Amazonian Dark Earth: A Model of Sustainable Agriculture of the Past and Future?

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Abstract: Amazonian Dark Earth (ADE), known in the Brazilian Amazon as "terra preta do índio", is a fertile anthropogenic soil that is considered to be a potential model for sustainable agriculture in Amazonia and beyond. Pedological studies have shown that pyrogenic carbon is a key feature of the soil, exhibiting many important functions that enhance nutrient availability and soil organic matter stability. Aside from these benefits, pyrogenic carbon is considered to be an effective carbon store and sink. This paper examines the history of ADE research and discusses the application of the ADE model for the development of carbon sequestration and soil fertilization technologies in the global market. The paper concludes with suggestions as to how such technologies may be adapted to benefit rural smallholders of Amazonia, the originally intended beneficiaries of ADE studies.

Keywords: Amazonian Dark Earth, Terra Preta Do Indio, Sustainable Agriculture, Carbon Sequestration

Introduction

ACROSS THE AMAZON Basin, vestiges of Pre-Columbian indigenous settlements can be found in the form of dark, fertile soils known as "*terra preta do índio*" or Amazonian Dark Earth (ADE). Accounts describing these soils date back to the late 1870s, but research projects dedicated to the study of ADE have only begun in recent decades. In contradiction of the prevailing notion that Amazonian *terra firme* (upland) soils inhibited the development of complex societies, ADE demonstrates that past human populations had altered the environment in ways that rendered regional soils more suitable for agricultural production and consequently, human habitation (Denevan 2001: 124-5; Heckenberger et al. 1999; Heckenberger et al. 2007; Stahl 2002; Woods and McCann 1999; cf. Meggers 1996).

Today, ADE has been touted as a potential model for sustainable agriculture in Amazonia and beyond (Glaser et al. 2001; Madari et al. 2003; Steiner et al. 2003). Pedological studies have shown that pyrogenic carbon (black carbon, charcoal) is a key feature of the soil, exhibiting many important functions that enhance nutrient availability and soil organic matter stability (Glaser et al. 2003; Lehmann et al. 2002). In addition to improving soil fertility, pyrogenic carbon is considered to be an efficient carbon store and sink (Sombroek et al. 2003). These factors have propelled the ADE phenomenon from relative obscurity to the attention of international agronomists and environmentalists. The media have also caught wind of the ADE phenomenon and have produced enthusiastic (although perhaps overly optimistic) articles about the potential of ADE for curbing global warming and promoting environmentally-sound agriculture (Binns 2006; Mann 2002a, 2002b; Marris 2006).

This paper seeks to illuminate the history of ADE, describing its initial scientific recognition and the development of international research projects dedicated to the study of the soil. This historical overview is followed by a discussion regarding the intended application of the ADE model for the development of a carbon sequestration and soil fertilization technology in the global market. Finally, this work addresses how bio-char technologies can be adapted to meet the needs of rural smallholders of Amazonia, the originally intended beneficiaries of ADE studies.

A Brief History of Amazonian Dark Earth

When the American Civil War ended in 1865, a number of Confederate families decided to migrate to Brazil rather than remain in the defeated South. One particular man, Major Lansford Hastings, surveyed parts of Central Amazonia and chose to establish a colony in an area south of the city of Santarém in 1866 (Griggs 1987). A little more than a year after having procured the land, Hastings died during a trip to recruit more settlers from the American South (ibid). Nonetheless, the colonists, known as "Os Confederados", remained and many of them situated their plantations on dark earth sites, whose fertility they most likely had learned of through local peoples (Woods and Denevan 2007).

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Around the time of Hastings's arrival to Amazonia, Charles F. Hartt, a young Canadian geologist, was exploring parts of the region with Louis Agassiz as part of the Thayer Expedition[1]. During the expedition, Hartt spent 15 months in Brazil and became intrigued by the geology and natural history of the land. After returning to the U.S. and accepting a teaching position at the newly founded Cornell University in 1868, he began preparing for a second trip to Brazil.

