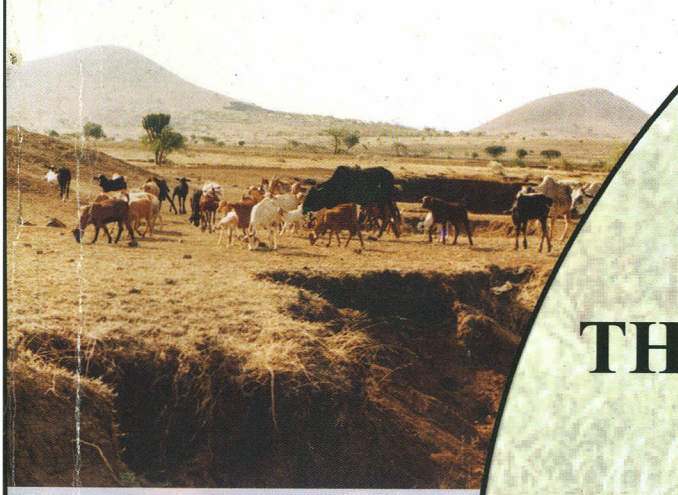

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THE ROLE OF INDIGENOUS KNOWLEDGE IN MANAGEMENT OF SOIL QUALITY AMONG SMALLHOLDERS IN CHUKA AND GACHOKA DIVISIONS, KENYA

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ABSTRACT

Scientists and farmers possess qualitative knowledge of agro-ecosystems that they observe, which could be a valuable resource for science. A study based on participatory methods was conducted to determine farmers' soil quality perceptions and common soil management practices that influenced soil fertility within farmers' fields in Chuka and Gachoka Divisions, in Meru South and Mbeere Districts Kenya. Soils characterized by farmers were geo-referenced after which they were sampled at surface depth (0–20 cm) for subsequent physical and chemical analyses, to determine differences within farmers' soil quality categories. Farmers used sensory information, based upon soil tactile and visible characteristics to distinguish soil productivity. Indicators for distinguishing productive and non-productive fields included crop yields and performance, soil colour and soil texture. There were significant statistical differences among soil fertility categories, using parametric techniques (ANOVA) for key soil properties ($p<0.05$), implying that the soils must have belonged to different populations and that there was a qualitative difference in the soils that were chacterised as different by farmers. Soil fertility and crop management practices that were investigated indicated that farmers understood and consequently utilized spatial heterogeneity and temporal variability in soil quality status within their farms as a resource to maintain or enhance agricultural productivity.

Key words: Farmers, farmers' perceptions, local indicators, scientists, soil fertility

INTRODUCTION

Scientists and farmers are becoming increasingly concerned about the declining fertility of soils in the highlands of eastern Africa (Sanchez and Leakey, 1997) and sub-Saharan Africa (SSA) (Stoorvogel *et al.*, 1993). Within Kenya's central highlands, high rainfall (1000-2000 mm), slope (4-60%), and inadequately maintained soils contribute to soil degradation (Rao *et al.*, 1999). As a result, farmers in the area have experienced declining crop yields (Mureithi *et al.* 1994; Mugendi *et al.* 1999).

Soil fertility in farming systems declines at a rate that is largely governed by the type of land use systems introduced and their management (Smalling, 1993, Zitong *et al.* 2003) due to changes in soil organic matter (SOM) (Noble *et al.*, 2003) and mainly active fraction (Von Lützowa *et al.*, 2002). Consequently farmers respond to soil changes, by adjusting to land use management that suits inherent agro-ecosystem capability. Although there is a growing recognition of the value of local knowledge, little has been documented on how it can potentially be utilised in conjunction with scientific knowledge to

improve soil productivity (Tenywa *et al.*, 1999) with particular reference to local indicators. In Kenya local indicators have not been adequately evaluated in smallholder frming systems. A comprehensive assessment of how farming communities recognize and measure soil quality is needed so that indigenous knowledge can be integrated with scientific knowledge to contribute to soil quality information (Doran and Parkin, 1994). Against this background, a study was initiated to identify soil fertility indicators that were consistent with farmers' perceptions. It attempted further, to link the information generated by farmers with measured soil parameters in the fields. As specific concepts, 'soil fertility' and 'soil quality' are used in congruinty, and in similar manner with Patzel *et al.* (2000).

