Soil Ethnoecology Paul Sillitoe

The majority of us, urban dwellers distant from land and farming, take the soil for granted and if it is brought to our attention, it stirs little interest, equated in our minds with clods of mud and mouldy rotting vegetation. The study of others' soil knowledge or "ethnopedology" (Tabor 1992; Sillitoe 1996), the subject of this chapter, reflects this popular attitude, having received relatively little attention compared to other ethnoscientific fields, notably ethnobotany and ethnozoology (see Winklerprins 1999 and Barrera-Bassols and Zinck 2003 for literature reviews).[1] This is strange, for even some early ethnographers noted the soil's importance, such as George Forster who together with his father acted as scientists on Cook's second voyage, who in an essay on the breadfruit tree observed that the "produce of the soil is deeply entwined in the fate of humankind" (Forster 1843:347); and his acolyte von Humboldt (1822:525), the renowned 18th century polymath, who referred to the "influence exercised by the composition of the soil on agriculture, trade and the more or less slow progress of society".

Box 1 Soil

Soil is a remarkable substance upon which all life depends. It is the medium in which plants root themselves and supplies the inorganic nutrients they use, along with water, sunlight and atmospheric gases, to synthesize the organic materials upon which the trophic pyramid of animal, including human, life stands. As Russell comments in the preface to his classic soil science textbook: "At first sight the subject appears very simple; in reality it is highly complex" (1912: vii). It is challenging because of the complexity of soil systems, their components interrelated in complicated feedback relationships, and the soil constantly changing with chemical and physical processes going on continuously.

Human-beings contribute to natural changes when they disturb the soil in cultivation, sometimes skilfully managing it to maintain fertility, other times degrading it. It adds a further dimension of complexity to consider the ethnopedological knowledge and management of soil by populations elsewhere, such as communities in the mountains of Papua New Guinea that are the ethnographic focus of this chapter. The relevant issues include how people think of, classify and appraise, their soils, how they manage them under cultivation, and the impact of their activities on soil conditions, notably what happens to soil processes, particularly productivity, under various cultivation regimes.

THE WOLA AND THEIR SOILS

The Wola speakers of the Southern Highlands Province live in small houses scattered along the sides of their valleys, in areas of extensive cane grassland, the watersheds between which are heavily forested (Sillitoe & Sillitoe 2009). Dotted across the landscape are their neat gardens. They depend almost exclusively on horticulture to meet their subsistence needs, living on a predominantly vegetable diet in which sweet potato (*Ipomoea batatas*) is the staple. They keep pig herds of considerable size. They hand these creatures, together with other valuable things, around to one another in unending series of ceremonial

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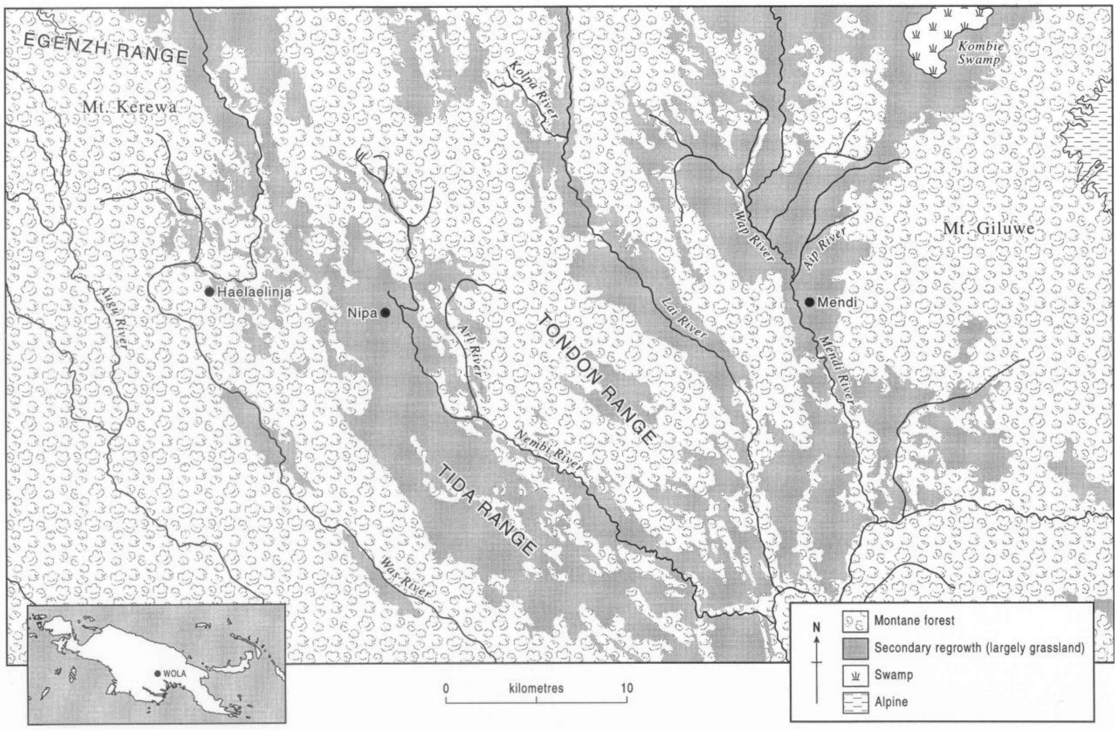
[1] Publications that contribute to ethnopedological knowledge in various regions of the world include: Africa & Asia (Fairhead et al. 2017), Niger (Lamers & Feil 1995; Osbahr & Allan 2003), Tanzania (Ostberg 1995), Nigeria (Kundiri *et al.* 1997; Adewole Osunade 1995) , Ivory Coast (Birmingham 2003), Burkina Faso (Krogh & Paarup-Laursen 1997; Gray& Morant 2003), Rwanda (Habarurema & Steiner 1997) , Nepal (Scott & Walter 1993), Latin America (WinklerPrins & Barrera-Bassols 2004), Brazil (Hecht 1989; De Queiroz & Norton 1992), Mexico (Barrera-Bassols, Zinck & Van Ranst, E. 2009), Peru (Sandor & Furbee 1996), Honduras (Ericksen & Ardón 2003) and Papua New Guinea (Sillitoe 1996, 1998).

exchanges, which mark all important social events. These transactions are a notable force for order in their fiercely egalitarian acephalous society.

Figure 1 Map of Wola region



The most widely cultivated soil types in Wolaland are Inceptisols and Andisols, which are derived from the sedimentary parent materials, variably affected by volcanic ash (dominated by it, to no evident effects), with some alluvial re-deposition. Some soils are subject to wet conditions and are gleyed, others are peaty. They feature dark topsoils, high in organic matter, with a porous crumb structure and indeterminate volcanic ash contents, overlying a firm, moist, aerobic, bright-brown clay subsoil, sometimes stony and faintly mottled (Bleeker 1983:67-70). These young soils, experiencing several rejuvenating episodes of volcanic ash fall, are fairly productive with appropriate management.

KNOWLEDGE AND CULTURAL CONTEXT

A challenge that faces the ethnosciences is how to interface with their eponymous natural science counterparts, which tend to dominate. There is a danger of uncritically imposing a scientific model on what we think we understand of others’ knowledge and distorting it. This was evident from the start in the ethnosciences with the categorization of subject matter according to supposedly synonymous scientific subjects, such as ethnobotany, ethnozoology and ethnopedology. It is an error to treat local understandings of the natural world as culturally decontextualised knowledge amenable to investigation according to the conceptual framework of the matching science. The assumption that there are delimitative bodies of knowledge independent of socio-cultural context is dubious, leading to ambiguous science-like representation that focuses on aspects thought to mirror science, whereas their status may be different from a local viewpoint.

