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Farmers' Resource Levels, Soil Properties and Productivity in Kenya's Central Highlands

Mira Ovuka and Anders Ekbom*

ABSTRACT

This study examines the correlation between soil productivity, erosion status, land management, land slope, precipitation and farm resource endowments among smallholders in the Central Highlands of Kenya. Composite soil samples, based on six replicates, were collected from 100 maize fields. Soil properties such as grain size distribution, CEC, amounts of exchangeable Na, Ca, Mg and K, available P, total N, organic C and pH were analysed. Rainfall data was obtained for the three survey years (1994-96). Erosion and land management were noted using the PLUS classification scheme. Annual yields and farmers' resource levels, proxied by capital and annual current income, were recorded in a household questionnaire survey.

The analysis shows that there are statistically significant differences in organic C, available P, grain size distribution, maize yield, soil erosion and land management between farms of different resource levels. The results indicate that the action needed to achieve higher yields and sustainable agriculture differs depending on farmers' resource endowment, and that agricultural policy advice needs to be adapted to farmers' resource levels.

INTRODUCTION

Agricultural production is the key sector of the economy in Kenya (MPND, 1998). It has declined substantially in both output and growth in recent years. Meanwhile, the rapidly growing population of Kenya requires increased food production and food security. Kenya's rural lands are subject to soil degradation with potentially very large negative effects on food production (Ovuka, 2000; Ekbom et al., 2001). Food and agricultural production are related to soil productivity. Soil productivity is the productive potential of the soil system that allows accumulation of energy in form of vegetation (Stocking, 1984; Hurni, 1996). It is a function of many factors including individual soil parameters, climate, management and land slope. Crop yield and soil nutrient status can be used as indicators of soil productivity.

In Murang'a District in central Kenya 95% of the population lives in rural areas or in small market centers (OVPMPND, 1997). About 90% of the district's population are engaged in agriculture and livestock farming. Murang'a District and the whole Central Province, are together with the western and coastal parts of Kenya, the most arable areas for agriculture, whereas more than two thirds of the country are unsuitable for intensive agriculture (Odingo, 1988). This resource scarcity, compounded by the facts that large-scale soil erosion continues and that food production in Murang'a District is insufficient to support its own population (OVPMPND, 1997), makes it necessary to identify new ways of increasing agricultural production and enhancing extension advice.

The objective of this study is to assess whether there is a correlation between soil productivity (i.e. soil nutrient status and maize yield) and different farm resource levels in Murang'a District, Kenya. Soil erosion and land management in the maize fields were also correlated with different farm resource levels. In addition, maize yields were compared with farm resource levels taking annual precipitation into account.

THE STUDY AREA

Murang'a District is located on the eastern slope of the Aberdare Range in the Central Highlands of Kenya (Figure 1). The district population predominately depends on agriculture. Livelihoods are dominated by small-scale subsistence farming (OVPMPND, 1997). The rainfall is bimodal, with long rains from March to May and short rains from October to November. These two rain periods allow two growing seasons. The agricultural potential in Murang'a District generally decreases from northwest to southeast, mainly because of decreasing rainfall and soil fertility. The population of the district was 1 056 000 in 1997 and the population growth is approximately 2.5% per annum. Due to plot fragmentation, the average farm size becomes smaller and smaller (OVPMPND, 1997).

The areas of interest, Mbari-ya-Hiti and Maragua, are in the main coffee agro-ecological zone (Jaetzold and Schmidt, 1983) with an average annual precipitation of 1560 mm (Ovuka and Lindqvist, 2000). Red-brown high humic soil, Nitisol, is the most common soil type (FAO/UNESCO, 1990). This soil type has developed over most of the deeply weathered basic volcanic rocks. It is fertile and widely cultivated. The main food crops are maize, bananas and beans. The main cash crop is coffee. There are also dairy activities.

*Mira Ovuka, Göteborg University, Dept. of Earth Sciences, Physical Geography, Box 460, SE-405 30 Göteborg, Sweden; Anders Ekbom, Göteborg University, Dept. of Economics, Environmental Economics Unit, Box 640, SE-405 30 Göteborg, Sweden. *Corresponding author: mira@gvc.gu.se