MATERIALS AND METHODS

Site description

The survey was conducted in Chuka and Gachoka Divisions, which fall within Meru South and Mbeere Districts respectively. Both districts are geographically adjacent, with both divisions separated by a 20 km distance. The sites are located approximately 150 km, North East of Nairobi on the eastern slopes of Mt. Kenya (GoK, 1991). Chuka Division lies in the Upper Midland Zone 2 and 3 (UM2–UM3) at an altitude of 1500 m, with annual rainfall ranging from 1200 to 1400 mm (Jaetzold and Schmidt, 1983). Farming systems in the area are dominated by a complex interaction of livestock and crop enterprises that are intensively managed (Lekasi *et al.*, 2001). The soil type is Humic Nitisol, characterized by well-drained, deep loam soils (Jaetzold and Schmidt, 1983). Gachoka division lies at the transition between the marginal cotton (LM 4) and main cotton (LM3) agro-ecological zones (Jaetzold and Schmidt, 1983) with a mean annual rainfall of 900 mm (GoK, 1997). The soils are dominated by the Nito-rhodic Ferralsols (Jaetzold and Schmidt, 1983). The population density is over 700 persons per km^2 (GoK, 2001), while that in Gachoka division is 74 persons per km^2 (GoK, 2001). The rainfall distribution pattern is bimodal, in both divisions with the short rains and long rains falling annually from March to June and October to December, respectively (Jaetzold and Schmidt, 1983).

Data collection and analysis

The study was conducted in the long rains of 2003. Thirty farms were randomly selected in both divisions in pre-selected administrative units (sub-divisions), to constitute the sampling frame from which a total of sixty farms were selected. Using semi-structured questionnaires, data was collected from 30 household units that were equally distributed within villages (clusters) in both sub-divisions. The questionnaire provided a guiding structure to the discussion, but, it was also sufficiently flexible to accommodate supplementary information. Farmers were asked to identify soils on their farms that they regarded productive (good quality) and non-productive (poor quality). Soil fertility indicator species were determined through transects in the field, with subsequent classification.

Soils that were characterised by farmers (Gachimbi *et al.*, 2002) were geo-refferenced (Tenywa *et al.*, 1999; Hoffmann *et al.*, 2001) and sampled at surface depth (0–20 cm) (Anderson and Ingram, 1993) for subsequent physical and chemical analyses. Soils were sampled from fields that farmers identified as to be under low fertility species (which were regarded as low fertility soils) and high fertility indicator species (which were regarded as high fertility soils). Two soil samples were

collected from each farm, with each representing fertile (good quality) and infertile (poor quality) soil niches identified within the fields. At each sampling point, ten topsoil samples were composited by thorough mixing after which 500g sub-samples were sealed and transported in cool boxes for laboratory analyses (Anderson and Ingram, 1993). They were then extracted in 2MKCl for available–N (NO_3^--N and NH_4-N) determination after which they were air-dried and sieved to 2mm (Anderson and Ingram, 1993).

Soil texture was determined using the Bouyoucos Hydrometer method after Gee and Bauder (1986). Soil pH was determined in 1: 2.5 soil-water ratio. Available P (Olsen) was extracted by a 0.5M $NaHCO_3$ + 0.001M EDTA, pH 8.5 solution followed by colorimetric determination. Ammonium-N was determined by the salicylate-hypochlorite colorimetric method, while Nitrate-N was determined by the cadmium-reduction method. Total organic Carbon was determined by digesting the soil at 130°C for 30 min in acidified dichromate, followed by determination of chromic ions (Cr^{3+}). Total N and P were determined using the Kjeldhal Digestion method (Anderson and Ingram, 1993). Exchageable acidity and exchangeable bases (Ca and Mg) were determined by 1M KCl extraction, followed by colorimetric and titrimetric determination respectively in similar extracts. The data was cleaned before running, after which it was entered in SPSS software package version 10 for analysis of the social data. Soil characteristics within fields in both divisions were compared using ANOVA procedures (Wardle, 1994) available in Genstat 5 Release 3, whereby the soil quality categories were the grouping variables.