It is necessary to acknowledge the 'cultural construction of the environment' (Simmons 1993; Atran and Medin 2008), that understanding of the natural world is culturally mediated. People may codify the intelligence amassed over many generations of trial-and-error in ways quite different to science. Furthermore, the imposition of scientific categories not only threatens to misrepresent knowledge, but also to limit analysis by prompting us to ignore issues that may be important to local understanding and experience, notably the non-empirical such as supernatural, symbolic, socio-political and kin considerations, albeit expressed in an alien idiom, perhaps involving spirits, mythical events, and so on

We see the consequences in scientific soil and land resource surveys that have limited relevance locally (Young 2017). While farmers may use some of the same information as soil scientists to assess soils (e.g. colour, permeability and texture), indigenous and scientific definitions of soils and land types, and associated soil classifications, often compare poorly (Sikana 1993). Soil scientists have long used local soil names. The pioneering Russian soil scientist Dokuchaev is an early example, using such vernacular terms as *chernozem*, *solonetz* and *gley* in his 19th century soil classification, some of which continue in scientific use to this day (Krasilnikov & Tabor 2003:201). A subsequent 20th century example concerns the incorporation of local soil names in a scientific soil survey in Sukumuland, Tanzania (Milne 1947), which have replaced those of scientific soil classification in the region (Acres 1984). [2] But it amounts here to little more than equating local names with soil science catenae, although it may promote interaction between scientific and indigenous knowledge, highlighting their potentially dynamic relationship. It is necessary to exercise care in scientifically recodifying and interpreting local understandings. It may isolate for analysis certain resource use practices from the broader circumstances that critically inform them.

Scientists identify classes by a range of technically assessed properties, whereas farmers frequently look for a dominant property which may have further associations, and their approach is frequently more holistic, incorporating exotic social and cultural aspects in distinguishing land and soils according to various uses and associations (Niemeijer 1995; Talawar & Rhoades 1998; Niemeijer & Mazzucato 2003). The manner in which New Guinea Highlanders classify soils illustrates the need to get outside the conceptual framework of Western science when considering pedological issues, for it is necessary to know something about their tribal political order to understand their approach to soil classification.

ISSUES OF SOIL CLASSIFICATION AND REPRESENTATION

In the Highlands of Papua New Guinea people have names for different types of soils, and we can match these terms against those of soil science in a Dokuchaev- cum Milne-like manner. Table 1 presents such a correlation for the Wola speakers. We might use their terms to name the soils mapped in a land resources survey. But this would be a distortion of their ideas, using their terms in an alien context because these people

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[2] In Sukumuland for example, the Ukiriguru Agricultural Research Institute continues to use Milne's (1947) names that feature in Lake Zone farming systems research.

traditionally have no notion of maps. (This criticism applies equally to participatory soil mapping exercises that seek to draw on local farmers' knowledge while imposing foreign cartographic representations -- Barrera-Bassols, Zinck & Van Ranst 2009.) It amounts to plucking their words out of cultural context and using them to gloss our classes; so instead of talking about Psamments for example we substitute *iyb muw*. But does this matter because we presumably see the same soil 'out there', to which we just give different names? The rub is that while we may see the same soil, we may think about it in quite different ways.

Box 2 Wola soil classification.

Regarding Wola naming of soils, people have no concept equivalent to the soil profile. They do not classify soils as entire profile sequences. They conceive of soils as a series of named horizons. The Chimbu people likewise name and classify soils by horizons (Brookfield & Brown 1963: 35-36). So the classes in Table 1 refer to the predominant subsoil at any location. When they talk about soils they name each horizon, adding qualifying terms as necessary to specify particular characteristics. So they might refer to a Humitropept, which is a common soil type overlying limestone in their region, as *suw pombray diy hundbiy* 'black soil and bright-orange-clay', and they may qualify this further by specifying notable features of each horizon *suw pombray hemem iyba wiy hundbiy araytol omb hul haeruw* 'black soil fertile with grease and stony bright-orange-clay with ferralitic nodules'.

If we think of spatial relationships between soils, as in land resource surveys, and dig pits at intervals across an area, and ask Wola people to comment on the soil exposures, they will name and may describe each horizon separately. Their manner of naming soils prompts them to treat each exposure independently, constructing an appropriate label using various terms to qualify what they see. There is no compulsion to organise classes so that they relate one to another, to form catenae or landscape related sequences. While they are fully aware that topography can influence soil type, that wet gleyed soils for example will more likely occur in low lying areas and depressions, they do not relate their soil classification systematically to landscape. In part this reflects their disinterest in soil genesis, which informs and orders the classifications of soil science. They name what they see with no such theory to structure their classes, which are consequently diverse and variable.

If we focus on the boundaries between soil classes, as opposed to the centrally defined modal categories, and ask what is going on, we see the Wola approach in an interesting light. Soils in the field naturally comprise a continuum usually without sharp discontinuous breaks between one class and another. They intergrade gradually one into another, whereas in soil mapping a firm line distinguishes sharply between them. The catena conveys the continuity, conceived as a series of defined soil types that change in some predictable manner across the landscape, as demarcated on a map. But the associated categorisation and spatial representation face particular challenges not overly to distort nature's arrangements. The Highland New Guinea system of soil naming handles the boundary conundrum better by doing away with it. Lacking any idea of representing soils spatially, the Wola have no need to draw boundaries between one soil class and another. They can accommodate to any observable changes in soil type they think significant as they move across the landscape by modifying their descriptor terms, so the soil here may be ‘some of this and a little of that’ whereas that one over there has ‘less of this and more of that’ and so on, with no thought to specify a boundary between them.

Figure 2 Soil profile pit

Figure 3 Soil profile pit

Figure 4 Soil profile pit

Figure 5 Soil profile section.

An intriguing consequence of the soil classification is that it is more straightforward than those of soil science and more faithfully reflects observed reality. These Highlanders have no rigidly defined classes into which they have to sort soils, only names subject to whatever qualifying terms are necessary to further specify the soil, horizon by horizon. They avoid the difficulties soil scientists often face in deciding exactly how to classify soils according to precisely defined classes and modal types; the monumental USDA scheme exemplifies the complexity (Soil Survey Staff. 2014). And scientists go further in soil surveys, drawing boundaries between different soil classes, which require them to decide that somewhere on the ground one soil type ends and another begins, represented with a line on maps, with different keyed colour codes either side for the two soil types distinguished.

A further consequence of doing away with the need to draw boundaries is that the classification scheme is inherently flexible and better able to handle the wide range of soils ‘out there’. The Wola have no need of a hierarchical classification scheme of the sort needed to accommodate evolutionary hypotheses, lacking, as noted, any concern for soil genesis. The problems that arise from scientific schemes structured in this way include sometimes putting agronomically similar soils into different, sometimes widely separated, soil classes according to their genetic criteria. The absence of a hierarchical scheme dispenses with the need rigidly to define classes and divide soils. If they wish, people can associate soils one with another, in any way that seems appropriate to them at the time.

The flat and fluid classification scheme reflects the culture in which it occurs. Briefly, Wola society is, as mentioned, aggressively egalitarian, albeit with a marked gender differentiation in social life. It lacks, as an acephalous or stateless order, any political offices that vest authority in certain persons over others. The ethos prompts the subversion of hierarchies that place some above others, and part of this compulsion is conceptually to obfuscate the existence of boundaries because their existence implies an embryonic hierarchy, the centre more important than the periphery (Sillitoe 1999). The stateless cultural context has further ramifications for any comparison of local and scientific perceptions of soils. There is no recognition of any expert authority to validate the correct identification and naming of soils. The upshot is that unexpected levels of disagreement characterise the system. Different persons may name the same soil somewhat differently, particularly at the level of descriptor terms, which suggests that they 'see' different features as characteristic of the soil. And no one can adjudicate over differences between them about the naming of soils. They are all 'correct'. This relates to indigenous knowledge being fragmentary and dynamic, not centralised and static. The fluidity of the local versus the rigidity of the scientific soil classifications reveals starkly the problems of comparing and correlating them, and questions the validity of such comparisons, when they depend on quite different criteria, one concerning everyday practical management and the other landscape evolutionary processes. Local indigenous knowledge is by definition parochial and culturally relative, its local embedded character is intrinsic to its success, whereas science strives for a generic and global perspective.

