Anthropogenic Dark Earths in Africa?

Recent research on the Amazon basin has led to a fundamental reappraisal of its social and natural history. Earlier arguments that the poor soils of the region had restricted pre-Hispanic social formations to the small, semi permanent settlements similar to those found among Amerindian people today (Meggers 1971), have been undermined by archaeological evidence of large sedentary settlements throughout the Amazon basin (Mann 2008; Schaan et al. 2008; Heckenberger et al. 2008). Areas of dark and highly fertile soils that can support intensive farming have been found to cover 1.2 - 1.8 million hectares of forested lowland Amazonia, undermining earlier interpretations that its infertile soils could not support large settled populations (e.g. contributions to Woods et al. eds 2009). These soils are known as Amazonian Dark Earths and are anthropogenic. The darkest (*Terra Preta)* are usually the middens of pre-Hispanic settlements, while others (*Terra Mulata*) are probably the outcome of pre-Hispanic agricultural practices (Lehmann et al. 2003; Glaser and Woods 2004; Woods et al. 2009). Pre-Hispanic populations are now known to have been far greater than earlier thought, their decline far more precipitous, and their impact on modern Amazonian forests far more significant (Woods et. al. 2009, Balee and Erikson 2008; Clement 1999; Lehmann et. al. 2003a, Denevan 2001).

The significance of these soils extends beyond a reappraisal of history. First, modern farmers value these soils, and many have developed distinct agricultural practices on them that contribute to more sustainable livelihoods (German 2003, Fraser 2009). Second, soil scientists are excited by the complex soil biology in their enduring improvement, and are researching ways to mimic their establishment to intensify land use and improve the efficiency of fertilizer use (e.g. Uphoff et. al 2006; Lehman 2009). Third, because the secret to these soils lies partially in their high proportion of charred carbon ('biochar'), farming technologies based on ADE could sequester enormous quantities of carbon, suggesting a high-potential 'win-win' opportunity for improving agriculture whilst mitigating climate change (Lehmann et. al., 2006, Sombroek et al. 2003, Lehmann 2007, Gaunt and Lehmann 2007, Lenton and Vaughan 2009).

To date, however, unfolding research concerning the qualities of ADE has been confined to Amazonia, or at least to the Neotropics of South and Central America (e.g. Graham 2006). Sillitoe has argued that the new research on ADE might offer a useful technology to import into Africa (2006) and some research has been initiated on biochar technologies in Kenya and Uganda. The hypothesis driving this proposal, however, is that farmers in humid tropical Africa already manipulate soil carbon and associated ecology in ways akin to Amazonian ADE, but researchers have overlooked the nature and significance of this, just as they had in Amazonia. Focusing on humid West Africa, this research will therefore ask:

- What processes of carbon enrichment and associated agro-ecological transformation are significant in West African farming?
- What mixes of social, ecological and technical; intentional and unintentional, and historical contemporary factors are involved?
- How do farmers distinguish, value and use these soils, and what is their significance in different farmers' livelihoods?
- To what extent and in what ways do the resulting soils share characteristics with Amazonian ADE?

Anthropogenic Dark Earths, Amazonia and Africa

Amazonian ADE contrast strongly with the soils that they develop in. They generally have about three times the soil organic matter (SOM), and more importantly, the component of SOM consisting of charred residues from incomplete combustion (carbons and charcoal) can be up to 70 times greater than that of background soils (Glaser et al. 2004; Liang et. al 2008). This is chemically stable and resistant to microbial degradation, so remains stable in the soil for centuries. This 'biochar' improves soil structure and aggregation, water infiltration and retention, and nutrient storage capacity (Lehmann et. al. 2003b).

The associated ecological processes in dark earth formation in Amazonia are becoming clearer (e.g. Hecht 2003,Glaser et al. 2004). ADE are not formed simply by wild fires and shifting cultivation, but through a combination of intensive nutrient deposition and charring, which together initiate a set of biological and chemical transformations. For example, pre-Hispanic farmers appear to have incorporated biochar from slow burning fire hearths and garden resides, alongside other inputs (such as bones and faeces) in ways which enabled ants and worms to dominate the soil fauna community. These powder and defecate biochar, mix it with soil and homogenise the soil profile (e.g. Ponge et al., 2006). Associated with this is a transformation in soil bacteria (O'Neill et al. 2006), phosphorous and nitrogen cycling, and soil acidity through feedback loops within an increasingly active soil ecosystem. The durable transformation that results in effect ratchets the soil into a different, more productive state that ‘multiple stable state’ theorising in non-equilibrium ecology sheds light on (Uphoff 2006). Farmers manage ADE in distinct ways, selecting and developing crop varieties in ways that support more intensive and sustainable production (e.g. Fraser 200, German 2003). Amazonian archaeologists, historians, anthropologists and ecologists now form an epistemic community (e.g. The Terra Preta Network) exploring the mix of timescales, sequences of practices and social/historical factors involved in their formation. The mixes suggest a family of dark earth types, produced through various pathways (Kampf et. al., 2003) although evidence of their modern formation remains limited (Schmidt and Heckenberger 2008, Steiner 2008).