RESULTS AND DISCUSSIONS

Farmers' criteria for soil quality assessment in Chuka and Gachoka Divisions

Farmers distinguished productive and non-productive fields using crop yields and performance, soil texture, soil colour, soil macro fauna, and various invading weeds (indicator plant species) that they associated with soil fertility status. Other features reported by farmers included fertilizer response and stoniness of soils. Table 1 shows the soil quality indicators used by farmers in both divisions.

Table 1: Indicators identified and used by farmers to distinguish soil quality status within fields in Chuka and Gachoka divisions, Kenya

Chuka Division			Gachoka Division		
Indicator	Farmers % (n =30)	Rank	Indicator	Farmers % (n= 30)	Rank
Crop yields	86(26)	1	Crop yields	80(20)	2
Crop performance	76(23)	2	Crop performance	76(19)	3
Soil colour (wet)	60(18)	3	Soil colour (wet)	83(25)	1
Soil macro-fauna	50(15)	4	Soil macro – fauna	37(11)	6
Soil tilth	40(12)	5	Soil tilth	40(12)	5
Soil texture	40(12)	6	Soil texture	43(13)	4
Fertiliser response	13(4)	7	Fertiliser response	20(6)	7
Soil moisture retention	7(2)	8	Soil moisture retention	7(7)	8

N=30 in both divisions
Values in parentheses are column frequencies

Farmers readily recognised that soil quality affected crop performance and yields. The prescence of soil macrofauna, particularly earthworms and beetle larvae were regarded as positive features indicating high soil quality. Some of the farmers that had experienced a low fertiliser response for many years in their fields associated it with unproductive soils, that could not yield adequately with fertiliser input. Soil colour and texture (indicative of soil organic carbon) (Nandwa, 2001) was also frequently used as an indicator, with darker soils representing the fertile soils.

Soil fertility indicator species in Chuka and Gachoka divisions

Table 2 a and b, presents the indicator species that were identified by farmers.

Table 2a: Indicator species of high soil fertility status in Chuka and Gachoka divisions, Kenya

Indicator species			Percentage frequency	
Scientific name	Common name	Botanical family	Chuka	Gachoka
Commelina benghalensis L	Wandering jew	Commelinaceae	77(23)	53 (16)
Galinsoga parviflora L.	Gallant soldier	Compositae	63 (19)	17 (5)
Bidens pilosa L.	Black jack	Compositae	43 (13)	67 (20)
Amaranthus spp	Pigweed	Amaranthaceae	20 (9)	27 (8)
Sonchus oleraceus L.	Sow thistle	Compositae	17 (5)	13 (4)
Commelina diffusa Burm.f.	-	Commelinaceae	9 (30)	53 (16)
Solanum nigrum L.	Black nightshade	Solanaceae	7 (2)	20 (6)
Rottboellia exaltata (L.f)	Guinea fowl grass	Gramminae	7 (2)	7 (2)

Table 2b: Indicator species of low soil fertility in Chuka and Gachoka divisions, Kenya

Indicator species			Percentage frequency	
Scientific name	Common name	Botanical family	Chuka	Gachoka
Melhania ovata (Cav.) Spreng	-	Malvaceae	67 (20)	93 (28)
Ageratum conyzoides L.	Goat weed	Compositae	37 (11)	10 (3)
Emilia discifolia (Oliv) C. Jeffrey	-	Compositae	37 (11)	3 (1)
Rhynchelytrum repens (Wild.) C.E.Hubbard	Common red-top grass	Gramminae	27 (8)	70 (21)
Pteridium aquilinum (L.) Kuhn	Bracken fern	Pteridophyte	27 (8)	14 (4)
Tagetas minuta L.	Mexican marigold	Compositae	16 (5)	23 (7)
Oxygonum sinuatum (Meisn.) Dammer	Double thorn	Polygonaceae	10 (3)	3 (1)
Schkuhria pinnata (Lam.) Thell.	Dwarf marigold	Compositae	3 (1)	10 (3)
Setaria verticillata (L.) Beav.	Bristly foxtail	Gramminae	-	23 (7)
Cucumis L.	-	Cucumbitaceae	-	20 (6)

Values in parentheses (Table II a and b) are column frequencies

In total, the smallholder farmers reported 18 weed species. High fertility indicators mainly included the Wandering Jew (*Commelina bengalensis* L.) and gallant soldier (*Gallinsoga parviflora* L.). Low soil fertility indicators included the common red top grass (*Rhynchelytrum repens* (Willd.) C. E. Hubb).