ISSUES OF SOIL CULTIVATION AND RECULTIVATION

The classificatory schemes of people only reflect part of their soil knowledge, which also has a practical dimension, notably in respect of management under cultivation. The farming regime found in the rugged Wola highland region defies characterisation according to any classification (Sillitoe 1983; 2010). The idea of stationary cultivation under a shifting regime appears a contradiction in terms, but this antilogy characterises the farming system. On some plots, people practice classic shifting cultivation, clearing for one, or possibly two cropping cycles, and then abandoning to natural regrowth for many years. Other plots they keep under almost permanent cultivation for decades, with occasional, brief periods of grassy fallow, which the Wola call *em hul* or 'bone gardens', after their bone-like durability.[3] They farm all plots, whatever their productive life, using the same methods and technology. The result is a continuous spectrum of agricultural land use, comprising a single farming system.

The maintenance of some gardens under crops long-term, within the broad context of a shifting cultivation strategy, contradicts widely held suppositions about subsistence farming in the tropics (Norman 1979; Ruthenberg 1976), which assume brief periods under cultivation followed by abandonment due to declining productivity (Nye & Greenland 1960:73-126; Sanchez 1976:374-380) with long intervals under natural fallow to allow soil recovery from nutrient losses, weed proliferation, disease build-up, erosion damage, and so on.[4] What is it about the soils and crops of this region that allows such a cultivation regime to exist, featuring minimal or no fallow breaks and no outside amendments (such as manure), without catastrophic declines in productivity, resulting in a degraded landscape like other tropical regions such as Amazonia following extended forest clearance? Indeed, how come the reverse sometimes occurs and crop yields improve?

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[3] These are not annual replantings but extend over one to two years usually, depending on the plants intercropped.

[4] Some of the data and argument presented in this paper have appeared in *A place against time* published by Harwood Academic and I acknowledge permission to reproduce them.

Figure 6 A view across valley side showing mosaic of gardens and forest

Figure 7 View of a slope showing gardens in varying stages of cultivation

If you put such questions to the Wola, they are likely to respond '*em hul wiya ngora*' (bone gardens just exist), which is sufficient to their minds and for their purposes. Encouraged to elaborate further they may comment '*nao shumbaen em nguwbiy bismiyuwp*' (our ancestors cultivated such gardens), implying that time and tradition have proved the practices effective. Some individuals might mention observations of some soil conditions under cultivation, such as '*em ngo suw iyba bawiy*' (soil 'grease' remains in such gardens).

In short, the Wola follow a cultivation system evolved over many generations[5] of experimentation without apparent need to explain the soil processes that underpin it. Indeed they maintain that when they cultivate a new garden, they often do not know for how long it will remain under cultivation,[6] soils changing and sometimes improving with use. They plant it and see how their crops fare (Sillitoe 1996:310-311). They may continue to cultivate it indefinitely if yields are respectable and the garden's location convenient.

The validity of people's assertions about their soil knowledge is difficult to assess. It is arguable that soil conditions enter indirectly into their calculations, because some of the landscape factors that inform their choice of site -- like slope, terrain and so on -- also influence soils. Furthermore, while they say that they do not inspect the soil before cultivating, they may do so unwittingly. They know their local regions intimately and may have no need to look closely at the soil before deciding to cultivate. They already know its status by virtue of constantly walking across the land during their everyday lives, and doing so barefoot, they are well aware of soil texture and structure -- they 'know' the soil through their feet. And the vegetation growing on a site may indicate soil fertility, by its luxuriance, even the presence of certain species above others, although farmers largely deny that this is so.[7] Whatever, the epistemological challenges that attend the documentation of such local environmental understandings are large.

If you are a Wola you just know, you are not used to being asked how you know. The awareness that you have of the soil for instance, is an accumulation of experiences, built up over the years, cultivating the soil and hearing many comments from others on it. These people live rather than reflect on their environmental knowledge. It has a marked practical aspect to it. When asked, for instance, to assess the soil at a particular site, individuals may inspect it, and even handle it, before passing judgement. If you then ask them to justify their assessment they will look somewhat bewildered. They will probably tell you to look at the soil for yourself, maybe even pass you a handful to feel, the implication being that surely you can judge for yourself.

The knowledge is passed on by informed experience and practical demonstration, more likely shown than spoken, being as much skill as concept, conveyed as required in everyday life. It is difficult for an outsider convincingly to gain some understanding of such knowledge. If actors know by doing, can we learn to know too, which presumes going barefoot, for instance, to make the tactile connection with the earth necessary to knowing? And if we can gain such tacit understanding, can we express it in words (Sillitoe 2017:300-303)?

LOCAL KNOWLEDGE AND NATURAL SCIENCE

There is another avenue, which reverses the foregoing critique and endorses soil science. While I can give an account of Wola horticultural practices (Sillitoe 2010:253-329) and report their comments on soils and their behaviour under cultivation -- about 'grease' levels and so on, so far as I apprehend them -- the question remains: what is it

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[5] Note that archaeological finds indicate that farming started in the New Guinea Mountains some 9,000 years ago (Denham 2017; Golson *et al*. 2017).

[6] Unless they intend to establish a stand of taro, a crop which they say rapidly reduces soil productivity; such a garden, usually on a wet site, will be a one-off cultivation.

[7] The Wola deny that they look systematically for the presence or absence of certain associations to assess soil fertility. If the vegetation, whatever the succession, obviously looks spindly and poor, they may take this as evidence of poor fertility.

about the soils and crops of this region that allow the anomalous cultivation regime to exist? No systematic answer is forthcoming locally. People follow practices that impact on the environment, without articulating a theory of why, which is understandable given the pragmatic character of their soil knowledge, it not being codified but diffuse and communicated piecemeal, even disjointedly from our perspective.

The theory and concepts of natural science allow us to address the question. The implication is *not* that we can translate Wola conceptions about the environment into scientific discourse. It is entirely foreign to them, with no ideas equivalent to nutrient ions, gas exchange, physical functions, and so on. Nor is the aim to assess the veracity of local ideas against scientific ones, both are relative. It is to further our understanding of environmental interactions within cultural context. Although taken up with different issues expressed in quite different idioms, both concern the *same* natural environment ‘out there’ and together can further our understanding of it, people’s place within it and the impact of their activities on it. (For simlar attempts, which consider both indigenous and scientific knowledge of soils in African and MesoAmerican cultural contexts, see Krogh & Paarup-Laursen 1997; Ericksen & Ardón 2003; and Gray & Morant 2003.) Furthermore, combining natural science with ethnographic enquiry responds to post-modern criticism, distancing such work from any pretence about achieving an understanding of a foreign population as it understands itself.

It is necessary to know something about the changes that occur in the nutrient status of soils under cultivation for varying periods of time to understand how the Wola can cultivate sites semi-permanently with no soil amendments. Briefly, the properties of the region’s soils (see Table 2)[8] that limit crop nutrition and production are: 1). low levels of phosphorus availability and high rates of phosphate fixation (reflecting the strong immobilising capacity of volcanic ash-derived minerals -- Parfitt& Mavo 1975);[9] 2); sub-optimal pH, these acid conditions interfering with the supply of some nutrients, notably reducing total base saturation; 3); depressed cation exchange capacities and lowered availability of exchangeable cations, which is particularly problematic with potassium; and 4); low levels of available nitrogen, which is probable with the high organic matter contents (as high C:N ratios indicate). The physical properties of the soils are, by contrast, generally favourable to crop production, with their high organic matter contents, low bulk densities, and good topsoil aeration and drainage.

The following soil-related processes occur with the establishment of a garden. The burning of cleared vegetation returns nutrient elements to the soil (except for that fraction lost as gas to the atmosphere) via ash that is rapidly broken down further for plant uptake, as documented for swidden regimes elsewhere. It increases pH and gives a critical, though short-lived boost to the availability of several elements. The boost is particularly significant for phosphorus, and also potassium and nitrogen, three major plant nutrients. The increased availability of these limiting nutrients is sufficient to allow the cultivation of a wide variety of crops, several of them annuals, including a range of beans (e.g. *Lablab niger, Phaseolus vulgaris*), green leafy vegetables (e.g. *Rorippa* sp., *Dicliptera papuana*), aroids (e.g. *Colocasia esculenta, Xanthosoma sagittifolium*) and cucurbits (*Lagenaria*

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[8] For details of analytical methods and discussion (including statistical analysis) see Sillitoe 1996:339-364; 1998.

