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A note on the response by smallholder farmers to soil nutrient depletion in the East African highlands

Chris A. Shisanya
Kenyatta University, Department of Geography, P. O. Box 43844, Nairobi, Kenya. e-mail: Shisanya@avu.org

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Abstract

Agriculture provides a major share of national income and export earnings in many developing countries while ensuring food security, income and employment to a large proportion of the population. Many people in developing countries rely on the land to sustain their livelihoods. Land may also inspire cultural and spiritual values, and more generally strengthen a sense of belonging. Fertile, good quality soils are an essential component for farming. Soil is a living system of organisms reacting with organic and inorganic matter. The soil quality comprises a range of chemical, physical and biological factors, which together affect the productive potential of the land. For our purposes, soil degradation can be defined as a permanent decline in the rate at which land yields products that are useful for sustaining livelihoods. Examples of soil degradation processes include erosion, declining soil organic matter, soil nutrient depletion, compaction, acidification, salinisation and soil pollution. In this research note, I examine the response by smallholder farmers in Eastern Africa to soil nutrient depletion using locally available resources.

Key words: Farming, ecology, soil fertility, agricultural practices.

Introduction

The maintenance of fertility of soils is the first condition for any permanent system of agriculture[5]. Agriculture provides a major share of national income and export earnings in many developing countries while ensuring food security, income and employment to a large proportion of the population. Many people in developing countries rely on the land to sustain their livelihoods. Land may also inspire cultural and spiritual values, and more generally strengthen a sense of belonging. Fertile, good quality soils are an essential component for farming. Soil is a living system of organisms reacting with organic and inorganic matter. The soil quality comprises a range of chemical, physical and biological factors, which together affect the productive potential of the land. For our purposes, soil degradation can be defined as a permanent decline in the rate at which land yields products that are useful for sustaining livelihoods. Examples of soil degradation processes include erosion, declining soil organic matter, soil nutrient depletion, compaction, acidification, salinisation and soil pollution. Soil fertility management and sustainable farming practices are issues that pre-occupy decision-makers across Africa[3,12,13,14,15]. Scientists and farmers are becoming increasingly concerned about the declining fertility of soils in the highlands of Eastern Africa[6,11,23]. Eastern African highlands are undergoing rapid environmental changes as a result of population pressure placed upon a finite agricultural resource base. The combined populations of Kenya and Uganda, for example, were approximately 17 million shortly after independence in the early 1960s with 86% dependent upon agriculture. After 30 years, the population had grown to 47 million with still 80% of the work force engaged in agriculture. Pressure induced by increased population of as much as 4% per year has led to a dramatic diminution of arable land in the smallholder farming areas of Kenya, especially in the so called "high potential areas." Ruthenberg [10] estimated that the per capita share of this ecologically favoured, highly productive land will have been reduced from 0.78 ha in the year 1965 to 0.2-0.3 ha in the year 2000. Population growth in rural areas resulted in the sub-division of family land holdings and increased reliance upon continuous cropping rather than rotational fallows. Human pressure upon land resources has resulted in depletion of soil nutrient capital and reduced availability of organic resources necessary for livestock feed and soil conservation. At the same time, growing populations strengthened local markets and allowed for land use intensification through greater availability of labour. In this research note, I examine the response by smallholder farmers in Eastern Africa to soil nutrient depletion using locally available resources.

Smallholder Farmers' Response to Soil Nutrient Depletion

The response by many smallholder farmers to diminished organic resource availability in the central highlands of Kenya has been spontaneous and effective. Farm boundaries, which were hitherto under-utilised in the past, are now being planted with multipurpose tree species such as Silk Oak (*Grevillea robusta*) and Calliandra (*C. calothgrysus*). Farmers maintain fewer, higher quality livestock that are raised under zero-grazing allowing former pasture areas to be placed under more profitable land use and facilitating the recovery of manure. Napier grass is planted along slope contours serving dual purpose as livestock feed and erosion control. Entrepreneurs purchase manure from neighbouring pastoral communities for use and sale in the central highlands of Kenya. Farmers supplement the nutrient requirements of higher value crops with inorganic fertilizers, which are being repackaged by local retailers into smaller affordable quantities more appropriate to smallholder demands. Farmer associations have grown around the need for change in farming practices including the Green Belt Movement, which assists farmers in planting trees, and the Kenya Institute of Organic Farming, which works with farmers on improved composting methods. Farmers are becoming increasingly aware that lands repeatedly sub-divided over many generations

Table 1. Local shrubs identified by farmers from the Tanzanian village of Kwalei.

