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Socio-economic Aspects of Acid Soil Management

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Socio-economic aspects of acid soil management

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Abstract

This paper provides an overview of recent research on the social, economic and cultural dimensions of managing acid soils. It highlights the folk knowledge of native farmers and their techniques for managing acidity and even transforming their soils into highly productive anthropogenic soils capable of producing high yields through high labor inputs. The paper also examines the conditions under which these management techniques may not occur. Emphasis is given to linking folk knowledge of soils to scientific classificatory schemes in order to enhance the collaboration of farmers with researchers.

Introduction

The management of acid soils has been a challenge to agriculturalists. For most of human history acid soils have been managed[1] by slash-and-burn techniques which ensure the transformation of plant biomass into nutrients some of which reduce the acidity present for at least one cropping season. This technique continues to be used throughout the tropical world both because it works and because it is more economical than applying lime and other correctives which often prove too costly for the average producer.

While burning biomass is the most common economic strategy for coping with acid soils, other practices have received far less attention. While acid soils are widespread, they occur in patches side-by-side with soils of higher pH. An important component of farmer strategy has been to select, whenever possible, soils less constrained by acidity and to locate plant varieties capable of coping with low pH on the more acid soils.

These strategies tend to work relatively well as long as farmers have stable control over their location (i.e. security of tenure). When regional and national policies influence the choice of crops and varieties being planted with the alleged goal of increasing output, or resettle people with the goal of making previously uncultivated lands productive, the consequences have often been the decline of production in the area of origin and marginal output in the new areas.

For improved management of acid soils in areas distant from markets and where prices are controlled for political purposes, it is important that farmers' knowledge of soil constraints and plant varieties become a greater focus of attention in agronomic research, extension and agricultural policy-making. Given the persistent failure of third world states to favour the agricultural sector in food price policy-making, and the widespread loss of tropical forests, it is not enough to keep promising lower fertiliser prices, or genetic breakthroughs.

Farmers in many parts of the third world, now have the knowledge of how to manage soils and plant-soil interactions, if they have not been moved from their land by resettlement schemes or by loss of tenure[2]. This paper examines evidence for the kind of knowledge that farmers have about soils and plant-soil inter-

[1] Although for most of human history farmers may not have defined many of their soils as "acid" they did recognize that slash-and-burn methods produced better crops than continuous cultivation in soils that we now describe as acid.

[2] This may not be true in a number of places including Australia where aborigines were pre-agricultural and where modern farmers are largely immigrants with cultural ideas about the landscape brought from Europe. The coupling of cultural knowledge to soil characteristics tends to develop optimally where family farming and production are concerned with self-provisioning.

Table 1. Correspondence of Local and FAO Soil Classification in Kenya

Sites		FAO Classification	Local soil names
Mitunguu			
1	(122/2–40)	Orthic Luvisol	Gitune
2	(122/2–30)	Rhodic Ferralsol	Gitune
3	(122/2–36)	Rhodic Ferralsol	Gitune
4	(122/2–37)	Orthic Ferralsol	Maramu
Voo			
1	(164/2–210)	Chromic Luvisol	Kitune/Nthangathi mixture
2	(164/2–215)	Ferralic Arenosol	Nthangathi
3	(164/2–211)	Chromic Luvisol	Kitune/Nthangathi mixture
4	(164/2–213)	Chromic Luvisol	Nthangathi
5	(164/2–214)	Orthic Luvisol	Nthangathi
6	(164/2–217)	Orthic Solonetz	Nthangathi, gravelly surface
7	(164/2–216)	Calcaric Cambisol, lithic phase	Nthangathi
8	(164/2–219)	Eutric Cambisol, lithic phase	Nthangathi
9	(164/2–212)	Eutric Cambisol, and stony phases	Kitune/Nthangathi mixture
10	(164/2–218)	Eutric Fluvisol, sodic phase	Nthangathi

Source: Tabor et al., 1990.

actions, their strategies for improving plant growing conditions and the socio-economic consequences of this knowledge.

Farmers' knowledge

All over the world farmers have developed land classification schemes[3] which provide useful insights into their farming systems. These classification schemes can serve as a particularly useful starting point for agronomic research and the development of appropriate technology. Conklin (1957) observed this almost 40 years ago, nevertheless, the number of publications focusing on this issue are few. Unlike soil classification schemes dominant in Western countries which give priority to soil genesis and subsoil characteristics in classification, the folk soil classifications of most people in the world focus on soil characteristics important to the farmer, i.e. they focus on management and production. Minimally, a folk soil classification serves to identify which characteristics make a difference in a given region to growing crops (e.g. soil moisture, clay content, organic matter, root content). Soninke farmers in drought-prone Senegal, Mauritania, and Mali make very fine distinctions between soils with respect to how they are affected by flood and drought extremes which impact directly on the productivity of crops in an area marked by large fluctuations in moisture.