[9] Phosphorus sorption isotherms, which give accurate assessments of phosphorus fixation, constructed for similar soils elsewhere in the Southern Highlands region confirm these observations of very high phosphate fixation capacities (Radcliffe 1986:114-18; Floyd *et al*. 1988).

siceraria, Cucumis sativus), plus some longer term crops such as bananas (*Musa* sp.) and sugarcane (*Saccharum officinarum*) (Sillitoe 1983:29-136). But the increase is short-lived. There is a decrease in the variety of crops cultivated after two or three plantings, reflecting a change in soil nutrient status, with nutrient availabilities falling to pre-burn levels due to soil processes largely, with some removed in harvested crops. Organic matter and nitrogen decline significantly with time under cultivation together with potassium, but it is the latter, together with phosphate (the availability of which is relatively low throughout) that fall to levels below those required by many crops (other nutrients show no significant variation).[10] They decline to new equilibrium points that remain relatively constant, even after years under cultivation.

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[10] These parallel findings elsewhere (Floyd *et al.* 1988; Goodbody & Humphries 1986; Wood 1979).

Figure 8 New garden with taro, greens, sugar cane and beans (trained up poles)

Figure 9 Mature garden of sweet potato with bananas and some sugar cane.

After the first couple of cropping cycles, a markedly narrower range of crops occurs, with many gardens passing under a virtual monocrop of sweet potato, perhaps with a few longer term crops, and the occasional patch of pumpkin (*Cucurbita maxima*), edible pitpit (*Setaria palmifolia*) and acanth greens (*Rungia klossii*). The sweet potato (Bourke 1985) occupies a central place in this farming system. It is the staple crop, comprising about 75% of all food consumed by weight (Sillitoe 1983:239), and makes up by far the largest area under crops. It has the capacity to continue producing tolerable yields under these nutritionally constrained conditions with its relatively low phosphorus requirements and preference for fairly high potassium to nitrogen ratio.[11] Contrary to expectations these changes in soil fertility do not necessarily lead to reduced staple sweet potato yields. Farmers maintain that the soil on some sites improves with use, becoming better for tuber production with time. Measurement of crop yields confirms their assertions, the harvest of tubers from newly cleared garden areas being some 40% below that from established ones. Far from experiencing a decline in yields, as the accepted model of low-input subsistence agriculture predicts, the reverse occurs on some sites and they increase under cultivation.

MANAGING SOIL RESOURCES

While sweet potato may yield adequately on soils relatively low in extractable phosphorus, even potassium so long as its ratio relationship with nitrogen remains favourable, farming arrangements must nonetheless maintain minimal levels for tolerable tuber production to continue. How do Wola farmers sustain them and keep their ‘bone gardens’ under near continuous cultivation without adding external amendments to the soil? The answer is by cultivating sweet potato in earth mounds, composted with the weeds and grasses that colonise sites during brief fallows. The plano-convex mounds of soil, called *mond* locally, vary in size, between two to three metres or so in diameter. This soil management technique is characteristic of subsistence agriculture across the central highlands of Papua New Guinea.[12]

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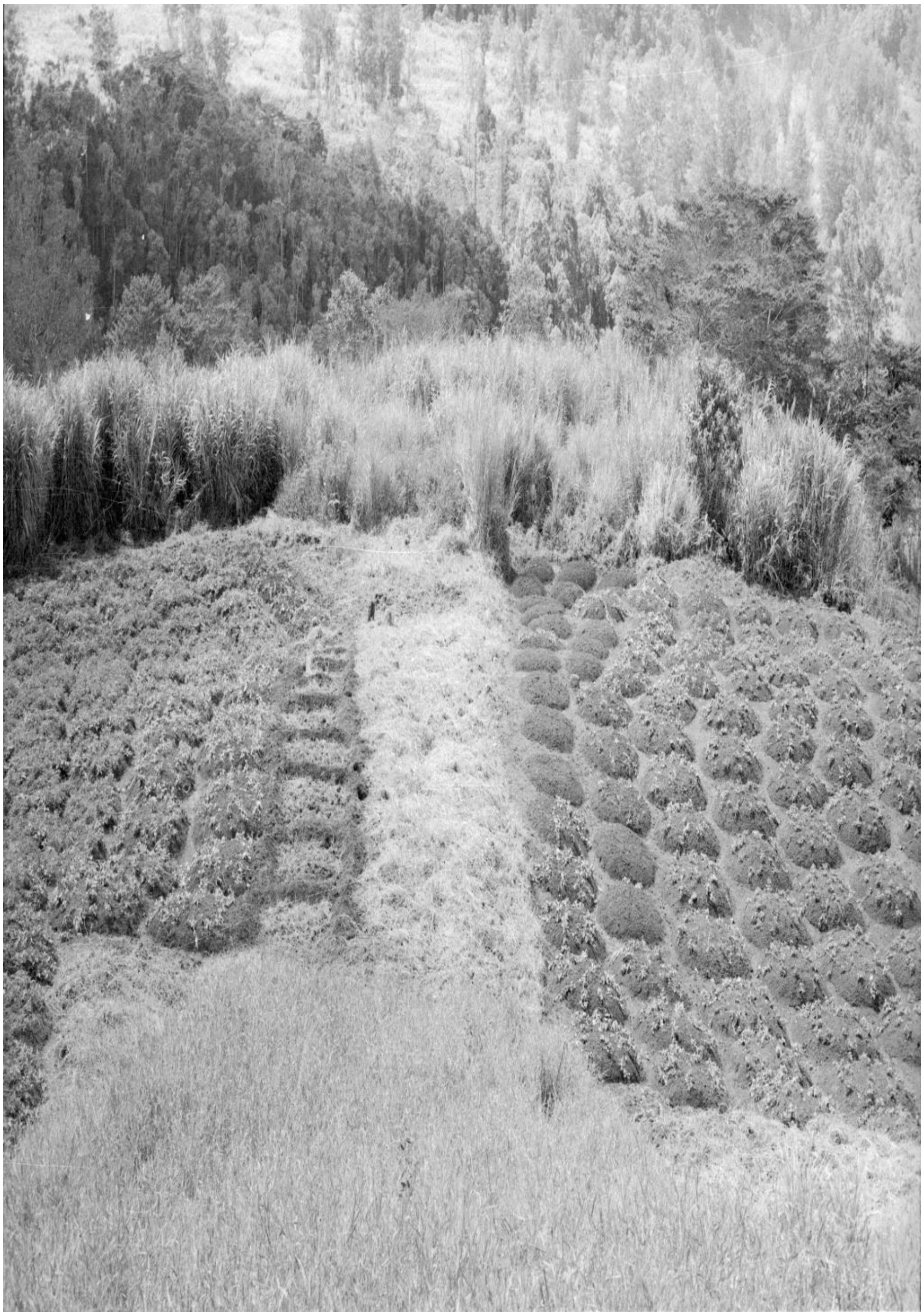
[11] Regarding sweet potato, a wide range of factors may limit yields, among them deficiencies in soil fertility, virus diseases, root-knot nematode infestation, leaf scab, insect damage, and the genetic potential of cultivars. The balance of environmental evidence, general observations of many gardens over several years, and the comments of local people, suggest that soil fertility is the major constraint on sweet potato production in the Wola region, the incidence of disease and pest infestation rarely rising to levels sufficient seriously to limit yields.

[12] On the role of mounding elsewhere in subsistence farming, see Dubois 1957, Stromgaard 1990, Siame 2006, McKey, Renard & Comptour 2017.