Our hypothesis that soils similar to Amazonian ADE are significant in West African farming emerges from our earlier research that was framed within concerns about forests and farming, and which pre-dated the explosion of research around ADE (e.g. Fairhead and Leach 1996, 1998; Leach and Fairhead 1995, Amanor 1994, 1996). For example, research in Guinea revealed the anthropogenic nature of the many forest patches in its forest-savanna ecotone that encircle existing and abandoned villages, hamlets and farm-camps. Kuranko-speakers term the soils of former settlements *tombondu* (*tombon* = ruin, *du* = soil/land), and particularly appreciate them for farming or tree crops (when not protected as sacred sites). These soils are darker than those surrounding them, and often contain pottery. Nearby, villagers speaking Kissia language also appreciate the fertility legacy of former habitation sites, calling them ‘*pulo ce pomdo*’ (*pulo* = soil/earth; *ce pomdo* = village-old). Here, soft stone statues (also called *pomdo*) are sometimes dug up when farming and are themselves regarded as a portent of fertility. Farmers say they upgrade soils to make them '*like tombondu*', by ‘opening’ hard and impervious new soils (*du kura*) with regular gardening, mounding and incorporation of burnt and unburnt crop and household residues. These soils become ‘oily’ (*tulu*), ‘mature’ and ‘ripe’ (*mo);* and become like abandoned sites (*a di ke tombondu di*). Significantly, the concept of a ruined village is thus a central metaphor for this purposeful and enduring soil transformation. This categorical transformation is also valued and recognised in land tenure.

Earlier work by Amanor reveals how yam farmers in Brong Ahafo in Ghana improve their soils and accelerate the wooding of fallows (that provide yam stakes and reduce pests) using series techniques to manage root mat and soils, leaving the soils dark with charring, decomposing and live roots and coppices, and a rich soil fauna. Charcoal production has become a lucrative by-product of the fallows, and whilst policy and elite narratives cast charcoal burning simply as environmentally destructive, farmers provide an additional viewpoint that crops grow better on charcoal production sites; drawing on evidence grounded not only in experience with the current urban charcoal economy, but also on sites historically linked to iron smelting (Brown and Amanor, 2006; Amanor and Pabi, 2007). Similar evidence on the relation between charcoal and soils can be found historically in old settlements associated with iron smelting.

It is nothing new to suggest that African farmers appreciate high-fertility patches within fields and wider landscapes, and that they nurture, and adapt cropping to, them (e.g. Allan 1965, Scoones 2001, Brouwer and Bouma 1997, Carter and Murwira 1995). Yet these improvements are generally represented either as temporary, or as sustained through continuous applications. There has been almost no attention to the durable transformations to the soil that current research on Amazonian ADE now reveals can occur. Equally, attention has not been focused on carbon enrichment, but only on nutrients - even in farming systems involving intentional ash deposition such as in Zambian Citemene farming. Researchers have been misrecognising 'upgraded' anthropogenic soils in Africa as natural (Fairhead and Leach 1998). Exceptionally, some archaeologists have observed the durable nature of anthropogenic soil transformations, and the improved ecological productivity of past settlement sites centuries after they were abandoned, and have used associated vegetation as archaeological indicators (Keay 1947, Blackmore 1990). Yet these observations have not been linked with research into farming practices and their social and cultural logic. Tantalisingly, Zech et al. note in passing the existence of 'humus rich soils similar to *Terra Preta* around former settlements in Liberia and Benin' (1990) but can supply no further details (pers. comm.).

The confinement of dark earth research to the Amazon has been sustained not only by the silence about anthropogenic dark earths elsewhere, but also by arguments asserting the uniqueness of Amazonian agro-ecological history which are overstated. Thus it is argued that because pre-Hispanic Amazonian farmers had only stone axes, they could not practice shifting cultivation and so were forced into the kind of intensive practices that build ADE (e.g. Denevan 1992, 2006). Yet although Africa had a much earlier iron-age, many African agro-ecological systems (or parts of them) have long involved intensive forms of cultivation not reliant on the efficiencies of iron technology. Second, is also argued that as Amazonia did not have domestic animals, aquatic environments were more important, and that ADE may be linked to fish diets and their chemical additions to soils (Neves et al., 2003). In relation to humid West and Central African livelihoods, such a distinction would overplay the relative importance of domestic animals there, and underplay the importance of fishing. This Amazonian exceptionalism also cannot be based on fundamental ecological differences: ADE are found over a wide range of ecological conditions in Amazonia, many of which are common to the lowland humid tropics of Central and West Africa, including the highly weathered and leached soils (Oxisols and Ultisols).