Local name	Botanical name	Family
Tughutu	*Vernomia subligera* (O. Hoffn)	Compositae
Mhasha	*Vernomia amyridiantha (*Hook J.)	Compositae
Mshai	*Albizia schiniperiana*	Mimosaceae
Mkuyu	*Ficus vallis-choudae* (del.)	Moraceae
Sopolwa	*Kalanchoe crinata* (Andrew Haw.)	Crassulaceae
Tundashozi	*Justicia glabra* (Roxb.)	Acanthaceae
Boho	*Bothriocline tementosa* (S. Moore)	Compositae

Source: after Wickama and Mowo[21]

become economically non-viable and are breaking with traditional inheritance practices. Furthermore, improving the availability of organic resources also increases the carbon sequestered within the farm, offering global benefits by offsetting atmospheric changes[22]. In the highlands of western Kenya, the steady depletion of soil nutrient stocks poses a serious threat to the welfare of smallholder farmers[11]. Continuous cultivation of lands in the absence of external nutrient inputs steadily reduces the nutrient stocks of lands (macro- and in particular micronutrients) through harvest removal, erosion, leaching and gaseous emissions resulting in poor crop yields[18]. The farmers in western Kenya have little opportunity to reverse this trend because of poor access to markets and restricted availability to modern farm inputs. The two most severely depleted nutrients are nitrogen (N) and phosphorus (P), with annual losses estimated at 42 kg N and 3-4 kg P per hectare over 30 years of cropping[19]. Ironically, sources to these nutrients remain just beyond farmers' reach, the atmosphere contains 70% nitrogen and East Africa is rich in agro-mineral deposits of phosphate-bearing ore[20]. A growing awareness centres on the concept of soil nutrient capital. The mineral nutrients contained within soils are no less a natural resource than forests, rivers or bodies of valuable ore, and to misuse or squander that resource encroaches upon the economic rights of future generations. Furthermore, operational strategies are being designed at national and grassroot levels to offer farmers opportunity to recapitalize their soil nutrients under the assumption that the benefits of such action are shared between society-at-large and farm households in terms of national and domestic food security and that both should be expected to pay[11]. On-farm nutrient replenishment activities are in the pioneer stage, with leadership being shared between large agricultural research institutes, universities, local non-governmental organizations, farmer associations and private enterprises. Soil phosphorus losses must be directly ameliorated through the more effective mobilization of East African phosphate reserves while nitrogen must be obtained through greater exploitation of symbiotic nitrogen fixation and more effective nutrient recycling [2,4,7,16]. In its recent Mid-term Strategy for Collaborative research, the African Association for Biological Nitrogen Fixation (AABNF) notes that "The upper limits of BNF may be steadily increased by the collection and evaluation of ever-more effective N_2-fixing microorganisms and their hosts because the distribution of this elite germplasm will necessarily accrue benefits following their introduction to production systems. The latter reaffirms that research in BNF must be nested into larger understandings of system nitrogen dynamics and land management goals before the comparative benefits of N_2-fixation may be realistically appraised and understood by society as a whole."[1]. The Minjingu phosphate mine in northern Tanzania markets finely-ground rock phosphate suitable for direct application to acidic soils for USD 50 ton $^{-1}$ and is approximately 700 km by road from the western highlands of Kenya. Even with transport considered, this rock phosphate offers a two-fold savings over processed fertilizer imported from developed countries. Yet, this fertilizer is seldom marketed by local retail suppliers, in part because of recommendations unfavourable to rock phosphate based upon excessive claims by suppliers and over-extrapolation of subsequent agronomic investigation in soils not well suited to rock phosphate solubilization. This policy is being re-considered through field trials conducted by the Kenya Agricultural Research Institute (KARI) and the World Agroforestry Centre (WAC). The Tanzania government has targeted the Minjingu deposits for overseas export by establishing a railhead to the Indian Ocean port city of Tanga and developing fertilizer-processing facilities. The 6 million-ton reserve of Minjingu can currently be mined at 100,000 tons per year, and, assuming that the agronomic and environmental safety considerations are resolved, this deposit may prove crucial to the amelioration of the 900,000 hectares of low-phosphorus soils in the highlands of western Kenya for several years[9]. Farmers are currently cultivating several food legumes in the highlands of western Kenya. Many other legumes have been introduced as forage, agroforestry trees, green manures and ground covers. Symbiotic nitrogen fixation and yield are greatly enhanced by improved phosphorus nutrition of soils[8] and through this approach, it is hoped to 'jump start' nitrogen replenishment, provided that the proper rhizobial microsymbionts is present. Legume inoculants are produced in Kenya by the University of Nairobi Microbial Resource Centre (one of UNESCO's international network of microbial resource centres, or MIRCEN's) and distributed by retail merchants and local non-governmental organisations (NGO's). Other organic local resources are becoming recognised as under-utilised. For instance, the Tropical Soil Biology and Fertility (TSBF) programme is examining the agronomic potential of the Mexican sunflower (*Tithonia diversifolia*) which was first introduced as an ornamental to Kenya, adopted as a herbal medicine for intestinal discomfort, then planted to mark field boundaries and is now harvested as a nitrogen-rich green manure. Farmers from the Tanzanian village of Kwalei have identified seven shrubs that seemed to improve the P nutrient content and workability of the surrounding soil through green manuring. The shrubs identified are shown in Table 1, while Table 2 shows the nutrient content of the identified shrubs. The observations by the farmers were confirmed by soil sampling and mineralisation studies, which also indicated that decomposition generally peaks within four to five weeks of application, and that modest amount of mineral fertilizer will offset the subsequent reduction in nutrients released after this period [21].