Figure 10 Mound recently planted with sweet potato cuttings

Figure 11 View across garden area previously under coarse grass showing mounds in various stages of cultivation



A key feature of mounding is the incorporation of all weedy regrowth and any remaining crop residues into them as compost, or coarse grasses[13] and herbaceous

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[13] Notably *Ischaemum polystachum*.

vegetation, either green or burnt, if a site is left fallow for any time. The vegetation soon rots down into a soft compost, the general Wola term for which is *paenpaen* (e.g. *iysh shor paenpaen*, literally 'tree leaf bedding-accumulated', for tree leaf compost, *gaimb paenpaen*, literally 'cane-grass bedding-accumulated', for cane grass compost, and so on). It allows farmers to manage soil fertility constraints by incorporating nutrients stored in plant residues into the soil, [14] particularly with organic matter playing a notable role in maintaining the fertility of soils containing volcanic ash. [15] The supply of those nutrients identified as the probable major constraints on yield -- namely potassium, phosphate and possibly nitrogen -- is more or less sufficient from grassy regrowth to meet the demands of sweet potato. Although phosphorus availability may remain below that necessary for optimal yields (Parfitt & Mavo 1975), the effect may be relatively insignificant given the crop's ability to manage on low phosphate supply (Nicholaides *et al.* 1985). The boost in available potassium is significant to the success of composted mounds in cultivating established gardens where levels are low, grasses being well known for their high potassium contents.

Box 3 The efficacy of mounds.

The benefits are several (Waddell 1972:150-166). The composted mounds are particularly suitable for the management of soils containing volcanic ash, the mechanism of nutrient uptake which they afford being especially effective at overcoming phosphate fixation and poor base saturation, it occurring directly from the decomposing vegetation concentrated at the centre of the mound as roots grow through it (Floyd *et al.* 1987).[16] The delay in the release of nutrients from the compost doubtless permits more opportunity for uptake, allowing time for initial root growth, and more intimate contact between roots and nutrients as they enter solution. Further benefits of compost include improved water holding capacity. The microbial decomposition of the compost also increases temperatures, further encouraging vigorous root growth. Composting mounds also helps control weeds, by burying them so that sweet potato has a head start in the competition for light. Another benefit mentioned by local people is that it reduces the incidence of disease and rotten tubers,[17] although care is needed, especially using crop residues, not to spread disease.

They also mention the physical results, pointing out that mounding ensures that the soil is friable, the compost giving mounds a soft centre favourable to root penetration and enlargement into long and straight, regular shaped tubers. The breaking up of the soil with mound tillage certainly avoids compaction and ensures favourable bulk densities

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[14] The incorporation of herbaceous and grassy regrowth as compost shows the role weeds may play in the management of soil fertility in shifting cultivation contexts (Lambert & Arnason 1989; Swamy & Ramakrishnan 1988).

[15] Adding crop residues or straw is successful on a range of soils under shifting cultivation, giving yield responses as good, or higher than fertiliser or manure applications (Sanchez 1976; Lal 1975).In twelve out of thirteen trials for example, conducted throughout Papua New Guinea, organic soil amendments increased sweet potato yields, these consistently positive yield responses suggesting that organic materials may offer more scope in this country for increasing food productivity than inorganic fertilisers (D'Souza & Bourke 1982; Velayutham *et al.* 1982).

[16] Floyd *et al.* (1987) also take the absence of any residual composting effect on the next crop as further evidence that it is direct nutrient uptake from decomposing compost that makes this manuring method particularly effective. Under traditional cultivation however, women add new compost to mounds every time they cultivate a garden. Although there may be no evident residual effects on yield, the addition of organic matter in composting makes a long-term contribution to the maintenance of soil fertility - carbon content decline being one of the few significant effects evident under on-going cultivation.

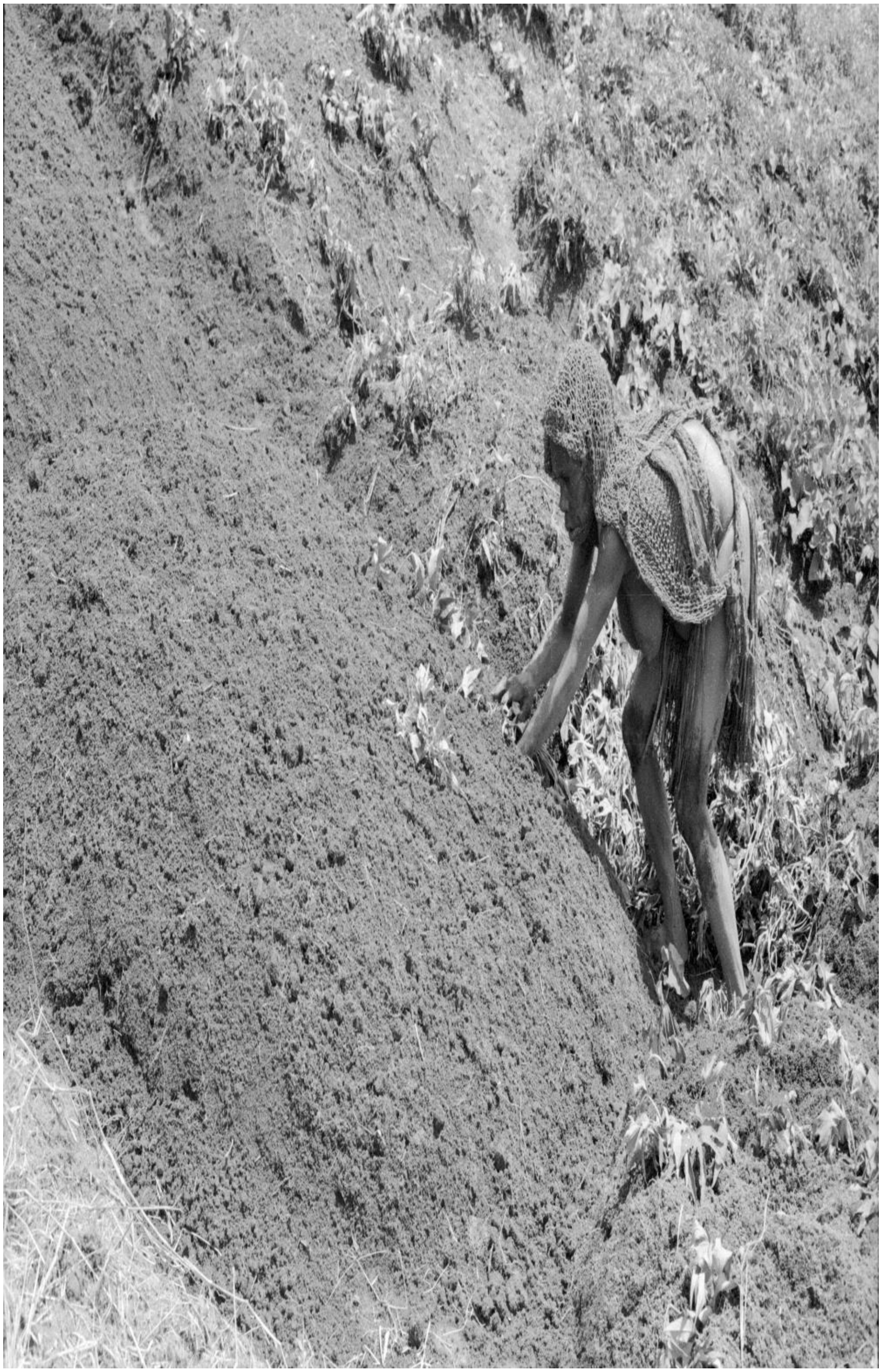
[17] In Enga Province in the central highlands, where people say compost helps prevent tubers from rotting, black rot (caused by *Ceratocystis fibriata*) was observed four to five times (2.5% to 13.6%) less often on tubers from composted mounds (Preston 1990).

regardless of the time soils are kept under cultivation. It also promotes soil aeration and drainage by encouraging a loose friable structure, which is significant in a climate where high rainfall is usual (Clarke & Street 1967). The building of mounds also increases effective topsoil depth, which is noteworthy in a region where they commonly cultivate steep slopes having shallow topsoils. Local farmers observe that tuberisation is poor with plants that have to root into the denser, clayey subsoil.

Figure 12 Starting mound: heaping crumbled soil over uprooted grass (newly planted mounds to left).