Between 1870 and 1871, Hartt led the Morgan Expeditions to survey geologic formations of Eastern and Central Amazonia (Hartt 1874). During this period, Hartt made contact with a number of Confederate families that had settled in the area near Santarém. One particular man, Romulus J. Rhome, had taken notice of the wealth of ceramics found in ADE and introduced Hartt to the dark earths and shell-midden (*sambaqui*) near Taperinha. There, Hartt made collections of ceramics and other cultural material, which today are held in the Peabody Museum at Harvard[2]. Upon return from the expedition, Hartt published the first description of ADE in 1874.

Outside of the Central Amazon, Hartt and his students also explored areas of eastern Pará, including Marajó Island. During this period, Hartt collaborated with Domingos Soares Ferreira Penna, a Brazilian scholar who conducted preliminary surveys of Marajó in 1870 (Hartt 1874: 3). Ferreira Penna and Hartt had met during the latter's first visit to Brazil during the Thayer Expeditions and the two corresponded frequently (Moraes Bertho 2001: 150). Some scholars consider Ferreira Penna to be one of the first Amazonian archaeologists as he surveyed numerous archaeological sites and wrote extensively about archaeology and ethnology of the Amazon[3]. Perhaps even more importantly, Ferreira Penna founded what would later become the Museu Paraense Emílio Goeldi, the primary institution of archaeological and anthropological research in Amazonia (Barreto and Machado 2001). Together, the archaeological investigations of Hartt and Ferreira Penna exposed the widespread existence of dark earths and related anthropogenic landscapes of Amazonia.

In this early stage of research, the relationship between the soil's fertility and indigenous occupation was not understood, but it was suggested that such sites were the product of Indian kitchen middens (Smith 1879: 168). The anthropologist Curt Nimuendajú supported this argument after surveying numerous ADE sites during expeditions across the region in the 1920s and 1930s (Nimuendajú 2004). Peter Paul Hilbert drew similar conclusions from his archaeological surveys in the region during the 1950s (Hilbert 1968). However, during this same period, several scholars would attempt to refute the idea that dark earths were the result of indigenous settlement. Felisberto Camargo hypothesized that the soils had formed from volcanic ash while Barbosa de Faria and Cunha Franco argued that they had formed from dried lakes (Camargo 1941; Barbosa de Faria 1944; Franco 1962; Falesi 1974). Despite this trend, later scholars continued to assert that humans played a crucial role in the formation of dark earth. Wim Sombroek, in particular, argued that areas of ADE were sites of former occupation while the more extensive *terra mulata* soils, a lighter variation of the soil with little ceramics, were ancient agricultural fields (Sombroek 1966). In the 1980's, following the publishing of Nigel Smith's 1980 article "Anthrosols and Human Carrying Capacity in Amazonia", this human link to Amazonian Dark Earths became more widely accepted once again (Smith 1980; Woods and Denevan 2007). Today, contemporary research has concluded that dark earths are in fact the product of indigenous occupation, although the exact processes by which they have formed are still disputed.

Recent Pedological Contributions to the Study of Amazonian Dark Earth

Since the early recognition of ADE, on-going pedological studies have done much to shed light on the dynamics of the soil's formation and fertility. Research has shown that pyrogenic carbon, derived from charred plant material, is found throughout the ADE soil matrix and its presence is considered to be one of the reasons for the soil's fertility. Although high concentrations of pyrogenic carbon are not equated with higher nutrient contents, the carbon plays an important role in maintaining nutrients in the soil and preventing nutrient leaching, a common problem in Oxisols of the Amazon (Glaser et al. 2003).

In slash-and-burn agriculture, which is a dominant practice in the Amazon today, the burning of slash produces mostly ash, which doesn't allow for effective retention of nutrients in the soil matrix. However, it has been suggested that Pre-Columbian indigenous groups maintained more intensive agricultural practices that contributed more charcoal to the soil matrix

[1] Agassiz, who led the expedition, sought evidence of Late Pleistocene glaciation at sea level in the tropics, an event which would have destroyed all life on land. Agassiz believed that such a discovery would demonstrate divine recreation, and thus disprove Darwin's Theory of Evolution (Brice and Figueiroa 2003).