While there is a possibility that analogues of Amazonian Dark Earths are to be found in West Africa – with soils of its former settlements sharing the characteristics of *Terra Preta*, and their mimicry through farming sharing qualities of *Terra Mulata* – our research cannot be restricted to this hypothesis. Amazonian ADE provide a family of carbon-enriched soil types which is not a singular basis for comparison (Hecht 2003; Hecht 2008; Schmidt 2007, 2008). Our research will therefore explore more broadly how farmers understand, manipulate and appreciate the spectrum of transformative carbon-enrichment and associated agro-ecological processes to be found, and how their formation balances intentional management with fortuitous historical and social conditions. The success of this research does not therefore hinge on 'finding' ADE in West Africa but on exposing the processes and logics through which farmers there manipulate and appreciate carbon-enriched soils in their agro-ecological contexts.

Envisioned Impacts

We envisage theoretical impacts of the research in several areas. First, it will advance understandings of local and 'indigenous' soil knowledge and practices in humid African settings, by revealing how knowledge draws on hitherto under-appreciated transformations in soil carbon and associated ecology, casting new light on the interplay of knowledge with tenure, settlement history, ecological practice and religious/symbolic beliefs relating to fertility and prosperity. This will involve theoretical reflection on the complex interactions of social, technical and ecological factors shaping investments in soils, and the importance of path-dependency, historical contingency, and the nature of intentionality in this. This reflection is important to understandings of the nature of 'investment' in African landscapes. Second, the research will provide the evidence and theoretical development concerning the nature of African anthropogenic dark earths that is necessary for establishing a conversation between Amazonian and African social, historical and soil researchers. It is hoped that new hypotheses will emerge, interesting to each of the contributing disciplines. It is entirely possible that key soil ecological ingredients to ADE formation are specific to Amazonia. This itself would be interesting, and would cast further light on the specificities of both Amazonian and African experience, and the possibilities or otherwise of technological transfer or mimicry.

Practically, this research will identify elements of agro-ecological and livelihood practices specific to West African settings which can inform potential new biochar initiatives for small farmers. Findings will inform wider policy and practice-focused debates addressing (a) soil infertility in Africa, (b) strategies to promote sustainable farming futures, and (c) strategies to enhance the sequestration of carbon in tropical agroecosystems. In particular, they should kick-start further initiatives to develop and apply biochar technologies, build on farmers' knowledge of them, and integrate them into pathways to agricultural sustainability in the humid tropics of Africa and beyond, addressing whether ADE technologies might support small farmers or industrial agriculture.[1] Given the new Alliance pushing to address African soil fertility and productivity in an 'African Green Revolution', and associated initiatives supporting fertilizer availability and targeting using fine scale soil mapping (AGRA 2009, Abuja Declaration 2006, CIAT 2009), ADE research of this nature has the potential to inject a new dimension into debates about appropriate technologies, strategies and policies (Scoones 2008, Thompson et al 2007).

Research strategy and methodology

The Upper Guinean forest region of humid West Africa provides an appropriate region for us to assess the significance of anthropogenic dark earths given its climatic ecotones; its soils, its diversity of social worlds and agro-ecological practices, and given our preliminary evidence of the importance of ADE and past research experience there. We propose to focus our research on four locations that capture key aspects of the region's agro-ecological and social diversity: its decreasing humidity from south to north, and the contrast between the more rice-based farming in the west (Liberia/Guinea), and the more yam-based farming in the east (esp. in the transitional zone of Ghana).

In Ghana, we propose focal sites in (a) Asamankese-Suhum (in the moist semi-deciduous forest zone, depopulated from eighteenth century, and repopulated in the twentieth century by cocoa/food crop farmers), and (b) Brong-Ahafo (in the dryer forest-savanna transition, partly urbanised around the 17^{th} century, now with relatively low populations of yam, maize and tree crop farmers). In Liberia and Guinea, focal sites will be in (a) probably Grand Bassa county in Liberia (in humid forest, historically populous but depopulated in slave trade era, now repopulated with rice/cash crop farmers), and (b) Kissidougou in Guinea (in less humid forest-savanna where farmers appreciate soils of ruined sites in a mix of rice, cassava, maize and tree crop farming).