Exhausted soils were associated with invading grasses (gramminae) and succulent species, mainly *Compositae and Commellinaceae* families with fertile soils. The brackenfern (*Pteridium aquilinum* (L) Kuhn) was mainly associated with depleted fields. *Barrios et al.*, 2000 shows that the species is mainly associated with acid soils, which can contribute to poor soils through the fixation of P.

Soil nutrients invariably determine the distribution and development of vegetation, by influencing the rooting environment. Smallscale farmers have closely bound up the nature and condition of vegetation, both native and planted with soil quality (Shaxson,1997). The emergence of plant species that only thrived under low soil fertilty was described by Nandwa (2001) as criteria used by SSA farmers. The species utilised by the farmers in both divisions, closely related to findings by Mureithi *et al* (2000).

Perceptions of soil fertility status in Chuka and Gachoka Divisions

There were contrasting responses in both divisions over temporal soil fertility changes in farmers' fields (Fig 1 and Table 3). Generally, farmers reported that soil quality has been declining in both divisions and realized that past management had influenced inherent soil fertility status.

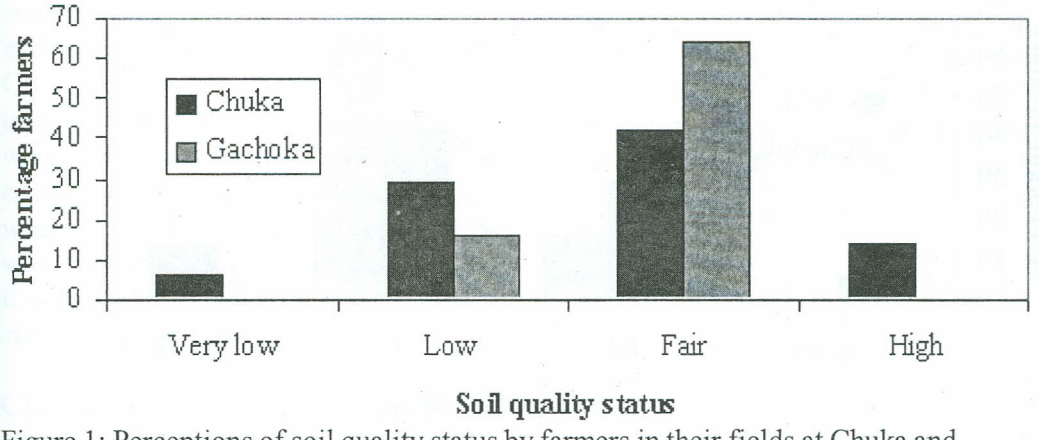

Figure 1: Perceptions of soil quality status by farmers in their fields at Chuka and Gachoka Divisions

Table 3: Soil fertility changes as reported by farmers in Chuka and Gachoka Divisions

Soil fertility changes	Percentage of farmers	
	Chuka	Gachoka
Declining	37 (11)	57 (17)
Improving	28 (9)	26 (8)
Not changing	10 (3)	7 (2)
Not able to determine	10 (3)	10 (3)
Declined but improved after introduction of soil replenishment technologies*	13 (4)	-
Total	100 (30)	100 (30)

Values in parentheses are column frequencies
* Soil replenishment and on-farm collaborative research initiative under the Rockefeller Foundation was launched 2 yrs ago in Chuka division

Table 4: Farmers' perceptions of soil erosion extent in Chuka and Gachoka Divisions

Soil erosion perceptions	Percentage of farmers	
	Chuka	Gachoka
Low	20 (6)	47 (14)
Fair	47 (14)	33 (10)
High	33 (10)	20 (6)
Total	100 (30)	100 (30)