[2] The archaeologist Anna Roosevelt examined Hartt's collection and writings before conducting her own investigation of Taperinha where she found the oldest pottery to date in Amazonia (see Roosevelt et al. 1991)

[3] Summaries of Ferreira Penna's contributions to archaeology are included in Helen Palmatary's article discussing pottery of Marajó Island (Palmatary 1949:270-273) as well as Hartt's *Contribuições para a Ethnologia do Valle do Amazonas* (Hartt 1885).

(Denevan 2001: 39). Others have suggested that village fires and other forms of burning may have contributed to the formation of ADE in an unintentional manner (Smith 1980). Regardless of how the material was introduced into the soil, it is known that pyrogenic carbon is chemically and microbially stable and can persist in an environment for centuries. Consequently, the carbon is a persistent feature that retains soil nutrients, thus improving the overall fertility of the soil (Lehmann et al. 2002).

Terra Preta Nova: A Model for Sustainable Agriculture

In 2002, during the First Amazonian Dark Earth Workshop in Manaus, the late Wim Sombroek proposed the idea of the *Terra Preta Nova* (New Dark Earth) project. The project was designed with the aim of replicating dark earths in order to improve the capacity of small-holder agriculture in the Amazon (Sombroek et al. 2002). The project was also presented as an opportunity for ADE researchers to network and collaborate. Members of the workshop agreed with the proposal and institutions from Brazil, the United States, Germany, and the Netherlands were invited to participate. Universities, research institutes, and a museum were integrated into the project in addition to EMBRAPA, the Brazilian Agricultural Research Corporation[4]. Through international collaborative research, it was hoped that a model for a "new dark earth" could be produced.

Bio-Char: An Amazonian Dark Earth-Inspired Technology

At the time that the *Terra Preta Nova* project was conceived, the corporation EPRIDA was founded in the United States[5]. The founder of the company, Danny Day, had collaborated with laboratories from the U.S. Department of Energy to develop a process by which biomass could be used to produce hydrogen fuel. Day found that charcoal produced in this same process could also be used as an agricultural amendment following the ADE model. From this research, Day founded EPRIDA and filed a patent for his process of producing hydrogen fuel and charcoal fertilizer, known as "bio-char". Day demonstrated that when biomass is converted to biochar, the carbon that is normally released into the atmosphere during the decomposition of the organic matter is locked in the charcoal. Thus, bio-char represents a simple technology that can diminish carbon emissions and improve agricultural yields by storing charcoal in soil.

Since EPRIDA opened its business, a number of other alternative energy companies have adopted similar models for the production of bio-char including Dynamotive, Bioware, Best Pyrolysis, and Terra Humana Clean Energy. Today companies offering pyrolizers and bio-char products exist in 10 countries across the world. While EPRIDA is promoted as a socially-responsible corporation focused on assisting subsistence farmers, other companies believe that they may be able to profit by promoting their model for industrial farmers and large agribusinesses. With the advent of carbon markets, it is believed that the use of bio-char for carbon sequestration can render such models profitable. As the FAO and other international organizations have begun to demand greater investment in research and development focused on improving the capacity of agricultural lands to sequester carbon (FAO 2004), private corporations are beginning to respond to this demand. Opportunities for such investment exist not only for agricultural lands under active management, but for degraded areas as well (See Lal 2004a; 2004b)

Responses to Bio-Char Technology

U.S. and European news corporations have caught on to the ADE phenomenon, publishing articles with such titles as "Scientists Promote Benefits of 'Black Magic' Soil" (Binns 2006) and "Black is the new green" (Marris 2006). However, not everyone has shared the same enthusiasm for the development of a new and profitable charcoal fertilizer. Some scholars feel that with the promotion of bio-char as a product designed for industrial agriculture, the original intention of the *Terra Preta Nova* project is being abandoned for big profits in international markets. In response to the *Nature* article "Black is the new green", three researchers spoke specifically about this trend:

> "…one might be left with the impression that the biochar initiative is solely directed towards agribusiness applications. From the start, this has certainly not been the case. Indeed, innovative biochar field trials involving a variety of crops are currently being conducted in Amazonia…These trials are specifically designed for implementation by smallholders, who comprise most of the world's farmers" (Woods et al. 2006).

