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Amazonian Dark Earths: Wim Sombroek's Vision

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Chapter 28
Terra Preta Nova – Where to from Here?

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28.1 Introduction

Terra preta de índio (also called Amazonian Dark Earths or ADE [a term introduced by Woods and McCann 1999]) is one of the most fascinating and intriguing re-discoveries in modern soil science. Its study led to a shift in our understanding about pre-Columbian civilizations (Neves et al. 2003) and provides a plausible explanation for a much greater carrying capacity of the highly weathered Amazonian soils than hitherto anticipated. ADE soils have sustained a high fertility (Lehmann et al. 2003b) as expressed in their elevated nutrient availability and organic matter contents for hundreds to thousands of years after they were abandoned by the populations that caused their appearance. Could it be that these soils were purposefully created by Amerindian populations to improve the productivity of the soil as suggested by some (Woods et al. 2000; Neves et al. 2003)? And, could the emergence of ADE even be the reason for the development of civilization in the Amazon with more numerous and more complex societies than was anticipated until recently (Heckenberger et al. 2003)? How did they do it? The answer to that question may also teach us valuable lessons for sustainable landuse management in our time.

However, the lessons that ADE can teach us do not hinge upon the fact whether or not the Amazonian populations intentionally created these fertile soils for improving soil productivity for agriculture or whether they are an accidental byproduct of habitation. We can even draw the most important conclusions without ever knowing how ADE was actually created. These lessons can be gleaned from the properties of ADE today and the fact that these were in some way 'created' at a particular point in history a long time ago. As we can understand it today, the most important aspect of ADE is its high nutrient availability and high organic matter content. The goal of the recent efforts in ADE research has therefore been to find the answer to the question how it is possible that these favorable properties can still be observed after such a long period of time. What is unique about ADE that explains its sustainable productivity? Some of these lessons will be discussed in the first part of this chapter. In the second part, one of these lessons will be discussed

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in more detail with respect to the development of a new soil and biomass management approach: biochar agriculture for environmental management.

28.2 Terra Preta as a Training Ground

A multitude of lessons have been learned from ADE research to date, and many more will certainly emerge over the coming decades. These lessons reach from getting a better understanding of the basic biogeochemistry of soil such as its organic matter cycles (Glaser et al. 2003), the long-term nutrient dynamics (Lehmann et al. 2003b), or its biological diversity (Thies and Suzuki 2003); but also lessons about the management of fertile soils with respect to weeds (Major et al. 2005) or agrobiodiversity (Clement et al. 2003); and ADE research provided important clues for the prehistoric soil management through archaeological excavations (Neves et al. 2003) as well as the study of contemporary ways to manage the fertility of ADE (Hecht 2003).

28.2.1 Soil Biogeochemistry

Possibly, the most important lesson that has already been successfully adapted into research for future soil management is the occurrence of large amounts of biochar (also called charcoal, biomass-derived black carbon or pyrogenic carbon) in ADE (Glaser et al. 2001). It is by now well established that the stability of organic matter in ADE is based on the macromolecular composition derived from biochar (Solomon et al. 2007). The high stability of biochar has been recognized for many soils worldwide (Preston and Schmidt 2006), largely through the analyses of the C^{14} age of the naturally occurring biochar fraction of soil organic matter. ADE provides a visible proof for the stability of biochar in soil: the age of the biochar can be related in a qualitative way to the occurrence of biochar. If more than 50% of the organic matter of a surface soil is composed of biochar as shown by Liang et al. (2006) with an age that can be traced back to activities occurring for example about 1,000 BP as observed in many ADE, then it can be concluded that this carbon pool is cycling very slowly in relation to the rest of the organic matter. However, a turnover time can not be obtained, as no approach has so far demonstrated how the original amounts of biochar can be estimated to calculate a mass balance. Possibly with the collection of more dates of ADE appearance in conjunction with their molecular characterization will provide opportunities for estimating biochar turnover. This will hinge upon the progress of archaeological excavations in the Amazon.