Values in parentheses are column frequencies

Farmers in Chuka Division reported moderate and high levels of soil erosion, mainly due to slope as compared to those in Gachoka who revealed low and moderate levels of soil erosion on their farms (Table 4). Farmers determined erosion extent, by examining the formation of rills and gulleys and by observing runoff during the wet seasons. Farmers employed various barriers including indigenous methods to prevent soil erosion as indicated in Figure 2.
Other measures include combinations of loglines and grass strips

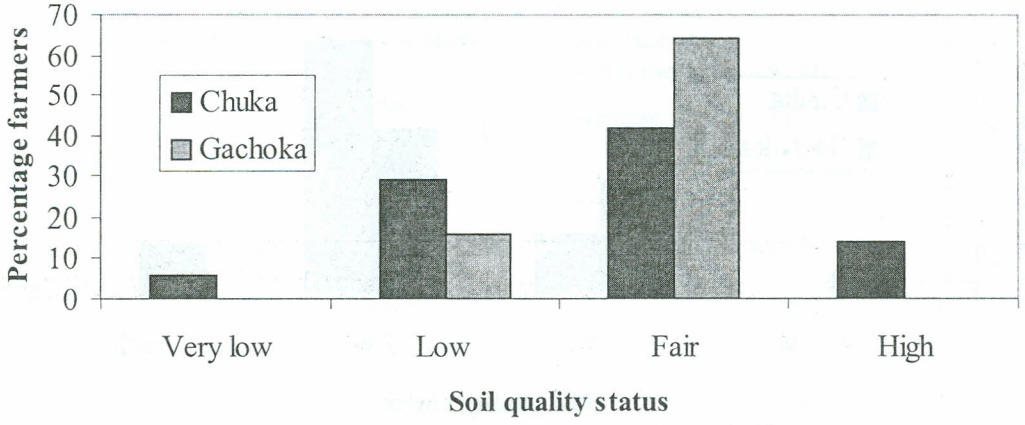

Figure 2: Soil and water conservation (SWC) measures used by farmers in Chuka and Gachoka Divisions

A wide range of soil and water conservation strategies were used in the field by farmers, including terraces and live agroforestry hedges, which were common in both divisions but much more especially so in Chuka division. Soil conservation measures were fairly common, with only 3 farmers in Gachoka division not placing the structures on their fields. Many of the farmers in Chuka division used terraces (63%) than the other soil conservation measures and also as compared to farmers in Gachoka division where only 40% used the terraces to control soil erosion. Trashlines were used by approximately 10% of the smallscale farmers in Gachoka division while none of the farmers in Chuka division used the trashlines. Dating back to the early 20th century, trashlines were used by the farmers in Mbeere district, and are made mainly

from millet (*Pennisetum spp*) or sorghum (*Sorghum* L. Moench) residues, to retain soil and to enhance soil fertility and moisture on gentle slopes. The farmers said that they usually laid the millet (*Pennisetum spp*) and sorghum (*Sorghum* L. Moench) residues in the field after which they added new farm residues as the older materials decayed. Provided the trashlines are well maintained, they can hold soils from losses and also withstand the deluges of rainfall, however the millet (*Pennisetum spp*)and sorghum (*Sorghum* L. Moench) residues also face competition in terms of dry season (Ellis-Jones and Tengberg, 2000).

Stone bunds and loglines were not a common feature for most of the farmers though they are an important indigenous conservation strategy in Mbeere district. In an earlier survey in the area, Ellis-Jones and Tengberg (2000) found that farmers used stonelines and loglines mainly where the respective raw materials (stones or logs) were available. On stony soils, the farmers cleared the soils of rocks to permit crop cultivation, which were later used to make the stonebunds to control soil erosion. Log lines were used where new land had been cleared and the wood biomass was of poor quality, such that it did not have much socio-economic competition for fuel or timber.