Figure 13 Finishing mound: scooping fine tilth over it (mature garden to rear)

Figure 14 Firming sweet potato cuttings into soil mound



The incorporation of compost in mounds has a significant effect on sweet potato yields. A series of trials in the Southern Highlands Province, on soils similar to those discussed here, showed a linear relationship between rate of compost application and increases in mean tuber yield (Floyd *et al.* 1988).[18] The extent to which compost augments soil fertility varies with the vegetation mix; although the Wola do not manage fallow sites to promote the growth of certain species above others. They use whatever vegetation comes naturally available. They manage things by the time they leave gardens fallow. The immediate cultivation of sites repeatedly (incorporating crop residues and pioneer weeds as compost, or after short-term fallow intervals with more advanced herbaceous colonisation) will result in declining sweet potato yields. The yield of fresh vegetation in such gardens ranged from 28 to 35 t/ha. But it only requires a longer fallow interval dominated by coarse grasses between some cultivations to sustain available nutrient supplies indefinitely at levels sufficient to assure adequate tuber yields. [19] When left fallow under grassy regrowth for several months, compost yields ranged from 32 t/ha after nine months, to 85 t/ha after two years plus, with a mean rate of 62 t/ha.[20]

Another source of fertiliser for small cultivations near to homesteads is *dowhuwniy* (sweepings of everyday refuse from inside houses) and *showmay iy hiym* (pig manure), which people regularly toss onto such gardens (Sillitoe 2010:16-17). They acknowledge that such waste promotes fertility, the small enriched areas supporting a variety of high-yielding crops. They exploit these nutrient sources when they abandon houses too, cultivating small mixed vegetable gardens after the building materials have rotted or are burnt. These sites can initially prove particularly fertile, acidity approaching neutral, which favours phosphate availability, and they have substantial exchangeable cation availabilities and nitrogen levels too, although the topsoils are usually thin and cannot sustain these nutrient levels for long.

CONSERVATION VERSUS DEGRADATION

Shifting cultivation has a maligned reputation, regardless of attempts to rehabilitate it (see, for example, Dove 1983; Aweto 2013). According to one commentator "shifting cultivation activities destroy 50,000 km^2 . . . of tropical rainforest a year", part of the problem being that "underlying soils are inherently infertile" (Park 1992: 46-47). Such conceptions derive in large part from Latin America and Equatorial Africa where people cultivate old soils, such as Oxisols and Ultisols that occur on ancient land surfaces (Nye & Greenland 1960; Spencer 1966; Watters 1971).[21] Some commentators argue that the horticultural activities of New Guinea Highlanders including the Wola result in similar land degradation, portending an ecological crisis (Brookfield & Brown 1963: 117-124; Wood 1979, 1982; Allen 1984; Allen & Crittenden 1987). We need to be wary of allowing our current concerns about the destruction of natural resources –deforestation, biodiversity loss, industrial pollution, global warming etc. – to distort our view of the activities of others. While in some tropical regions, such as Amazonia and the Congo, a

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[18] The observed response to the improvements in soil fertility was an increase in tuber initiation over tuber bulking, with more tubers per plant, with considerably more tubers reaching marketable size (>100g).

[19] A long-term soil exhaustion experiment at Aiyura Highlands Agricultural Experiment Station in the Eastern Highlands Province, which was first planted in November 1955, demonstrates the effectiveness of grass fallows between crops in maintaining sweet potato yields (Kimber 1974).

[20] There was a marked increase in the amount of decomposing grass litter the longer sites were under fallow, adding considerably to their compost yields. The dry weight of the vegetation was about one-third of its green weight.

[21] Recent research on these old soils has revealed that people can manage soil fertility in previously unforeseen ways, notably through traditional cultivation practices involving biochar, such as the anthropogenic dark earths of Amazonia (*terra preta*), recently reported in Africa too (Glaser *et al.* 2001; Glaser & Birk 2012 Frausin *et al.* 2014; Fairhead *et al.* 2017).

degraded environment results from extended cultivation, it is an error to generalise from them for all the tropics. In view of the wide variation in land resources across tropical latitudes (Sanchez 1976:52-87; Juo & Franzluebbers 2003:131-237), we should anticipate different environmental responses to cultivation. After all, it is common knowledge that volcanic fallout may rejuvenate soils, keeping them youthful, although it leads to certain nutrient availability problems.

The claims of Wola farmers that some soils progressively improve and staple crop yields increase the longer they are under cultivation, and that the only way to ascertain this is to garden them, are the exact reverse of the widespread image of soils quickly exhausted and forcing a change of site. The evidence suggests that the Wola have a remarkably conservational horticulture regime within the constraints of their technology. The flexibility afforded by fallow options keeps cultivation in sustainable equilibrium with soil resources, so long as the appropriate fallow time elapses. When sites show signs of reduced yields, farmers leave them longer under grass to recover their fertility status, whereas when they crop well, they may cultivate them again immediately. It is a stable management system. The character of the region's soils, their response to clearance and cropping, together with local people's understandings and their management of them under cultivation, are central to understanding the processes that allow the continuance of this agricultural regime, which allow farmers to maintain semi-permanent plots of non-perennial crops by overcoming the soil constraints reported elsewhere in the tropics that oblige subsistence farmers to shift their cultivations frequently.

REFERENCES

Acres, B.D. 1984. Local farmers' experience of soils combined with reconnaissance soil survey for land use planning - an example from Tanzania. *Soil Survey and Land Use* 4: 77-86.

Adewole Osunade, M. A. 1995 Identification of Crop Soils by Small Farmers of South-western Nigeria. *Journal of Environmental Management* 35:193-203.

Allen, B. J. 1984 Land use, population and nutrition. In B. J. Allen (ed) *Agricultural and nutritional studies on the Nembi Plateau, Southern Highlands*. UPNG Geography Department. Occasional Papers (New Series) No. 4 (pp. 89-95).

Allen, B.J. & Crittenden, R. 1987 Degradation and a pre-capitalist political economy: the case of the New Guinea highlands. In P. Blaikie & H. Brookfield (eds.) *Land degradation and society* (pp. 143-156). London: Methuen.

Atran, Scott and Medin, Douglas 2008 *The native mind and the cultural construction of nature*. Cambridge MA: MIT Press.

Aweto, Albert O. 2013 *Shifting cultivation and secondary succession in the Tropics*. Wallingford: CAB International

Barrera-Bassols, N., and Zinck, J. A. 2003 Ethnopedology: a worldwide view on the soil knowledge of local people. *Geoderma* 111 (3-4),171-195.

Barrera-Bassols, N., Zinck J. A. and Van Ranst, E. 2009 Participatory soil survey: experience in working with a Mesoamerican indigenous community. *Soil Use and Management* Volume 25, Issue 1, Pages: 43–56.

Birmingham, D. M. 2003 Local knowledge of soils: the case of contrast in Côte d'Ivoire. *Geoderma* 111 (3-4): 481-502.

Bleeker, P. 1983 *Soils of Papua New Guinea.* Canberra: CSIRO & Australian National University Press.

Bourke, R.M. 1985 Sweet potato (*Ipomoea batatas*) production and research in Papua New Guinea. *Papua New Guinea Journal of Agriculture, Forestry & Fisheries* 33 (3,4): 89-108.

Brookfield, H.C. & Brown, P. 1963 *Struggle for land: agriculture and group territories among the Chimbu of the New Guinea Highlands*. Melbourne: A.N.U. and Oxford University Press.

Clarke, W.C. & Street, J.M. 1967 Soil fertility and cultivation practices in New Guinea. *Journal of Tropical Geography* 24: 7-11.

De Queiroz, J.S. & Norton, B.E. 1992. An assessment of an indigenous soil classification used in the Caatinga Region, of Ceara State NE Brazil. *Agricultural Systems* 39, 289-305.

Denham, Tim 2017 The antiquity of agriculture. In J. Friede, T. Hays and C. Hellmich (eds.) *New Guinea Highlands: art from the Jolika collection*. San Francisco & Munich: De Young Fine Arts Museum and Prestel Publishing DelMonico Books. Pages 57-61

Dove, M. 1983. Theories of swidden agriculture and the political economy of ignorance. *Agroforestry Systems* 1:85-99.

D'Souza, E.J. & Bourke, R.M. 1982 Compost increases sweet potato yields in the highlands. *Harvest* 8 (4): 171-75

Dubois, J. 1957 Semis forestiers sur buttes incineres. Leur importance dans les travaux de feforestation des savanes du Bas-Congo. *Bulletin d'Information de 'l'Institut nationals et Agronomique du Congo Belge (INEAC)* 6 (1): 21-30.