Another opportunity that the defined time of biochar accumulation in ADE provides is the study of the changes of biochar over time. Such studies are much more difficult to conduct in soils with natural and recurring biochar accumulation that show average ages. Biochar fractions would need to be physically separated, which is laborious and does not lead to well-defined age classes due to the continuum of biochar properties (Krull et al. 2006). Several other opportunities to obtain sites with defined biochar deposition exist for example from charcoal accumulation for fuel production in the vicinity of pig iron ovens which was a common practice throughout the eighteenth and nineteenth century in the Eastern and Midwestern U.S. (Schallenberg 1975). These kilns were in operation for only several decades at a time that provide relatively distinct deposition periods. Other examples are dark earths sites in Europe (Schmidt et al. 1999), in Africa (Brooks and Smith 1987; Fairhead and Leach, this volume), or Australia. But rarely will such an opportunity be found as in ADE with ages ranging from 500 to 8,000 BP in sufficient numbers and in a relatively small area to allow age comparisons to be made.

One of the most striking features of ADE apart from biochar is their high concentrations of available phosphorus and calcium. In most cases these will stem from accumulation of fish residues and are therefore composed of biogenic calcium phosphates (Lehmann et al. 2004). ADE therefore offers the possibility to study biogenic calcium phosphates and their dissolution over long periods of time. First results indicate that most of the calcium phosphate disappears 2,000–3,000 years after its accumulation, with a shift from crystalline hydroxy-apatite to tri-calcium phosphate to less crystalline di-calcium phosphate. Similar studies of molecular changes over long periods of time may be done for trace metals such as manganese, copper or zinc which are also abundant in ADE. No studies exist on organic nitrogen forms in ADE especially in conjunction with biochar, most likely due to the analytical challenges associated with N-15 NMR techniques (Smernik and Baldock 2005).

Much hope and discussion has been associated with the biology and specifically the microbiology in ADE. It is by now clear that ADE indeed harbors a population of microorganisms that is unique compared to adjacent soils (Yin et al. 2000; O'Neill et al. 2006). However, the microbial composition should rather be seen as a result of the unique habitat that ADE provides than a cause for ADE. It will not be possible to extract a 'magic microbial potion' from ADE that can be used to recreate ADE. Nonetheless, the unique microbial population may perform functions that change soil nutrient and carbon dynamics in ways that promotes the sustainability of ADE. Not the identification of a specific organism but the function of a group of organisms would need to be investigated. This is a challenge to be resolved in the future.

ADE does not always provide a suitable experimental opportunity to test certain hypotheses. For example, the reason why the microbial community structure is specific to ADE may be very difficult to identify. ADE is a very complex mixture, and any of its components may have an impact on microbial life, or possibly only a few or only one of them. Yet this conclusion will most likely not be obtained from the study of ADE, but probably only from controlled experiments. In the case of biochar, ADE research provides one of the decisive starting points for investigation of microbial diversity. Only high-resolution spatial measurements will in the future be able to unequivocally link certain organisms or their groups to the occurrence of biochar. Whether functional information can be obtained through this type of observation such as turnover or the use of certain food sources or the production of certain metabolites, is debatable. Again, only controlled field experiments outside of ADE will be able to link the presence of biochar with a certain microbial community and their function.

28.2.2 Blast to the Past

Archaeological studies are fundamental to answering some of the most interesting questions that guide both research on soil biogeochemistry in ADE as well as lessons for future soil management. For example, changes of biochar properties or phosphorus forms over time as discussed above can only be investigated with solid information about the time of ADE formation. The same is true for comparisons between ADE sites that differ in environmental or edaphic properties or simply for a generalization of certain ADE properties studied at a limited number of sites. An ADE soil that formed 2,000 years ago such as Açutuba will necessarily have different chemical properties than an ADE that formed 1,000 years ago such as Lago Grande (Liang et al. 2006). Without proper age identification and context of formation, interpretations of ADE characteristics are in many cases very difficult.