These folk systems of soil classification and land use are complementary to Western classificatory schemes and ignoring them results eventually in the loss of the empirical knowledge of farmers. While extension agents and others trained elsewhere may not know them, most local people with extensive farming activity know these systems and for production scientists to learn them provides a basis for greater rapport between scientist/extension agent and farmer. Just as there is no agreement or ease of translation of one soil from the FAO system to the Brazilian system to the USDA Soil Taxonomy or to the Belgian classification, despite the scientific rigour of each, one can expect diversity of opinion among farmers about their soils in the folk system, although probably less than amongst scientists. Most folk classification schemes are *local* in scope, although there may be similarity within a region if environmental conditions, soils and crops are similar. This again should not be surprising since a lot of the cacophony of soil classification today results from the dissatisfaction of an agronomic community with the classification scheme of another community in differentiating the differences in their *local* soils.

"Farmer interviews allow the soil scientist to rapidly identify all the soils that are of importance to the farmer; determine each soil's relative productivity and their value for agriculture.... and locate typical soils of each type and correlate them to other systems, both scientific and indigenous. Collecting this information.... would require a large amount of time and expense if the soil scientist works independently of the farmer. Tapping 'indigenous knowledge' is not new in soil surveys,

[3] Although some of the folk classifications of soils could be best described as "soil characterization, rather than the more rigorous scientific classifications used today, there are numerous cases of sophisticated folk soil classifications that exhibit many of the characteristics of scientific ones: they are vertically and hierarchically organized, they use complex and multi-criteria variables for classification, and some even pay attention to the subsoil-although it is more common for folk classifications to focus on the "plow layer and to be directed at management issues rather than classificatory or genesis questions.

the USDA's 1951 Soil Survey Manual has a whole section on collecting information from the farmer" (Tabor et al., 1990[4]).

Even a soil map at a scale of 1:20,000, which is rarely available anywhere in the third world, may be too coarse for farmer use if fields are small and soil variability high. Given the costs of producing maps at a scale below 1:100,000 it is unlikely in the foreseeable future that maps at the scale needed by farmers will be produced by agronomic surveys. This requires, therefore, that collaboration between farmers and soil scientists develop more than it has, to arrive at more precise synchrony of plants to soils within local systems of land use. Farmers can provide technicians with the information about what soils are present, what they are good for and when, and what plant varieties can produce reliable yields where. For any local region, the limited technical personnel can collect this information and generate a local map that is more reliable than existing ones. In the process, the technicians can take soil samples of each class in the folk classification scheme and eventually translate these classes into meaningful traditional soil taxonomy terms, or at least have the information that may be needed to show why a rethinking of our classification may be necessary. Table 1 lists the site locations, FAO classification and local classification of soils in a region of Kenya to exemplify how this might be done. The authors were able to produce a detailed understanding in a brief trip through the region of the folk understanding of soils, of plant-soil associations, and to identify many of the major constraints perceived by farmers in the locally-named soils. This provides a useful short-cut to both extension and agronomic research in distant areas where permanent research stations may not be present (Tabor et al., 1990).

Knowing the local folk classification can also help avoid needless land use conflicts. Some soils in Meru, Kenya are identified as Yumba soils that are used for making clay pots and Kithaayo are soils that are used for salt licks by livestock and wildlife. In Mitunguu, an area near Meru, one area of Yumba soils was considered of such high value to the community for making fired-clay pots that no individual was granted sole ownership of such areas but, rather, they belonged to the community as a common property resource (Tabor et al., 1990). Understanding local systems of how to control community property avoids uninformed efforts to "privatise" all resources without regard for local protection of shared resources. The same could be said for areas known locally to be susceptible to flooding every few years, or known to be harbours of disease vectors, or too unpredictable for reliable crops.