Other concerns are voiced by Madari et al. in the volume *Amazonian Dark: Explorations in Space and Time* (Madari et al. 2004). Due to the larger history of Amazonian Dark Earth and its relationship to in-

[4] See Madari et al. 2004 for a complete listing of institutions participating in the Terra Preta Nova project.
[5] Visit www.eprida.com for further information regarding the company's history and its products.

digenous people of South America, they argue that it is more appropriate for such technology to be developed and managed in the Amazon region (specifically Brazil):

> "It is important to emphasize that many of the ADE sites have a reasonable amount of archaeological material which makes these areas important subjects of cultural heritage preservation. The objective of studying this phenomenon by no means can be the exploration of discovered new sites, but the use of the 'buried' information in these soils. This information should be considered as the intellectual property of the indigenous people of Amazonia. For this reason, it would be fortunate if the administration of a project aiming to study and use the knowledge of this phenomenon stayed with a Brazilian national institution like Embrapa (Brazilian Agricultural Research Corporation) which would ensure proper handling of intellectual property rights and even-handed and socially acceptable distribution of the products and technologies" (Madari et al. 179).

By the time these words were published, however, the development of such technologies had already moved beyond the Amazon to the U.S. and Europe, linking it to the larger global market of industrial fertilizers and carbon trade. How this development relates to the original dark earth and the application of bio-char in Amazonia is a question that requires further analysis.

Cultural and Intellectual Property Questions

Due to Amazonian Dark Earth's association with indigenous settlements, Madari et al. (above) claimed that such soil should be considered either cultural or intellectual property of indigenous people (Madari et al. 2004). However, ambiguities that exist in the current understandings of ADE and intellectual and cultural properties themselves make such a determination difficult at best. Strathern describes cultural property in the following manner: "…one of the tests of a group's claims may be the transmissibility of cultural knowledge over the generations: it is authentic because it can be shown to have been handed on" (Strathern 1999:169). Clearly, Amazonian Dark Earth fails to hold up to this definition. These soils are in part defined contemporarily by their divorce from the peoples that are responsible for their formation. Intellectual property, in contrast, is described by Stathern as claimable precisely because it is not handed on over generations (ibid.). In other words, the knowledge associated with the phenomenon must be isolated and controlled. Amazonian Dark Earth does not comply with this definition of property either. First, the soil is distributed widely throughout the basin, in a number of different countries and contexts. Second, no evidence has shown that ADE is more than a bi-product of indigenous habitation, begging the question as to whether or not there's any human process related to its formation that can be considered "intellectual". Even if one were to consider ADE an intellectual property, how would it be managed and by whom? How would compensation be provided for using it as a model and who would benefit from this compensation?

The fact remains, however, that ADE's origins are intimately linked to past indigenous occupation in the Amazon. How these anthropogenic landscapes can be managed and defined as "properties" is an issue that demands further consideration by anthropologists and civil society at large. Currently, the FAO is considering ADE as one of the world's Globally Important Ingenious Agricultural Heritage Systems (GIAHS 2006). Such programs may draw greater attention to the existence of anthropogenic environments and their value for understanding long-term relationships between humans and the environment. Also, as research has shown that ADE soils contain up to 70 times more pyrogenic carbon than surrounding soils (Glaser et al. 2001) and consequently represent important carbon stores, contemporary smallholders and indigenous groups that occupy ADE sites could potentially receive some compensation for their management of these soils under the new carbon economy.

Biopiracy and the Neighbors to the North

The tensions that are apparent in the commercialization of bio-char and the handling of ADE as a cultural property are situated in a larger context of Brazilian uneasiness with foreign interests in Amazonia. In October of 2006, the British Secretary of State for Environment, Food and Rural Affairs, David Milliband, was planning to propose an initiative that would call for the privatization of parts of Amazonia (Hennessey 2006). When the news was released by the British newspaper *The Daily Telegraph*, Miliband's office rejected the story, in attempt to avoid mounting political backlash. Responding to the notion of such a plan, Brazil's Foreign Minister and Environment Minister simply stated: "Amazonia is not for sale" (Geraque and Canônico 2006).