Even though the positive proof of a purposeful creation of ADE by Amerindian populations and the techniques involved are not vital to most of the lessons learned from ADE research as pointed out above, still, such information may not only provide new insights for future soil management and lend validity to the lessons learned, but would naturally also revolutionize our view of pre-Columbian civilization as started by Heckenberger et al. (2003) among others. Positive proof may be difficult to develop for times gone bye. But some evidences appear to be starting points for further investigation. For example, in an ancient settlement at a site called Lago Grande (Neves et al. 2003; Arroyo-Kalin, this volume), a defensive wall separates a small peninsula from the mainland. The peninsula shows clear signs of habitation with development of ADE with a depth of in some places up to 2 m, accumulation of potshards and a central plaza area without ADE (EG Neves, 2008, personal communication). The interesting observation is that ADE can also be found outside the defensive structure. Is this an indication that ADE outside the village walls are rather agricultural land? Again, a close collaboration between archaeologists and soil scientists is crucial to the success of such investigations.

28.2.3 Terra Preta Nova?

Many of these insights from archaeology and soil biogeochemistry may and some already have led to practical recommendations for future landuse – a vision put forward by Wim Sombroek (Sombroek 2001; Sombroek et al. 2002) as *terra preta* *nova. Terra preta* in its entirety, however, may not be a model for sustainable land use or only under certain circumstances that are likely of local rather than global importance. For one, ADE have widely differing properties that are a reflection of the location (hydrological, geological, as well as biological regime) as well as the management in pre-Columbian as well as recent times. Consequently, no ADE "as such" exists but soils that are classified as belonging to a group of soils that share the same anthropic origin, but can have variable properties (Kämpf et al. 2003). Secondly, in most instances ADE contain remnants of a multitude of additions from for example biochar (Glaser et al. 2001), animal manures, human excrements, human and animal bones (Neves et al. 2003), aquatic plants (Mora 2003), fish residues (Gilkes et al. 2004; Lehmann et al. 2004), turtle shells (Sombroek 2001), and many others. It is hard to imagine that such a complex mixture will yield a useful management suggestion. Nor do all of these ingredients provide critical contribution to the sustainability of ADE. One such ingredient and possibly the one that makes Terra preta "tick" is biochar, which is being developed into a soil management approach.

We should, therefore, rather be talking about *terra preta nova* technologies than about producing *terra preta nova per se*.

28.3 Biochar Agriculture for Environmental Management

The first and so far most important outcome of a *terra preta nova* technology is the purposeful management of biochar as a soil conditioner. Although, biochar has been produced by humans extensively and for very long periods of time for a variety of purposes including metallurgy, filtration, or artistic drawing (Harris 1999), its use as a soil amendment is less well documented. Limited circumstantial evidence suggests that adding biochar to soil has also been part of nursery or kitchen garden management and the beneficial effects of biochar in soil have been recognized for some time, as well. For example, the President of the Highland Agricultural Society of Ohio writes in 1850: "We have evidence upon almost every farm in the county in which I live, of the effect of charcoal dust in increasing and quickening vegetation. The spots where charcoal pits were burned 20, and some say even 30 years since, still produce better corn, wheat, oats, vegetable, or grass, than adjoining lands" (Trimble 1851). Some scientific work explaining biochar soil management dates back to the beginning of the last century with studies on the effect of biochar on tree seedling growth (Retan 1914; Fig. 28.1) or a very thorough study on the soil chemical and physical processes affected by biochar (Tryon 1948). Only relatively recently, however, research into the chemical properties of ADE (e.g. Glaser et al. 2001) triggered a proliferation of scientific studies related to the effects of biochar on soil fertility (e.g. Topoliantz et al. 2002; Lehmann et al. 2003a; Oguntunde et al. 2004, and several others). The following discusses possible ways forward for the framework in which biochar could operate, and articulates several visions of biochar use in the future.