It is all too common to hear technicians complain that farmers do not understand the value of correcting the acidity in their soils. While there are surely farmers who do not understand, the studies that have focused on this issue, have found that most farmers recognise the value of fertilisers but also their limitations and high cost (Wilken, 1987). With increasing disposable income, farmers tend to increase their use of chemical fertilisers. However, for the great majority of poor farmers, money is too valuable to be spent on an input that commonly lasts only one cropping season and has to be reapplied next year. Given the fluctuations in prices for commodities and the uncertainties of climate, they prefer to turn to other alternatives. One of the preferred options in areas with significant numbers of livestock is manuring. Manure lasts longer than chemical fertiliser, increases the water retention capacity of a soil and there is less risk of crop damage through misapplication (Tabor et al., 1990). There is a considerable literature that suggests that fertilisers are often applied in either insufficient or excessive amounts.

The keen awareness of farmers about differences in soil quality in their immediate environment is reflected in their local classification systems. "The indigenous taxonomies are familiar to the farmers, are finite for a given locality and information on plot assignment to appropriate categories is readily obtainable" (Dvorak, 1988). Conklin (1957) found that the Hanunóo in the Philippines used ten basic and 30 derivative soil categories. These were based on four classes of firmness, nine of colour, five of topography and three of slope, all of them relevant criteria in their agricultural system. Dvorak (1988) determined the efficacy of local taxonomies in agricultural production research by studying three villages in the semi-arid tropics of India. Subsequent analysis of soil samples supported the farmers' way of thinking about their soil and soil fertility (Dvorak, 1988). Moreover, important classifying characteristics from the farmers' standpoint that had been missed by the scientific criteria were identified. In one of the three villages the folk system performed much better than the formal system in stratifying the soils into groups for analysis. In the other two

[4] Tabor et al., 1990 Reconnaissance Survey of the Ethnopedology in the Embu, Meru, Machakos and Kitui Districts of Kenya's Eastern Province. Unpubl. manuscript prepared by the MidAmerica International Agricultural Consortium, the Kenya Agricultural Research Institute and the USAID.

Table 2. Mean soil test values for soil groups in Kanzara, Maharashtra, India (Dvorak, 1988)

Soil Group (local term)	pH	Available water (g 100g soil)	CEC ($cmol_c$ kg^{-1})	Organic C (%)	Available P (mg kg^{-1})	Ca (meq L^{-1})	Mg (meq L^{-1})	K (meq L^{-1})	Na (meq L^{-1})
Deep black	8.09	17.5	40.9	0.69	2.05	22.59	15.18	0.69	0.75
Medium black	8.00	10.9	37.4	0.51	4.41	25.52	10.17	0.67	0.25
Medium shallow black	7.86	[a]	[a]	0.47	2.73	26.29	11.83	0.51	0.14
Shallow red	8.08	32.8	32.8	0.50	[a]	11.75	11.05	0.67	0.19

[a] Indicates no test values taken for these characteristics on these soil groups.

villages, the two systems performed about the same. Farmer distinction between soil groups was frequently subsumed under one or two classes in the imported taxonomy. The folk system provided a better basis for indexing variation in plot quality, and did not require a larger number of soil categories to do so. The chief limitations of a folk system seem to be the uncertainty of the extent to which taxonomic principles from a representative village can be extrapolated to a larger area. Table 2 illustrates the folk soil groups and their chemical composition. The soil analyses confirmed the accuracy of the folk soil groups.

This is not to say that folk knowledge is even. As noted earlier, the accuracy of farmer knowledge depends on their longterm experience within a local environment (Conklin, 1957; Moran, 1981). Such knowledge will tend to be greater about soils and plant varieties than about pests and plant diseases, especially where there has been a great deal of change in the cropping patterns or major shifts from polyculture to monoculture (Bentley, 1989, 1990).

Not only have extension agents and agronomists in recent years tended to neglect the folk knowledge of farmers about soils and soil-plant interactions, but so have other scientists as well. A priority for future research clearly lies here. There is an urgent need to record these local systems of land use and classification and jointly with the farmer convert them into soil maps at local scale appropriate for research and management. It will be necessary to determine the extent to which extrapolation is possible and along which dimensions change in classification occurs in local systems. What rules are used to assign a correct name to a soil in the local system? The tightening of rural credit throughout most of the world and a greater recognition of the environmental costs of high input approaches will mean that these local systems of soil and plant use will gain in importance as economical and environmentally-safe ways to maintain productivity of acid soils.