Since Henry Wickham left Belém with a ship full of rubber seeds, which later led to the establishment of rubber plantations in Southeast Asia and the bust of the 'Rubber Boom', Brazilians have become increasingly suspicious of the activities of foreigners in Amazonia. Some have argued that Wickham left the country with the Brazilian port authority's full knowledge of the seeds that he was carrying, but regardless of whether this is true or not, the event became symbolic of a larger concept introduced to contemporary discourse concerning property rights and biological research: the notion of "biopiracy".

Biopiracy is a concept that has been used to describe foreign extractive activities that lead to the development of products derived from biota endemic to an area or region. The American Heritage Dictionary defines biopiracy as the following: "The commercial development of naturally occurring biological materials, such as plant substances or genetic cell lines, by a technologically advanced country or organization without fair compensation to the peoples or nations in whose territory the materials were originally discovered" (Pickett 2000). One recent example of biopiracy comes from a patent filed for the process to extract fat from cupuaçu (*Theobroma grandiflorum)* seeds. The process, which is used for the making of *cupulate* (a product similar to chocolate) was developed by EMBRAPA, but had been claimed by the Japanese corporation Asahi Foods. Asahi Foods also placed a trademark on the name "cupuaçu" for the sale of its products derived from the fruit. Both of these claims eventually went to international courts and were sided in favor of EMBRAPA (Medina and Almeida 2006). Similar legal wrangling occurred over international patents and trademarks related to the use of the recently popularized Amazonian berry, *açai* (ibid.). As Amazonians witness foreigners attempt to profit from products native to their region, their relationships with these outsiders is not without a sense of resentment and regret.

In the case of bio-char, biopiracy is not an issue, yet research and development on the subject may cause similar tensions. As outside companies develop processes to produce charcoal fertilizer and carbon sequestration technologies inspired by ADE, Amazonians are faced with another example in which outsiders are capitalizing upon their natural and cultural resources.

Revisiting World Systems Theory and Dependency Theory

A multitude of theoretical arguments have been made to explain the process by which some nations and/or groups have exploited others through time in the global economic and political arena. In the 1970s, Immanuel Wallerstein's "World Systems Theory" and Andre Gunder Frank's "Dependency Theory" were particularly popular models for explaining the historical forces which bind "developing" nations to a cycle of "underdevelopment."

In Wallerstein's work *The Modern World System I* (1974), he examines the origin of the European World-Economy in the 16th century. In this historical account of capitalist origins, Wallerstein distinguishes between "core" countries and "the periphery". The relationship between the periphery and the core is defined by unequal exchange, in which the core countries produce high-profit, high-capital intensive goods that are exchanged for low-profit, low-capital intensive goods produced in the periphery. Wallerstein concluded that this unequal exchange produced increasing social and economic disparities between the core and the periphery, which perpetuated such imbalance.

Andre Gunder Frank, a contemporary of Wallerstein, had proposed similar ideas, describing countries in terms of "metropoles" and "satellites". Rather than view "development" and "underdevelopment" as two distinct phenomena, Frank understood them as being intimately linked (Frank 1966). According to his argument, the metropolis extracted surplus from the satellites, inhibiting their development and feeding its own. Frank described this as "the development of underdevelopment", which perpetuated the same disparities as described by Wallerstein.

In the contemporary knowledge-based economy (Gibbon et al. 1994), it is difficult not to draw similar comparisons between the manner in which information and knowledge is drawn from the periphery and satellites to the contemporary cores and metropoles, much in the same way natural resources and labor once were (and are). However, critics of the work of Wallerstein and Gunder Frank have described these models as too simplistic, essentialist or deductivist. It has been pointed out that *within* nations termed as either metropoles or satellites, there exist further networks of metropoles and satellites. Moreover, it has been argued that with the advent of the internet and global mass communication, the flow of information and resources is far too disarticulated to be explained by models presented in such terms. Yet it is recognized that rural Amazonia remains at the periphery, or at best, the frontier (see Schmink and Wood 1992). This is evidenced by its treatment historically as a target of *extraction* and not a focus of *development*. In fact, much of the debate regarding issues of sustainability, biodiversity maintenance, and global climate change has centered on the issue of whether the global community should allow for the development of Amazonian forests, or perhaps pay Amazonian nations to leave them untouched[6]. As such, the U.S., Western Europe, and Japan have sought to promote research to understand and protect Amazonia's natural wealth while attempting to bar Amazonian nations from developing the region for