Fig. 28.1 Seedlings of white pine grown in the nursery (from left to right): without biochar additions, and with biochar added 2 years before, 6 months before or at time of seeding (Retan 1915)

28.3.1 Biochar as a Routine Management in Agriculture

Can biochar become a routine management option in agriculture? The basic principle why biochar acts as a valuable soil amendment is by now well established and mainly builds on its recalcitrance in soil and its ability to retain nutrients (Glaser et al. 2002; Lehmann and Rondon 2006). Other properties that are much less understood are the effects on soil biology (Lehmann and Rondon 2006), which may have substantial yet hitherto largely unquantified benefits for crop productivity (Lehmann 2007a). Due to these soil-changing effects, biochar should be primarily considered as a soil conditioner and not as a fertilizer. Biochar improves the essential soil functions for long periods of time, but does not replace the need for nutrient additions through either inorganic or organic fertilizers.

Some types of biochar can, however, contain significant amounts of soluble nutrients, which may under certain conditions improve plant nutrition and productivity by direct nutrient addition. Biochar made from chicken manure is especially rich in calcium and phosphorus (J Lehmann, unpublished data), and most biochars contain large amounts of soluble potassium (Lehmann et al. 2003a). The yield increases in response to such direct fertilization effects are most likely comparable to those achieved by adding nutrients separate from biochar. However, for some types of biochar the release may be slower and the nutrients may be less prone to leaching losses than if added separately, and should be investigated in the future. The yield benefits achieved by such direct nutrient additions are a welcome short-term benefit, but are not a proof of the sustainability of biochar soil management and may in some instances even obscure the more important long-term effects. In that sense, pot experiments have more value in testing for allelopathic effects that may decrease crop yield, in quantifying the immediate benefits of reduced leaching or gaseous losses and in tracking the short-term changes of biochar in soil.

In any event, nutrients have to be applied each cropping season to compensate for yield export and possible losses by for example volatilization, leaching or erosion. Since biochar is intended to be a sustainable amendment, a combination of a function of nutrient delivery and long-term improvement of soil organic matter is not a mandatory and possibly not even an appropriate strategy. One-time and large applications of biochar may be the preferred strategy where rapid soil improvement is required, feedstock is not regularly available (as in a shifting cultivation scenario), or the economics favor one-time applications through possibly reduced costs of transportation. This would preclude a combination with fertilization as an annual intervention.

However, low amounts of annual biochar additions in combination with inorganic or organic fertilization is a possibility that could have advantages under certain conditions. For example, the production of biochar can be combined with a precipitation of ammonium bicarbonate on its surfaces which may be energetically and possibly economically advantageous for creating a nitrogen-rich biochar. A combination of low amounts of biochar and fertilization may offer procedural and, hence, economic advantages in that the same pass for applying fertilizer to soil also adds the biochar. Whether this is a useful strategy will most likely depend on the specific cropping system and farming equipment used to apply fertilizers. A third aspect that can be mentioned is the verification of carbon sequestration needed to justify carbon credits. The fertilizer distribution system can double as a verification tool. In addition, a biochar-fertilizer mixture will most likely be inappropriate as a fuel source and risks of diversions from the intended sequestration are unlikely.

The vision of biochar as a routine management tool in agriculture should be explored in large-scale field operations and must include full economic and environmental assessments. Biochar should also be adopted by the organic grower community and be allowable as a certified organic soil management where the integrity of the biochar product can be guaranteed.

28.3.2 Biochar for Sustainable Recapitalization of Soils

Biochar leads to a secure recapitalization of soil organic matter that can improve crop productivity through a one-time and large application to soil. A recapitalization with biochar may be especially attractive for improving the agricultural production base on highly degraded soils as often found in tropical regions. Biochar should therefore be explored for sustainable development in rural areas of developing countries.