Changing the soil condition

Even less frequently discussed in the literature than the folk knowledge of local farmers in managing their soil constraints, has been their active efforts to change their soils (Balée, 1989). The small size of plots owned or controlled by small-scale farmers may actually be an advantage in this regard in that on a one or two hectare plot the number of soil amendments that can be effectively practiced may be greater (Wilken, 1987). As noted earlier, manure is the most common means by which farmers try to deal with acidity and low nutrient conditions. It is used wherever corralled or stabled animals are part of the farming system. Manure is often mixed with kitchen refuse and these mixed with kitchen ashes, creating layered compost heaps that result in high quality soil additives. "Availability determines manure application rates" (Wilken, 1987). Those with numerous animals tend to apply heavier dressings of manure than less fortunate farmers and applications tend to give preference to crops that are higher yielding and/or more profitable. Availability of, and access to, inorganic fertilisers, determine the rate of adoption of this means of controlling acidity. Proximity to limestone deposits and effective ways to get

Table 3. Composition of Chinampa soils (Wilken, 1987)

Sample	pH	NO_3–N (mg kg^{-1})	P (mg kg^{-1})	K (mg kg^{-1})	CEC ($cmol_c$ kg^{-1})
D-43 (surface)	6.6	32	-80	+500	74.0
D-92 (surface)	8.1	16	+80	+500	88.0
D-93a (surface)	7.6	31	+80	338	70.0
D-93b (depth of 0–30cm)	8.2	73	+80	195	84.0
D-93c (depth of 30–60cm)	7.6	27	37	147	74.0
D-93d (depth of 60–90cm)	7.0	4	38	225	74.0

the fertiliser to small-scale farmers at low prices, influence whether or not they use inorganic fertilisers.

Also used to modify soil acidity are ant-nest refuse and plant residues (Wilken, 1987). Ant-nest refuse could never provide sufficient manure for crops but it is used for particularly valuable crops, like chillies (*Capsicum*) in Mexico. Plant residues are used in situations where plant remains stay in the field after harvest of the crop. Burning is sometimes used to reduce bulk of organic matter on the surface and to reduce labour and time required to replant the area. The internment of plant remains in furrows between mounds is an activity that is easy and prepares an organic-rich layer for the next cropping season (Wilken, 1987). Organic dressings are commonly created from household refuse, leaf litter, aquatic plants and weeds removed from fields (Wilken, 1987). Some mulches are of little nutritive value but are valuable in improving soil structure.

One of the classic examples of soil modification and management by people are the chinampas[5] of Mexico (Table 3). Chinamperos dredge just enough muck from canals to form seed beds that are about 20 to 30 m^{-2} in area. Low earthen borders contain the semiliquid muck which solidifies within a few hours after which it is cut with knives into squares and planted with seeds. It is evident from Table 3 that these are soils high in plant nutrients (Wilken, 1987). The pH of chinampa soils varies from 6.6 to 8.2. They have a high CEC (74–88$cmol_c$ kg^{-1}) and respectively >80 and >500 mg phosphorus and potassium kg^{-1} soil (Table 3). In addition, all have >7% organic matter and >40 mg Fe kg^{-1} soil. They are a uniform clay loam texture with 27–30% sand, 36–39% silt and 34–35% clay.

The application of leaf litter, as an agricultural soil improver or fertilizer, from nearby forested land is rarely mentioned and is found where population density is high enough to justify it. Wilken (1987) calculated that one hectare of forest in Quezaltenango, Guatemala, produces about 4,000 kg of litter annually. Given an application rate of 20 to 30 tons ha^{-1} yr^{-1}, this would require that 5 to 8 ha of forest be harvested for its litter to apply a sufficient amount to one ha of land. This practice is not used on sandy soils of the hill slopes but is reserved for higher quality areas which have been continuously cultivated for generations without adequate replacement of nutrients and that can remain productive only by regular amendments. They know that sandy soils benefit more from manure than from leaf litter, while the more clayey soils benefit more from leaf litter. The massive leaf litter applications mainly improve soil structure and water retention, and act as buffers for animal wastes.

Balée (1989) has estimated that at least 12% of the upland forests of the Brazilian Amazon are anthropogenic forests that result from long-term management by native Amazonians. It is believed that indigenous populations have modified the Amazonian soils, creating islands of richer soil through long-term accumulation of debris, human refuse, ashes and other organic materials. In poor soils one finds evidence of drainage canals, mounding and other practices suggestive of intensive agriculture (Denevan, 1966; Zucchi and Denevan, 1979).

