and Woods 2004). In recognition of his enormous contributions to *terra preta* research, the two recent *Amazonian Dark Earths* books and this one are all dedicated to Wim, "The Godfather of Amazonian Dark Earths," who passed away in 2003.

In the 1970s, reports of Amazonian dark earths are scattered and uneven. They include, among others, Falesi (1970; 1972:33–39; 1974:210–214), Klinge et al. (1977), Ranzani et al. (1970), and Simões (1967, 1974). Botanists Prance and Schubart (1977:569; 1978:61–62) in the lower Rio Negro region examined *campina* forest on fertile *terra preta* in contrast with surrounding open *campina* scrub. Archaeologist Betty Meggers in her 1971 bestseller book on Amazonia (pp. 132–134) brought *terra preta* to the attention of a wide audience outside Brazil, but she failed to realize the significance for prehistoric cultivation either then or in the revised edition 25 years later (Meggers 1996:132–134). Meggers (e.g. 2001:310–319) attributes the development of these distinctive soils to recurrent short-term occupations of the same general site over long periods of time. The archaeologically demonstrated presence of large, planned, and persistent pre-European settlements associated with dark earths in the lower Negro and upper Xingu regions (Heckenberger 1996:2005; Heckenberger et al. 1999; Neves et al. 2003; Petersen et al. 2001) strongly suggests that the Meggers' view is in need of serious reconsideration (Fig. 1.3).

Fig. 1.3 Archaeologists Eduardo Neves and Betty Meggers meeting for the first time and discussing *terra preta at* the XI Congresso da Sociedade de Arqueologia Brasileira, 24 September 2001, Rio de Janeiro, Brasil. (Photograph taken by William Woods)

1.4 Conclusion

The first century of publications about Amazonian dark earths, involving discovery and initial descriptions, properly ends in the late 1970s. The modern period of scientific study can be identified as beginning with the soil science publications by the Japanese Renzo Kondo in 1978 and by the Germans Wolfgang Zech et al. and Gerhard Bechtold in 1979. Then, in 1980 Nigel Smith's influential survey article was published in the *Annals of the Association of American Geographers*.[4] The number of publications with reference to dark earths increased from 24 in the 1970s to 42 in the 1980s to 78 in the 1990s to 124 from 2000 through 2004 (Fig. 1.1), an indication of the dramatic explosion of dark earth research and commentary since 1980 and particularly since 1990. Thus, the topic of Amazonian dark earths is finally receiving focused scientific attention following a century of inattention to the reporting by perceptive observers such as Hartt, Katzer, Nimuendajú, Sombroek, Falesi, and a few others.[5]

[4] Nigel Smith was a doctoral student of Hilgard Sternberg.

[5] Internet search engines provide another measure of spectacular growth in interest in the dark earths. A 2008 query at google.com using the entry "*terra preta*" yielded over 600,000 internet site links; the same entry in 2000 would have provided at most a few dozen. Some of this difference is certainly due to the greater efficiency of the search engine, but most of the entries are post-2000. There is some duplication and many items which are not for Amazonian *terra preta*. Nevertheless, amazing!