What is the most likely long-term productivity of a one-time and large application compared to annual and small applications? If biochar is assumed to be completely recalcitrant to microbial decay, such a one-time application most likely achieves significantly greater cumulative yields over the long term than annual applications as shown in Fig. 28.2. Even by considering that biochar actually

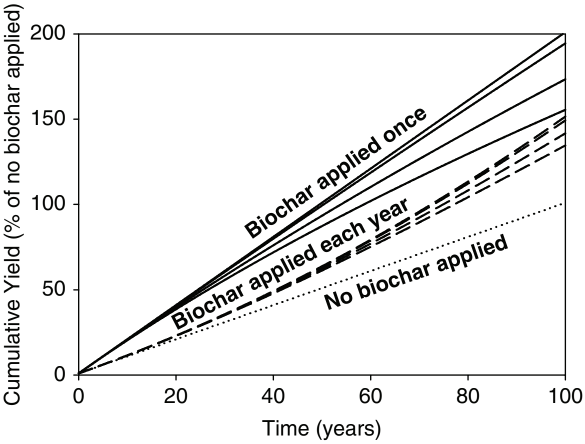

Fig. 28.2 Cumulative yield over 100 years comparing one-time application of biochar with a hypothetical doubling in yield (solid lines) and the repeated application of the same total amount with a yield increase proportional to annual biochar additions (dashed lines), compared to an unamended control (dotted line). Four scenarios were calculated: no decomposition of biochar, a half life of 500, 100, and 50 years (from top to bottom for both biochar scenarios)

decomposes over time, one-time applications still appear to be superior to annual applications with respect to yields. With a biochar half life of 500, 100, and 50 years, 91%, 76%, and 60% greater yield increases can still be achieved if the biochar is applied once at the beginning than annually over the same period of time. This calculation exercise also demonstrates that biochar does not need to have a half life of several thousand years to be considered a long-term soil improvement. Already with a half life of 100 years, 73% and 42% compared to the yield improvement without biochar decomposition would be achieved during a 100-year period for one-time or repeated biochar applications, respectively. A half life of 100 years is currently considered a low estimate for biochar and biochars will most likely have longer half lives of up to several thousand years (Preston and Schmidt 2006), depending on biochar and ecosystem properties.

Such a calculation assumes that yield increases are proportional to the amounts of biochar applied. This assumption may not necessarily be correct as shown for a greenhouse experiment with beans on a highly weathered savanna soil (Rondon et al. 2007). It also assumes that biochar is equally effective in improving soils immediately after it was applied to soil and after a long period of time such as 100 years. However, it is known that recently produced biochar has a low ability of retain cations and attains cation exchange capacity only over time (Lehmann 2007a), in most cases during a period of months to a few years (Cheng et al. 2006). On the other hand, biochar appears to maintain a high cation exchange capacity over the long term of centuries and millennia as shown by analyses of biochar contained in ADE (Liang et al. 2006). Therefore, the most likely effect of time on biochar properties also favor a one-time and large application over annual and small applications.

Some situations may even dictate one-time applications as in the case of the already mentioned shifting cultivation scenario: biomass is only available in large quantities at the land clearing stage that can produce sufficient amounts of biochar to recapitalize soil organic matter (Lehmann and Rondon 2006).

It should not be forgotten, however, that nutrient additions are still required to compensate for nutrient exports. In a situation as for example seen in Africa with high prices for fertilizers especially in land-locked countries such as Malawi (Sanchez 2002), a slight increase in the efficiency of applied nutrients could make a large difference to farm economies. In 2003, the farmer price per ton of urea in the United States was $227, whereas 1 t of fertilizer cost $336 in Nigeria and even $828 in Angola (Gregory and Bumb 2006). In such a situation, short-term financial support by international agencies or foundations to recapitalize soil productivity through biochar additions may achieve a long-term and sustainable impact. This may be an important aspect in a climate of typically short funding cycles and changing priorities that many organizations face.