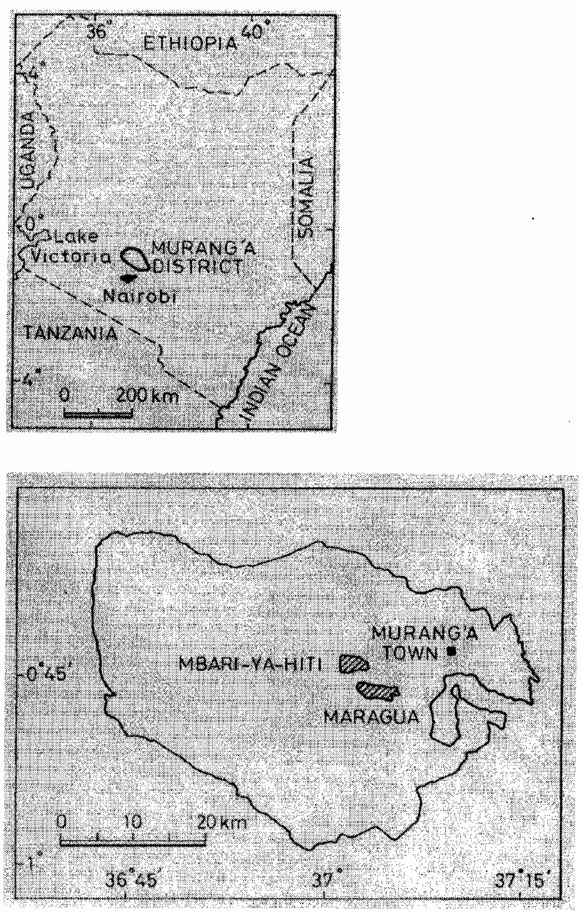

Figure 1. Location of the study area.

METHODS

Composite soil samples were collected from 100 randomly chosen maize fields (with an average area of 1.1 ha) in the two study areas during two field periods: 1996 and 1997. In each maize field six samples were taken from the topsoil, between 0 and 15 cm depth, which were combined to form one composite sample. Places where mulch, manure and fertilizer were visible were avoided for soil sampling. An inclinometer was used to measure the land slope of the sampled fields. Erosion and land management were noted in all sampled fields using the PLUS (1994) classification scheme, for example splash, sheet, rill and gully erosion were noted separately in the field. Each erosion form has four classes, so what class *E0* corresponds to no erosion, *E1* slight, *E2* moderate and *E3* severe erosion. A land management rating included erosion status, ground cover, crop husbandry, pasture, water, trees and soil and water conservation. This rating has five classes, *class 4* excellent with exemplary practices, *class 3* good with acceptable quality practices, *class 2* fair with some cause for concern, *class 1* poor with major cause for concern and *class 0* very poor, where none of the requirements for better land husbandry are met. More detailed descriptions of the methodologies are given in PLUS (1994).

Air-dried soil samples were analysed at the Department of Soil Science (DSS), University of Nairobi. The following soil properties were determined: grain size distribution, cation exchangeable capacity (CEC), amounts of exchangeable Na, K, Mg, Ca, available P, total N, organic C and pH. Grain size distribution was determined by hydrometer. CEC was analyzed by leaching the soil with ammonium acetate at pH 7. Na and K were determined by flame photometry while Ca and Mg were by atomic absorption spectrophotometry. Available P was analyzed using the Mehlich method, total N using Kjeldahl digestion and organic C using the Walkley and Black method. pH(H_2O) and pH($CaCl_2$) were both analyzed using soil-water and soil-salt ratios of 1:2.5. Further details of the standard analytical methods used at DSS are given by Okalebo et al. (1993).

Annual maize yields from the sampled fields and farmers' resource level were recorded in a household questionnaire survey over a three-years period (1994, 1995 and 1996). Maize, intercropped with beans and Irish potatoes, was the cropping system chosen to facilitate comparisons between farms. Farm resource categorisation is often based on participatory rural appraisal where farmers identify the categories themselves (Loiske, 1995; Altshul, et al., 1996; Briggs, et al., 1998; Tengberg, et al., 1998). Based on findings from these studies and our field experiences criteria used to identify farmers' resource level in this study are the household's capital, current (annual) income and access to cash income, respectively. Household capital is defined as the value of the landholding, based on average land value in the area, plus the value of livestock as reported by the farmers. Household's current income is the sum of the annual agricultural production profit, income from milk and egg production, and income from non-agricultural activities. Access to cash income is in this case represented by the income from non-agricultural work. The sampled farms were divided into three resource levels: low, medium and high. They are listed in Table 1. An additional subdivision of farm categories (introduced in Table 2) was made based on land slope of the sampled field, one class with gentle slope (< 15%) and one with moderate slope (>15 %).

Soil nutrients and soil grain size distribution, maize yield, erosion class and land management between the resource categories within each slope class were compared using Kruskal-Wallis H test (Goldman and Weinberg, 1985). To identify significant differences with respect to average soil nutrients and grain size distribution, maize yield, erosion classes and land management between the two slope classes within each resource level, the Wilcoxon test (Goldman and Weinberg, 1985) was used.

Annual precipitation for Station No. 90 37 204, was obtained for the three years, 1994 to 1996, from Kahuro Divisional Office. These records help us to understand some of the maize yield variations during the study period.

RESULTS

Interpretations of soil nutrient contents from the study areas indicate relatively moderate levels of Na, Ca and organic C, and high levels of Mg in all sampled fields. K and available P levels are high and moderate on gentle slopes, and moderate and low on moderate slopes respectively according to Thomas' (1997) manual for Kenyan soils. Significant differences exist

Table 1. Farm resource categorisation in the study area of Murang'a District.