Ericksen, P. J. & Ardón 2003 Similarities and differences between farmer and scientist views on soil quality issues in central Honduras *Geoderma* 111 (3-4): 233-248.

Fairhead, J. Fraser, J. A., Amanor, K., Solomon, D., Lehmann, J. and Leach, M. 2017 Indigenous soil enrichment for food security and climate change in Africa and Asia: A Review. In P. Sillitoe (ed.)

Indigenous knowledge: Enhancing its contribution to natural resources management. Wallingford: CAB International (pp. 99-115).

Forster, George 1843 *Saemtliche Schriften*. Volume 4. Leipzig: F.A. Brockhaus.

Floyd, C. N., D'Souza, E. J. & LeFroy, R. D. B. 1987 Composting and crop production on volcanic ash soils in the Southern Highlands of Papua New Guinea. Port Moresby: Department of Primary Industry Technical Report 87/6.

Floyd, C. N., Lefroy, R. D. B. & D'Souza, E. J. 1988 Soil fertility and sweet potato production on volcanic ash soils in the highlands of Papua New Guinea. *Field Crops Research* 19:1-25.

Frausin, V., Fraser, J. A. Narmah, W., Lahai, M. K., Winnebah, T., Fairhead, J. and Leach, M. 2014 'God made the soil, but we made it fertile': Gender, knowledge and practice in the formation and use of African dark earths in Liberia and Sierra Leone" *Human Ecology* 42 (5): 695-710.

Glaser B., Haumaier L., Guggenberger G., & Zech W. 2001 The *terra preta* phenomenon: a model for sustainable agriculture in the humid tropics. *Naturwissenschaften* 88 (1): 37-41.

Glaser, B and Birk, J. 2012 State of the scientific knowledge on properties and genesis of Anthropogenic Dark Earths in Central Amazonia (*terra preta de Índio*). *Geochimic et Cosmochimica Acta* 82: 39-51.

Golson, Jack, Denham, Tim, Hughes, Philip, Swadling, Pamela and Muke, John (eds.). 2017 *Ten Thousand Years of Cultivation at Kuk Swamp in the Highlands of Papua New Guinea*. Canberra: ANU Press (Terra Australis 46).

Goodbody, S. & Humphries, G.S. 1986 Soil chemical status and the prediction of sweet potato yields. *Tropical Agriculture* 63 (2): 209-11.

Gray, L. C., and Morant, P. 2003 Reconciling indigenous knowledge with scientific assessment of soil fertility changes in southwestern Burkina Faso. *Geoderma* 111 (3-4): 425-437.

Habarurema, E. & Steiner, K.G. 1997. Soil suitability classification by farmers in southern Rwanda. *Geoderma* 75, 75-87.

Hecht, S.B. 1989. Indigenous soil management in the Amazon Basin. Some implications for development. In Browder, J. (ed.) *Fragile Lands of Latin America* Westview, Boulder Colarado, USA (pp166-181).

Humboldt, Alexandre de 1822 *Voyage aux régions équinoxiales du nouveau continent, fait en 1799, 1800, 1801, 1802, 1803 et 1804 par A. de Humboldt et A. Bonpland*. Tome VIII. Paris: chez N. Maze. Page 525.

Juo, A. S. R. & Franzluebbers, K. 2003 *Tropical soils. Properties and management for sustainable agriculture*. New York: Oxford University Press.

Kimber, A. J., 1974 Crop rotations, legumes and more productive arable farming in the highlands of Papua New Guinea. *Science in New Guinea* 2 (1): 70-79.

Krasilnikov, P. V. & Tabor, J. A. 2003 Perspectives on utilitarian ethnopedology. *Geoderma* 111 (3-4): 197-215.

Krogh, L., and Paarup-Laursen, B. 1997 Indigenous soil knowledge among the Fulani of northern Burkina Faso: linking soil science and anthropology in analysis of natural resource management. *Geojournal* 43: 189-197.

Kundiri A.M., Jarvis, M.G. & Bullock, P. 1997. Traditional soil and land appraisal on Fadama lands in northeast Nigeria. *Soil Use and Management* 13: 205-208.

Lal, R., 1975 Role of mulching techniques in tropical soil and water management. *International Institute of Tropical Agriculture Bulletin* 1.

Lambert, J.D.H. & Arnason, J.T. 1989 Role of weeds in nutrient cycling in the cropping phase of milpa agriculture in Belize, Central America. In J. Proctor (ed.) *Mineral nutrients in tropical forest and savanna ecosystems*. Oxford: Blackwell. (pp. 301-13).

Lamers, J.P.A. .& Feil, P.R. 1995. Farmers' knowledge and management of spatial soil and crop growth variability in Niger, West Africa. *Netherlands Journal of Agricultural Science* 43, 375-389.

McKey, Renard, D. & Comptour, M. 2017 Will the real raised-field agriculture please rise? Indigenous knowledge and the resolution of competing visions of one way to farm wetlands. In P. Sillitoe (ed.) *Indigenous knowledge: Enhancing its contribution to natural resources management.* Wallingford: CAB International (pp. 116-129).

Milne, J.A. 1947. A soil reconnaissance journey through parts of Tanganyika Territory, December 1935 to February 1936. *Journal of Ecology* 35, 192-265.

Ngailo, J. A., and Nortcliff, S 2007 Learning from Wasukuma ethnopedology: An indigenous well established system for transfer of agro-technology in Tanzania. *Indilinga - African Journal of Indigenous Knowledge Systems* 6 (1): 64-75.

Nicholaides, J. J., Chancy, H. F., Mascagni, H. J., Wilson, L.G. & Eaddy, D.. 1985 Sweet potato response to K and P ferilization. *Agronomy Journal* 77: 466-70.

Niemeijer, D. 1995. Indigenous soil classifications: complications and considerations. *Indigenous Knowledge and Development Monitor* 3: 20-21.

Niemeijer, D., and Mazzucato, V. 2003 Moving beyond indigenous soil taxonomies: local theories of soils for sustainable development. *Geoderma* 111 (3-4): 403-424.

Norman, M. J. T. 1979 *Annual cropping systems in the tropics*. Gainsville: University of Florida.

Nye, P. H. & Greenland, D. J. 1960 *The soil under shifting cultivation.* Harpenden: Commonwealth Bureau of Soils Technical Bulletin No. 51.

Osbahr, H., and Allan, C. 2003. Indigenous knowledge of soil fertility management in southwest Niger. *Geoderma* 111 (3-4): 457-479.

Ostberg, W. 1995. *Land is coming up: The Burunge of Central Tanzania and their environments.* Stockholm: Almqvist and Wiksell International.

Parfitt, R.L. & Mavo, B. 1975 Phosphate fixation in some Papua New Guinea soils. *Science in New Guinea* 3:179-90.

Park, C. C. 1992 *Tropical rainforests*. London: Routledge.

Preston, S. R. 1990 Investigation of compost ∗ fertilizer interactions in sweet potato grown on volcanic ash soils in the highlands of Papua New Guinea. *Tropical Agriculture* 67 (3): 239-42.

Radcliffe, D. J. l986 The land resources of Upper Mendi. (2 vols) Konedobu: Dept. Primary Industry Research Bulletin No. 37 (AFTSEMU Tech. Report No. 8).

Russell, Edward J. 1912 *Soil conditions and plant growth.* London: Longmans, Green & Co. (Monographs on Biochemistry).

Ruthenberg, H. 1976 *Farming systems in the tropics* Oxford: Clarendon Press.

Sanchez, P. A. 1976 *Properties & management of soils in the tropics* New York: Wiley.

Sandor, J.A. & Furbee, L. 1996. Indigenous knowledge and classification of soils in the Andes of Southern Peru. *Soil Science Society of America Journal* 60, 1502-1512.

Scott, C.A. and Walter, M.F. 1993. Local knowledge and conventional soil science approaches to erosional processes in the Shivalik Himalaya *Mountain Research and Development* 13:1 61-72.

Siame, J.A. 2006 The Mambwe mound cultivation system. *LEISA Magazine* 22(4): 14-15.