The costs, however, may be substantial. If all 255 million hectares of soils which in 1990 were estimated to be degraded by agriculture in Africa (Oldeman et al. 1991) were to receive 10 $Mg\ ha^{-1}$ of biochar to jump start production, the rather large sum of $255 billion was required (at a price of $100 per tonne of biochar). These are high but not insurmountable costs even though they are four times the amount that the UN Hunger Task Force projects to eliminate hunger world-wide during the coming 5 years (Sanchez and Swaminathan 2005). Costs can be reduced by prioritizing sites where biochar additions are economically or environmentally most effective, and by determining with greater accuracy the critical amount of biochar necessary. The latter will certainly be a function of crop species and location (Lehmann and Rondon 2006). To be successful, such a large undertaking requires careful planning and consideration of the local conditions.

Such a recapitalization is also secure. Once biochar is incorporated into soil, it will not accidentally disappear, can not be sold, or used for different purposes. For comparison, investments in livestock can be risky, as animals can die of disease, be sold for short-term benefits, be stolen or killed. Similar considerations apply to investments in woodlots for timber production. Biochar in soil on the other hand, becomes a long-term environmental asset that sustainably improves the agricultural production base and will create revenues for very long periods of time, as exemplified by ADE. The task ahead is to determine the opportunity costs and financial benefits of adding biochar to soil for a large-scale recapitalization campaign.

The time that biochar will remain in soil is difficult to generalize for reasons of feedstock and environmental variability (Lehmann 2007a). Yet decomposition occurs gradually and can be predicted for a certain situation, and even comparatively rapid decomposition will still achieve most of the expected yield increases over the long-term as shown by Fig. 28.2. Leaching is certain to transport some portion of the added biochar into the subsoil, which may be advantageous for improving subsoil fertility and rooting depth. On the other hand, such a transport will decrease biochar concentrations in the topsoil where most crops have their roots and where most nutrients are taken up. At present, the vertical transport is thought to be negligible on the short term of a few years (Major et al. 2007), and will only change subsoil biochar contents significantly over long periods of time likely exceeding decadal or centennial time frames. Erosion of biochar is different in this respect and may have a significant yet largely unquantified impact on the effectiveness of biochar (Rumpel et al. 2006).

A risk-averse recapitalization program of degraded soils is an intriguing vision for the poorest regions of the world. With such a large-scale intervention, biochar to soil could significantly contribute to achieving two of the eight Millenium Development Goals of the UN by 2015: eradicate extreme poverty and hunger, and ensure environmental sustainability. Biochar is able to directly address actions 3, 4, and 7 of the UN Hunger Task Force (Sanchez and Swaminathan 2005). It is a promising approach for the suggested entry point by the Task Force to invest in soils as a battle against world hunger.

28.3.3 Biochar for Mitigation of Climate Change

The case for biochar as a promising approach for the mitigation of climate change has been made previously (Lehmann et al. 2006; Lehmann 2007b). Some aspects of this strategy require renewed careful consideration and are briefly discussed here. One, the conversion of biomass into biochar can either be primarily a net withdrawal of carbon dioxide from the atmosphere or a net emission reduction or both. For example, the harvesting of bioenergy crops such as fast-growing trees or grasses and their conversion into biochar in conjunction with replanting of the vegetation is primarily a withdrawal. The conversion of crop residues, however, that would decompose within short periods of time (Jenkinson and Ayanaba 1977) into biochar is both a net withdrawal and an emission reduction. In contrast, the lower evasion of nitrous oxides (Yanai et al. 2007) and lower fertilizer requirements for crops due to biochar additions to soil constitute an emission reduction that is not linked to a withdrawal of atmospheric carbon dioxide. These distinctions help in framing the discussion about the impact of biochar on greenhouse gas balances and carbon trading.