The team is international and interdisciplinary, drawing together researchers in social and soil science including (a) ecological anthropologists/historians with longstanding experience researching the focal study areas and local agro-ecological knowledge there (Amanor in Ghana, Fairhead and Leach in Guinea and Liberia); (b) a leading soil scientist of Amazonian ADE (Lehmann); (c) a postdoctoral agro-ecologist/anthropologist who has assessed the significance of Amazonian ADE in farmers' livelihoods (Fraser), and (d) postgraduate research officers from Ghana (Tontieh Kanton) and Guinea (Dominique Millimouno) It builds collaborations with soil scientists, social researchers and historians at the universities of Legon (Ghana), Kankan (Guinea) and Monrovia (Liberia). Fairhead and Leach are an established research team, and have collaborated with Amanor on earlier DfID funded research (1998-2001) and Fairhead supervised Fraser's PhD. Amanor will oversee research in Ghana, and Fairhead, in Guinea and Liberia. Research is in four phases. Researcher inputs into these are detailed and justified in the JES form, and vary substantially according to existing knowledge of the research sites.

Phase 1: Review and start-up (3 months). This will comprise a re-review of relevant agro-ecological, historical and anthropological literature for the Upper Guinean forest region in particular, but humid Africa more generally. We are familiar with this literature, but need to revisit it systematically to draw out the spectrum of potentially significant elements of dark earth production and appreciation. We will link this with electronic consultations with social and agricultural researchers/practitioners in the region, facilitated through a web-based information-sharing and discussion site. The latter should (a) reveal unpublished information (e.g. in Feb 2009, Rademakers described in the Terra Preta Network biochar practices in Cameroon grassfields in which buried grass is burnt during soil preparation) and

[1] http://www.guardian.co.uk/environment/2009/mar/24/george-monbiot-climate-change-biochar
http://www.scidev.net/en/news/charcoal-plan-for-carbon-storage-under-fire.html
Both sites accessed 26/04/09

(b) generate wider interest and policy/practitioner engagement in the research. Precise fieldwork locations where potentially interesting exemplars of anthropogenic dark earths appear likely to be found will be identified on the basis of this review, together with the researchers' existing experience.

Phase 2: Field research (12 months) Following initial consultations with national stakeholders to share project aims and further refine country-specific questions and methods, teams will initiate research in each country. For each site (village or small cluster), fieldwork will develop and apply a parallel set of techniques:

- To identify the range of *locally-conceptualised categories and exemplars* concerning soil enrichment including 'ADE' each team will use a combination of focus groups (four, covering male/female and youth/elder farmers), key informant interviews, oral histories of settlements and sites, transect walks and participant observation of field clearance and preparation. The teams will observe and discuss physical features, ecological and soil fauna characteristics, agronomic properties, social and tenurial categories, attending to local classifications of both 'states' (soil types) and possible 'transitions' between them. Preliminary soil observations (e.g. of texture, colour, charcoal and pottery admixture, macrofauna, and locally salient categories) will be backstopped with ongoing electronic communication, exchanging photographs and video clips of sites and soils with the team's soil specialist. Soil scientific categories will be compared with local conceptualisations.
- To elucidate the *pathways* through which exemplars of key soil categories have developed, each team will use interviews and on-site discussions to co-construct with key informants 'soil pathway biographies' highlighting key events and conjunctures along a simple timeline (and the different versions and timescales that different men, women, elders and youth may offer) in soil transformation. Oral accounts will be triangulated where possible with remote sensing and documentary evidence and local archaeological expertise (drawing here on local consultant archaeologists). This will expose the social and agro-ecological interactions involved in soil transformations, and how the mix of intentionality and unintentionality, path-dependency, and interlocking of practices across different timescales unfold in particular pathways. It will reveal how the knowledge and values of different farmers – women and men, older and younger, different cultural and language groups - both feed into and help to shape these pathways. In integrating an understanding of complex dynamics with attention to their 'framing' by particular social groups, the research draws on (and will contribute to) the 'pathways approach' being developed by the ESRC STEPS Centre (Leach et al. 2007).
- To discern the *significance of dark earths* in different farming repertoires we will use qualitative research because at this stage it is important to discern the different kinds of significance of an unknown variety of ADE for the diversity of households. Early in the research each team will key informant interviews to indentify 10-15 focal farming households that represent the diversity of labour, land access, and other income conditions that shape farming opportunities, and with them conduct field use biographies concerning the previous 5 years. These will identify intra-and inter-household variability (e.g. by gender, age, wealth) in valuing different soils types including dark earths. We will identify cropping and crop variety assemblages, scheduling, rotational and fallowing practices, to generate a profile of local agricultural knowledge and practice relating to soil enrichment, carbon enrichment and ADE which can discern whether improved soils play into farmers varietal selection, and thus whether there are co-evolutionary dynamics on anthropogenic dark earths as opposed to background soils.
- To elucidate *the wider pertinence of the conceptualisation, use and significance* of ADE found in these intensive study sites, 4 other locations will be selected for rapid (3-4 days) comparative evaluation in both Ghana and in Liberia/Guinea. These will use focus group discussions, transect walks and field biographies. Sites will be selected through discussions with local informants and national stakeholders to offer a range of relevant social and ecological contrasts.
- Through ongoing electronic interaction, field teams and the soil specialist will identify (and global position) a spectrum of anthropogenic dark earth exemplars for further soil science investigation.