Sikana, P. 1993. Mismatched models: how farmers and scientists see soils *ILEA Newsletter* 9 (1): 15-16.

Sillitoe, P. 1983 *Roots of the earth: The cultivation and classification of crops in the Papua New Guinea highlands*. Manchester: Manchester University Press.

Sillitoe, P. 1996. *A place against time: land and environment in the Papua New Guinea highlands.* Amsterdam: Harwood Academic.

Sillitoe, P. 1998 It's all in the mound: fertility management under stationary shifting cultivation in the Papua New Guinea highlands. *Mountain Research and Development* 18 (2): 123-134

Sillitoe, P. 1999 Beating the boundaries: land tenure and identity in the Papua New Guinea Highlands. *Journal of Anthropological Research* 55 (3):331-360.

Sillitoe, P. 2010 *From land to mouth: The agricultural 'economy' of the Wola of the New Guinea Highlands.* New Haven: Yale University Press.

Sillitoe, P.2017 *Built in Niugini: Constructions in the highlands of Papua New Guinea*. London: Royal Anthropological Institute Monograph Series, Volume 1. Canon Pyon: SK Publishing.

Sillitoe, P. & Sillitoe, J. A. 2009 *'Grass-clearing man': A factional ethnography of life in the New Guinea Highlands.* Long Grove (Ill.): Waveland Press

Simmons, I. G. 1993 *Interpreting nature: Cultural constructions of the environment*. London: Routledge

Soil Survey Staff. 2014. *Keys to soil taxonomy*. (12th ed.) Washington, DC: USDA-Natural Resources Conservation Service.

Spencer, J. E. 1966 *Shifting Cultivation in Southeastern Asia*. Berkeley: University of California Press (Publications in Geography Volume 19).

Stromgaard, P. 1990 Effects of mound-cultivation on concentration of nutrients in a Zambian *miombo* woodland soil. *Agriculture, Ecosystems & Environment* 32: 295-313.

Swamy, P.S. & Ramakrishnan, P.S. 1988 Ecological implications of traditional weeding and other imposed weeding regimes under slash and burn agriculture (*jhum*) in north-eastern India. *Weed Research* 28: 127-36.

Tabor, J.A. 1992. Ethnopedological surveys - soil survey that incorporate local systems of land classification. Soil Survey Horizons (Spring 1992).

Talawar, S., and R. E. Rhoades. 1998. Scientific and local classification and management of soils. *Agriculture and Human Values* 15, no. 1: 3-14

Velayutham, K.S., Pondrilei, K.S. & Natera, E.A. 1982 Effects of soil native nutrients and applied nutrients on sweet potato. In R.M. Bourke & V. Kesavan (eds.) *Proceedings of the Second Papua New Guinea Food Crops Conference*. Konedobu: Department of Primary Industry (pp. 382-90).

Waddell, E. 1972 *The mound builders: agricultural practices, environment, and society in the Central Highlands of New Guinea.*Seattle: University of Washington Press.

Watters R. F. 1971 *Shifting cultivation in Latin America*. Rome: Food and Agriculture Organization of the United Nations.

WinklerPrins, A. & Barrera-Bassols,N. 2004 Latin American ethnopedology: A vision of its past, present, and future. *Agriculture and Human Values*, vol. 21, issue 2, 139-156.

Winklerprins, A. M. G. A. 1999 Local soil knowledge: A tool for sustainable land management. *Society and Natural Resources* 12:151-161.

Wood, A.W. 1979 The effects of shifting cultivation on soil properties: an example from the Kirimui & Borrai Plateaux, Simbu Province, Papua New Guinea. *Papua New Guinea Agricultural Journal* 30: 1-9.

Wood, A.W. 1982 Food cropping systems in the Tari Basin. In R. M. Bourke & V. Kesavan (eds.) *Proceedings of the Second Papua New Guinea Food Crops Conference*. Konedobu: Department of Primary Industry (pp. 256-67).

Young, A. 2017 *Thin on the ground: Soil science in the tropics*. 2nd edition. Norwich: Land Resources Books.

WOLA		**USDA**		**FAO**
MAJOR GROUP	MINOR GROUPS	SUB-ORDER	GREAT GROUP	
haenbora		Orthent	Troporthent	Lithosols
haen hok		Rendoll		Rendzinas
hundbiy	*payhonez*	Tropept	Humitropept	Cambisols
	kas	Humult	Tropohumult	Acrisols
	tongom			
tiyptiyp	*kolbatindiy*	Andepts	Hydrandept	Andosols
			Dystrandept	
iyb dor tilai		Fluvent	Tropofluvent	Fluvisol
iyb muw		Psamment	Troposamment	Arenosol
pa tongom		Aquepts	Andaquept	Gleysols
			Tropaquept	
		Aquent	Fluvaquent	
iyb uw damiy		Saprist	Troposaprist	Histosols
		Hemist	Tropohemist	
			Cryohemist	
waip		Folist	Tropofolist	
		Fibrist	Tropofibrist	

Table 1 Soil names of the Wola correlated with those of USDA and FAO.

	SITE STATUS: VIRGIN THROUGH CROPPED TO FALLOW VEGETATION											STATISTICAL SIGNIFICANCE		
	Virgin	**Cropped Sites: Times Cultivated**						**Fallow Sites: Years Under Fallow**						
	Sites	**1**	**2**	**3**	**4**	**>5**	**>10**	**<1**	**1-5**	**5-10**	**>10**	**F**	**P**	
pH	5.02 (0.66)	5.39 (0.92)	5.08 (0.47)	4.94 (0.40)	5.01 (0.67)	5.32 (0.53)	5.25 (0.28)	5.28 (0.61)	5.22 (0.41)	5.1 (0.31)	4.86 (0.27)	1.14	0.34	N.S.
Phosphorus (ppm)	17.1 (12.1)	17.3 (16.2)	12.2 (13.4)	7.1 (4.5)	7.8 (6.3)	7.2 (5.5)	5.7 (5.2)	13.9 (17.4)	7.2 (7.9)	6.6 (6.0)	7.2 (6.8)	1.71	0.09	N.S.
Potassium (me/100g)	1.04 (0.57)	0.56 (0.20)	0.68 (0.30)	0.63 (0.36)	0.44 (0.49)	0.27 (0.13)	0.28 (0.17)	0.87 (0.96)	0.58 (0.28)	0.79 (0.97)	0.46 (0.25)	2.09	0.03	S.
Calcium (me/100g)	13.9 (11.2)	12.2 (6.4)	14.1 (9.4)	8.7 (7.4)	15.3 (11.7)	16.7 (15.8)	8.1 (3.7)	19.7 (23.8)	12.4 (9.4)	8.0 (5.3)	7.3 (7.7)	1.23	0.29	N.S.
Magnesium (me/100g)	3.04 (2.53)	3.36 (2.25)	3.25 (2.23)	1.90 (1.31)	2.11 (1.54)	2.14 (0.70)	2.35 (0.98)	2.65 (2.48)	2.04 (0.92)	1.66 (0.96)	2.45 (2.39)	0.95	0.49	N.S.
CEC (me/100g)	31.3 (5.2)	27.4 (9.4)	31.0 (8.3)	27.1 (5.6)	27.4 (12.1)	29.0 (4.9)	22.6 (7.4)	28.0 (7.4)	31.6 (6.4)	23.3 (7.1)	26.9 (6.9)	1.58	0.13	N.S.
Carbon (%)	25.9 (6.6)	17.6 (8.6)	17.3 (6.4)	14.9 (5.3)	16.8 (10.9)	12.8 (5.9)	11.6 (6.4)	14.5 (6.8)	16.7 (5.2)	11.9 (4.1)	17.5 (6.0)	3.55	0.001	S.
Nitrogen (%)	1.41 (0.62)	0.96 (0.29)	1.06 (0.41)	0.86 (0.39)	0.99 (0.32)	0.93 (0.28)	0.74 (0.26)	0.93 (0.42)	1.12 (0.43)	0.79 (0.29)	1.08 (0.46)	2.23	0.02	S.

Table 2 Measures of topsoil chemical fertility compared with site land use status (values in brackets = standard deviations; n=110 sites; degrees of freedom=10, 99).