Crop distribution and soil quality in Chuka and Gachoka Divisions

Farmers cultivated different crops in productive and non-productive fields, though some were also grown on both soil categories. Crops that farmers cultivated in Chuka Division included food crops like maize (*Zea mays* L.) (100%), beans (*Phaseolus vulgaris L.*) (83%), bananas (*Musa* spp) (67%), irish potatoes (*Solanum tuberosum* L.) (60%), sweet potatoes (*Ipomea batatas* L.) (30%), and cash crops mainly tea (60%) and coffee (53%). Farmers in Gachoka mainly grew a variety of cereals including maize (73%), finger millet and sorghum (*Sorghum bicolor* L.). Other common crops in Gachoka included beans (*Phaseolus vulgaris* L.) (67%), cowpeas (57%), cassava (*Manihot esculenta* L.) (57%), and sweet potatoes (*Ipomea batatas* L.) (27%). Cash crops such as tea is grown on steep slopes, and on soils that farmers regarded unsuitable for food crop production. Farmers mainly grew valued crops, on soils that they regarded fertile, mainly due to a propensity for soil moisture retention into the dry season. Crops that were intended for markets were cultivated on sites regarded as fertile. Tubers (cassava and sweet potatoes) and fodder crops like napier grass were mainly grown on sites regarded as of being of low soils fertility status in both divisions. Prior to European contact, smallholders locally used napier to control soil erosion (Boonman, 1993). The farmers recognized their importance in erosion control and fertility restoration as cover crops and also as complementary measures for mechanical soil erosion control.

Table 7: Means for soil physical and chemical properties for top soils (0-20) in productive and non-productive fields in Chuka and Gachoka divisions.

Farmers' soil category		PH	Ca	Mg	N	P	TN	TP	C	Clay	Sand	Silt
			$Cmol_c kg^{-1}$		mg kg^{-1}		%					
Site												
Chuka	High	5.6a	8.2a	3.1a	2.74a	20.5a	0.16a	0.05a	3.4a	32.9a	37.9a	29.2a
	Low	5.1b	7.5a	2.8b	2.79a	16.0a	0.16a	0.05a	2.4b	34.5a	38.0a	27.5a
SED		0.08	0.65	0.12	0.16	4.27	0.018	0.01	0.40	3.69	3.74	4.97
Gachoka	High	6.5a	5.8a	1.8a	2.43a	17.8a	0.16a	0.05a	1.5a	30.3a	67.1a	2.7a
	Low	6.4b	3.8b	1.3b	1.40b	6.2a	0.02a	0.05a	1.2b	32.9a	64.0a	3.1a
SED		0.09	0.48	0.15	0.20	7.27	0.18	0.01	0.08	5.5	3.19	4.97

The mean clay and sand contents were almost similar by division, suggesting that the test sites are of similar pedological origin (Jaetzold and Schmidt, 1983), and that the differences in measured properties resulted from past soil management (Murage et al., 2000). This provided the basis to evaluate the chemical soil properties on a comparable basis (Karlen, 2001). Percentage silt was sligtly higher in productive soil category, as compared to the non-productive soils, and especially on sites that farmers had identified soil erosion as the main constraint to crop production. This concurs with the principle that silt is usually the first mineral component of the soil to be detached from the soil in water erosion processes (Brady, 1984). The productive soils showed a higher pH ($p<0.001$) and exchangeable cations than non-productive soils in both divisions. Exchangeable cations also varied significantly for Mg^{2+} ($p<0.05$) in both divisions, while Ca^{2+} ($p<0.001$) was only significantly different in Gachoka Division. Additionally, total organic carbon varied significantly ($p<0.05$) between the productive and non-productive soils in both divisions. The levels of extactable inorganic-N showed were not different in Chuka Division for both soil categories, though there were significant differences ($p<0.05$) in Gachoka division. There were no differences in total N and P in both divisions suggesting that they were not sensitive indicators of soil quality. However total N in Gachoka averaged 0.16% and 0.002% for productive and non-productive soil categories respectively.

CONCLUSIONS

From the responses to questions and subsequent discussions, it was possible to distinguish broad areas of farmers' knowledge. There was an undersanding among farmers of physical soil characteristics, especially soil colour, texture, tilth, crop production potential and soil erosion risks. Organic Carbon was above the critical level of 2% in Chuka and below in Gachoka, indicating differences in organic matter levels, that significantly associated with division and farmers' soil categories. Studies and PRAs are increasingly showing that farmers percieve and articulate differences in the fertility levels in their fields . Farmers are aware of the root causes of soil fertility decline, but often lack resources to invest in raising the quality of soils. Local knowledge systems can offer practical and cost effective solutions for farmers to base upon soil fertility evaluation, and subsequent land use and management decisions.

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