Second, even though about 75% of the biomass weight is typically lost during charring, only about 50% of the carbon is emitted (Fig. 28.3). Most of the mass driven off results from losses of oxygen and hydrogen. The resulting biochar shows up to double the concentration of carbon, yet the pyrolysis process itself always leads to a short-term net evasion of carbon. This has to be considered when designing biochar projects. The loss is assumed to be compensated for by the greater recalcitrance against microbial decay over the long term (Lehmann et al. 2006).

Third, in order for conversion of biomass into biochar to constitute a net sink, the amount of biomass that was charred has to be regrown. Deforestation and biochar production, for example, is not a net sink, but a net source of carbon dioxide, since about half of the carbon in biomass is emitted during pyrolysis (Fig. 28.3). This

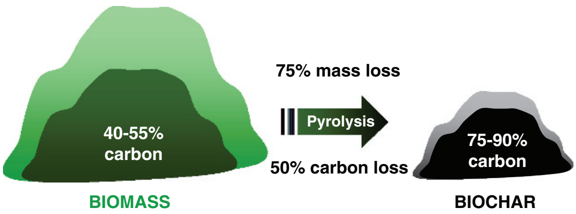

Fig. 28.3 Typical conversion of biomass (such as trees, grasses, green wastes) into biochar. The carbon and mass losses can vary significantly depending on the type of feedstock and the pyrolysis conditions (e.g. temperature, moisture, sweep gas)

emitted carbon can be captured in a bioenergy process (Lehmann 2007a), but will eventually be returned to the atmosphere under any scenario (Lehmann 2007b).

Fourth, whether or not biochar additions lead to emission reductions depends on the change in practice. The already mentioned use of otherwise living trees for biochar production results in a net source of greenhouse gas emissions. However, if the change in practice is from shifting cultivation that uses slash-and-burn to a slash-and-char practice (Lehmann et al. 2002), about half of the emissions are avoided and the change in practice results in emission reductions. In another example, the use of crop residues for biochar production instead of leaving them in the field for eventual complete decomposition to carbon dioxide, constitutes an emission reduction, as well (Gaunt and Lehmann 2007). Therefore, careful carbon and energy accounting is required to assess the impact of pyrolysis technologies on greenhouse gas emissions under a particular scenario.

28.4 The Terra Preta Nova Phenomenon

More than providing the decisive incentive to question common beliefs about the limitations of ancient landuse in Amazonia (Heckenberger et al. 2003; Neves et al. 2003), ADE has ignited the interest in sustainable soil use practices of today's agriculture. ADE can be credited of having inspired the most recent and widespread efforts in exploring biochar as a soil amendment, even though biochar was recognized as a soil improver for a very long time. Also, ADE has in general put soils at center stage and spurred the interest of a wide range of environmentalists. It has captured the imagination of a broader audience and may contribute to creating a greater interest in soils in the future. In some instances, sound soil management has been dubbed *terra preta* management, irrespective of whether or not a specific approach builds on insights gained by studying ADE properties or believed to mimic Amerindian soil management. These public responses have created a 'Terra preta nova phenomenon' of unexpected proportions.

The term *terra preta* has almost become a marketing tool. Companies are starting to promote their products using this term without demonstrating any obvious understanding whether it actually builds on ADE properties or ancient management. Given the ongoing research on the biochar aspect alone (Lehmann 2007a), this may not even be possible at this moment. The translation as 'dark earth' evokes images of fertility and sustainability combined with the mysterious and inexplicable. *terra preta* soil management may be perceived as gaining legitimacy by the suggested heritage of what ancient and supposedly sustainable land management did in harmony with the environment. It may also come with less ideological baggage than organic agriculture and could therefore be more easily accessible to a larger audience.

How ADE research and development will be carried forward is difficult to predict. Biochar gained its own momentum particularly in the context of climate change discussions (Lehmann 2007b). *Terra preta* currently combines a notion of solid scientific insight and perceived ancient wisdom with the hope for a solution to some of the most pressing environmental problems. In the end, only an unbiased view can truly capitalize on the lessons that ADE can teach.

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