Table 2. Nutrient content of the shrubs identified by farmers from the Tanzanian village of Kwalei.

Local name	Botanical name	%N	%P	%K
Tughutu	*Vernomia subligera* (O. Hoffn)	3.6	0.25	4.7
Mhasha	*Vernomia amyridiantha* (Hook J.)	3.4	0.23	4.5
Mshai	*Albizia schiniperiana*	3.1	0.32	1.3
Mkuyu	*Ficus vallis-choudae* (del.)	3.0	0.23	4.4
Boho	*Bothriocline tementosa* (S. Moore)	2.1	0.27	1.5
Sopolwa	*Kalanchoe crinata* (Andrew Haw.)	2.1	0.23	3.8
Tundashozi	*Justicia glabra* (Roxb.)	2.0	0.27	2.1
Alizeti mwitu	*Tithonia diversifolia*	3.2	0.24	3.4

Source: after Wickama and Mowo[21]

One innovative approach to nutrient replenishment is under development by Moi University, Kenya, and several local NGOs. The phosphate Rock Evaluation Project at Moi University has developed PREP-PAC[9]. PREP-PAC was formulated as a 'best-bet' technology for nutrient-depleted patches in smallholder farms in western Kenya. As such, it represents the hypothesis concerning its composition and advantageous interaction between them. PREP-PAC consists of 2.0 kg Minjingu rock phosphate, 200 g urea, seeds of various symbiotic nitrogen-fixing legumes, rhizobial inoculant, Gum arabica seed adhesive, lime for seed pelleting and instructions for use of these materials. Soil nutrient depletion typically manifests itself as patches of unhealthy plants in farmers' fields. PREP-PAC is designed to ameliorate low fertility patches of soil for testing in farmers' fields. The general principle is to apply the slowly available nitrogenous fertilizer and to intercrop with a legume that provides residual fixed-nitrogen and inorganic inputs to the soil. Local retailers have been impressed by the preliminary results of these trials and are stocking this package as a new product. It costs USD 0.67 to assemble and is intended for application over 20-25 m^2. The Organic Matter Management Network, which in the past focused exclusively upon organic farming, is now shifting to integrated nutrient management approaches complementing organics with modest additions for inorganic fertilizers[17]. Another approach under development by KARI will target 1,200 farm households surrounding three marketing centres by establishing practical demonstrations, strengthening fertilizer suppliers to local retailers and providing farmers with credit to purchase farm inputs. The above-cited examples from the East African region are by no means exhaustive. The resilience of smallholder farmers in improving the supply and use-efficiency of organic resources, without assistance from large government programmes, is highly commendable. The success or failures of the examples cited are dependent upon the degree and effectiveness with which affected communities and locally available resources are mobilized. Take for example the soil amendment package under development by Moi University, Kenya. Representatives of NGOs and farmers' associations first expressed its need. It consists of rock phosphate from Tanzania, seeds purchased from Kenya private sector, legume rhizobial inoculants produced by the University of Nairobi, Gum arabic from northern Kenya and lime from eastern Kenya. Only urea is imported from outside East Africa. The product is undergoing on-farm, farmer-managed testing with participants encouraged to modify or combine it with other technologies as they deem fit. Only then do university students and NGO representatives evaluate the effectiveness of the product, its versatility under farm conditions and its potential for wider application. The potential for adoption by farmers and agricultural suppliers is much greater under such circumstances than if it was imported or its use strictly prescribed. Yet, community-oriented and participatory approaches are seldom a solution in them, but rather a necessary ingredient in multidisciplinary and multi-level approaches to overcoming natural resource constraints. It is unlikely that soils can be recapitalized with phosphorus until trade restrictions within the East African region are eased, yet improved supply does not guarantee action in absence of strong farmer networks.

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