[6] With the development of carbon markets, Amazonian nations can potentially receive compensation for maintaining tracts of forest intact or reducing national deforestation rates following "compensated reduction" plans (see Santilli et al. 2006; UNFCC 2007)

their own needs of land, energy, and resources. Although the development of bio-char as a technology modeled after ADE is only a footnote in the larger history of this process, it is testament to the perpetuation of a lopsided exchange.

Ironically, it can be argued that the force that led to the end of ADE's formation (i.e. Western imperialism powered by global capitalism) is the same force that has led to the introduction of this indigenous phenomenon to contemporary global markets. Global capitalism's opportunistic exploitation of resources and knowledge is a familiar intellection, but its increasing capacity to transform local natural and cultural resources into new global technologies while simultaneously isolating the actors from which they were drawn is concerning. Fortunately, in the case of Amazonian Dark Earth, the process that foreign corporations have developed to produce bio-char fertilizer does not prevent South American corporations from devising a similar process for the production of charcoal fertilizer and carbon sequestration technologies, and some corporations in Brazil have begun to do so. Yet whether these models will ever come to benefit to rural Amazonian smallholders is another question entirely.

An Amazonian Dark Earth Technology Exchange?

For developed nations, ADE and more specifically, bio-char, represents a model that can facilitate a shift towards agriculture that is perceived as environmentally friendly and "sustainable". How this model of sustainable agriculture for the developed world can benefit rural Amazonians is not clear. As much of the present research regarding bio-char is moving its focus towards application for large-scale mechanized agriculture, it appears that the rural smallholders of Amazonia will have little to gain from these developments.

Recently, however, technologies similar to those developed for the production of bio-char have been introduced to Amazonian communities by the *Centro de Desenvolvimento Energético Amazônico* (Center of Amazonian Energy Development) from the Universidade Federal do Amazonas[7]. These technologies are being used to process açai seeds for the production of biodiesel that can be used to power community generators. As EPRIDA and other corporations have shown, this technology can be used not only to harness fuel from biomass, but also create bio-char, which could serve as an added benefit for local farmers, all while sequestering carbon for the developed world. Although it would require tremendous investment, pyrolizers modeled after those of bio-char corporations could finally contribute to the development of a "New Dark Earth" in the Amazon. Perhaps more importantly, if smallholder farmers and indigenous groups are able to demonstrate that they actively heighten carbon sequestration in their agricultural lands, such communities may be able to attract investment from the international carbon market. Further pilot projects must be carried out in tandem with organizations like the *Centro de Desenvolvimento Energético Amazônico* in order to explore the potential of such technology for rural development.

Conclusion

The development of bio-char as a technology is the indirect result of more than 100 years of research in Amazonia and an even longer history of occupation by its indigenous inhabitants. The potential this technology has for improving agricultural production and sequestering carbon is promising, but how these benefits will be distributed is yet to be seen. The purpose of this analysis here is not to demonize foreign corporations for profiting on this model since they are equally responsible for its modern application, but rather point out that efforts must be made to implement these technologies for the benefits of rural farmers in Amazonia and the tropics in general, as these were the originally intended beneficiaries of ADE research. If Amazonia and the rest of the developing tropics are to become images of sustainable development, then the developed world must cease to view them as "pristine" forests needing to be saved, but rather complex social spaces where development projects must attend to not only the needs of the local environment, but its people as well. By providing alternative sources of energy while sequestering carbon in the form of charcoal, new bio-char processing technologies have the potential to do exactly this. With the development of carbon markets, bio-char processing technologies may not only contribute to the objective of stabilizing global carbon emissions, but they may provide necessary income for rural smallholder communities as well.

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[7] Visit the site for the Center of Amazonian Energy Development from the Universidade Federal do Amazonas at http://cdeam.ufam.edu.br/

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