Phase 3: Detailed soil investigation (3 months, overlapping with end of phase 2). The specialists in Amazonian Dark Earths (post-doctoral researcher supervised by Lehmann) will visit the 4 sites, over a 6 week period. They will work with the field teams and national soil scientists to (a) observe soils and soils fauna using soil profile pits (or auger samples where mining and ancestral issues render pits socially sensitive), and (b) sample and conduct a series of tests on 6 soil exemplar gradients in each sites as identified in phase 3. As with observations, tests will sample soils from across gradients from highly transformed anthropogenic soils, to less transformed/differently transformed/less managed soils, to untransformed ecological reference sites. Soil tests will include those usually used in assessing Amazonian dark earths. These concern, first, nutrients: (i) Total carbon and Nitrogen, and (ii) Phosphorous (available, calcium bound, and total Lehmann et. al. 2004) which can reveal anthropogenic phosphorous. Carbon and nutrient contents will inform us about habitation intensity. C contents are expected to be elevated in all areas of habitation and agricultural areas, but high P contents are expected only around habitation sites with accumulation of food and animal residues (Woods et al., 1999). Second, analysis of (iii) Cation Exchange Capacity will help in identify (in comparison with total Carbon) whether the agricultural soils indeed have greater legacy fertility irrespective of the current nutrient status (Liang et al., 2006). Elevated CEC is a characteristic property of Amazonian Dark Earths, which is still untested for African dark earths. In each location, two sites most resembling Amazonian ADE (and their comparator baselines) will be chosen to conduct more expensive tests; first of black carbon (using Nuclear Magnetic Resonance as in Liang et al. 2008) which can prove unambiguously whether carbon enrichment is of biochar - Black soils exist worldwide that are not necessarily rich in biochar/black carbon), and second C-14 dating of charcoal macro-fragments, using standard methodology, to discern time series of charring interventions and timescales of soil transformation. Laboratory analysis will be conducted in country and in Cornell, as appropriate. This phase is timed so that field interaction between soil and social scientists can generate further hypotheses for local investigation during the final weeks of fieldwork. Feedback workshops will be held in Ghana, Liberia and Guinea to sensitise national stakeholders to the research, discuss preliminary findings and help identify the rapid comparator sites (above).

Phase 4: Analysis, communication and publication (6 months). Interdisciplinary analysis will integrate the social/historical and soil science findings to identify soil pathways that lead to different types of carbon-enriched dark earths, and who values these, how and why. Local conceptualisations, and the qualities and properties of identified African dark earths will be compared and contrasted with dark earth family types found in Amazonia. Interdisciplinary analysis and publication will be facilitated by electronic communication culminating in a one-week workshop/writeshop to be held at a nodal point for Amazonian ADE research, EMBRAPA in Brazil. This will (a) enable the teams to liaise in final analysis and (b) communicate and discuss the importance of African dark earths with Amazonian specialists in the Terra Preta network, enabling comparisons between Amazonian and African experiences and their future practical and research significance to be debated.

Our publication and communication strategy (outlined in ‘Academic Beneficiaries’) is geared to publication of 6+ high impact peer-reviewed journals in and across the contributing disciplines (Anthropology, Soil Science, Development Studies, African Studies), to inform both academic debates and evidence-based policy. As outlined in the attached ‘Impact Plan’, these will be complemented by short, focused contributions and briefings geared to research, policy and practitioner networks (e.g. Terra Preta Network, Network of magazines on low external input and sustainable agriculture, African Network for Soil Biology and Fertility), print and broadcast media (e.g. New Scientist), and online debate, assisted by the communications and knowledge impact services managed by the STEPS Centre.