In the better soils, like the Alfisols, one finds large areas of liana forests, characterised by an unusual concentration of plants of economic utility for human populations: for food, to attract game, materials for house construction, for medicine, for insect repellent

[5] Chinampas refer to the "floating gardens or islands constructed in 'stages from drainage canal sludge and water-loving trees which have been used since pre-Columbian times in the central valley of Mexico (Armillas, 1971). These are labor-intensive methods of cultivation that permit high yielding agriculture in a swampy region. Chinamperos refers to the people who practice ' this kind of agriculture today.

and firewood. The preference of Amazonian farmers for liana forests to prepare their swiddens has been observed several times (Balée, 1989; Moran, 1977, 1981; Sombroek, 1966). No simple correlation can be made between liana forests and a given soil type, a particular climatic regime or any other criteria (Falesi, 1972) but they do seem to occur with greater frequency in areas with anthropogenic soil patches (Heindsdijk, 1957; Smith, 1980) and in Alfisols (Falesi, 1972; Moran, 1981, 1993). Spontaneous fires do not explain the presence of liana forest, since this vegetation does not occur in areas that will catch fire, unless the forest has been cut and allowed to dry (Pires, 1973). Balée (1989) collected samples in the anthropogenic black soils associated with liana forests in the state of Maranhão, Brazil. One of those layers had a black organic horizon of 39 cm depth and a phosphorus content of 31.8 g kg^{-1}. Calcium also was high and the pH 5.8 together with a low 0.2 g kg^{-1} aluminium saturation, that is relatively uncommon in Amazonia, resulted in excellent plant growing conditions (Balée, 1989). The Assuriní and Araweté Indians in this region have not only adjusted to the acid soils in their region, but they have looked for and used the small areas of black organic soils that resulted from prehistoric occupation. Use of these soils is common and extreme care is required to avoid their loss through erosion or leaching. It was suggested that these soils required hundreds of years to form, and while it has been suggested by Smith (1981) that each centimetre of anthropogenic black soil represents ten years of occupation, a recent study showed that it depended also on population density and edaphic factors (Kern, 1988).

Among the Suruí Indians of the Aripuanã reservation in Rondônia, babaçú (*Orbignya phalerata*) forests are located on sandy soils of low fertility that are never used for agricultural production. This is a good decision, since Suruí agriculture is corn- rather than manioc-based. Moreover, once babaçú is established it tends to dominate, especially with repeated burning and eventually becomes a dominant species in the landscape. The Suruí know and use the patches of high quality Alfisols in their territory, where they locate their corn fields, while managing the sandy areas for babaçú production, which is used for thatch, for oil and for attracting game animals (Coimbra, 1989).

Conclusions

Farmers have a wide array of ways to achieve high levels of production per unit of land on acid, nutrient-poor soils. Whether they can realise satisfactory levels of income depends to a great extent on economic and social institutions outside the control of farmers and scientists alike. The expectation of reasonable return for one's labor is a powerful incentive and one that must be stable and predictable for it to lead to the application of the knowledge that farmers have. There are many farmers who make intensive use of their labor to modify the growing conditions of their crops in acid soils and an even greater number who are unable to make the same soils productive. The differences between them have many sources. For some they may lie in lack of local knowledge due to resettlement, for others on inadequate local social and political organisation that can harness the efforts of the households in controlling common property resources such as water or canal muck and in resolving the inevitable disputes over access to resources (Guillet, 1992; Netting, 1993; Wilken, 1987). No less important are the prices and transportation networks that ensure rewarding returns for labor expended in production. In many places, local systems of latifundia, low wages, credit policies and price controls act to repress intensification of labor and capital. Instead, one can observe too many cases of increased output based on increasing the amount of land under cultivation with no accompanying land use intensification. Small-scale farmers are the most frequent purveyors of land use intensification, rather than large-scale operators who rely on high levels of input, subsidised credit and extensive methods of production. In a world whose population is sill doubling every forty years, it is important to value the sustainable, labor-intensive methods of production that are observable where they have not been driven out by misinformed development schemes.

Native farmers have adjusted to the acid soils within their territory by slash-and-burn methods of land preparation, by selecting crops and varieties capable of relatively high production in acid, low nutrient, soils and by making sophisticated use of their folk systems of soil classification and use. They have also actively developed sophisticated methods of manuring, ridging, mounding and mulching that improve soil conditions and reduce the negative effects of initial conditions such as low pH. None of these labor intensive methods is likely to be implemented if the farmers have insecurity of rights to land, if they lack forms of social organisation that facilitate resolution of disputes (Guillet, 1992; Netting, 1993) and if the value of their products is below the costs of production.

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