Resource Criteria	Farm Resource Level		
	High (N=21)	*Medium (N=55)*	*Low (N= 24)*
Mean household's total capital	200' [110' – 360'][a]	145' [60' – 245']	94' [40' – 180']
Mean household's total annual current income	51' [29' – 107']	16' [3' – 29']	3' [0 – 9']
Household's annual cash income (CI)	CI > 30'	3'< CI < 30	CI < 3'

All figures followed by ' are in 1 000 KSh, 1USD= 61.9 KSh (January 1999).
[a] Figures in brackets […] indicate min-max range.

Table 2. Soil properties in Murang'a District (N=100).

Soil Properties	Gentle slope (<15%) Farm Resource Level			Moderate Slope (>15%) Farm Resource Level		
	High (N=12)	*Medium (N=27)*	*Low (N=14)*	*High (N=9)*	*Medium (N=28)*	*Low (N=10)*
Sand %	17.8 *[a]	13.7 *	11.8 *	12.9 [a]	13.9	12.5
Silt %	20.7 *	23.3 *[a]	23.4 *[a]	21.1	20.5 [a]	18.9 [a]
Clay %	62.0	63.0	65.1	66.0	65.6	68.6
CEC meq/100g	22.4	20.1	20.0	20.4	21.3	17.7
Na meq/100g	0.6	0.7	0.8	0.7	0.7	0.7
K meq/100g	1.5	1.9	1.6	1.6	1.7	1.3
Mg meq/100g	4.2	4.3	4.0	4.8	5.1	4.6
Ca meq/ 100g	4.3	5.9	6.1	4.3	6.2	5.0
P ppm	26.5 [a]	29.1	21.3 [a]	15.2 *[a]	21.6 *	9.0 *[a]
N %	0.26	0.29	0.24	0.25	0.28	0.23
C %	1.70 *	1.91 *[a]	1.51 *	1.50 *	1.63 *[a]	1.30 *
pH (H_20)	5.1	5.3	5.3	5.3	5.4	5.2
pH ($CaCl_2$)	4.5	4.7	4.8	4.8	4.8	4.5

* indicates significant differences (p= 0.10) of means of soil properties between the resource level classes, Kruskal-Wallis test.
[a] indicates significant differences (p=0.10) of means of soil properties within a resource level between the slope classes, Wilcoxon test.

Table 3. Precipitation and maize yield during three years, 1994-96, in Murang'a District, Kenya. (Source: Kahuro D.O. and interviews, N=100).

Year	*Precipitation (mm/year) Kahuro D.O. St. 90 37 204*	Maize yield (kg/ha) per year					
		Gentle slope Farm Resource Level			Moderate slope *Farm Resource Level*		
		High (N=12)	*Medium (N=27)*	*Low (N=14)*	*High (N=9)*	*Medium (N=28)*	*Low (N=10)*
1994	1 558	1 270 **	1 037 **	862 **[a]	1 103	935	1 034 [a]
1995	1 355	1 464 [a]	1 086	1 247 [a]	976 [a]	1 180	871 [a]
1996	927	974 **	719 **[a]	568 **	910 **	502 **[a]	340 **

**Indicate significant differences, p= 0.05, of means of maize yields between the resource levels, Kruskal-Wallis test.
[a] Indicate significant differences, p= 0.10, of means of maize yields within resource levels between the slope classes, Wilcoxon test.

between the resource level groups for grain size distribution, available P and organic C (Table 2). Mean values of the soil nutrients indicate that the rates of both available P and organic C are higher on the gentle slopes compared with moderate slopes.

Proposed optimum rainfall for maize in areas with a bimodal rainfall regime varies between 1 000 and 1 600 mm per year depending on the temperature, precipitation distribution and other factors (Doorenbos and Kassam, 1979). Maize yield variations (Table 3) between the surveyed years could possibly be explained by the variation in rainfall. Table 3 shows significant differences in mean maize yield for 1994 and 1996 between the farm categories. Most maize was harvested from fields with gentle slopes. The largest variations in maize yield between the farm resource levels were recorded on moderate slopes during 1996, the year with rains below optimum for maize production.

Average land management on gentle slopes ranged from fair *(class 2)* to good *(class 3)*. On moderate slopes the average land management ranged from poor *(class 1)* to fair *(class 2)* (Table 4). Steep slopes require a lot of labour for conservation and maintenance of conservation structures. The lowest rating of land management was found for farms on moderate slopes with low resource levels while the highest rating was found on gentle slopes with high resource levels. Splash erosion, which was noted on all visited fields, showed no significant difference between farms. Sheet and rill erosion were more serious on moderate slopes than on gentle slopes (Table 4). Most sheet erosion on gentle and moderate slopes were found in "the group of the poorest" farmers' fields. Rill erosion was most severe on moderate slopes occupied by low resource farms. Gully erosion affected only five sampled fields and is not considered further in this study.

DISCUSSION

Field studies from various similar places in East Africa have indicated that farm management practices and cropping systems are related to farm resource levels (Loiske, 1995; Altshul, et al., 1996; Briggs, et al., 1998; Tengberg, et al., 1998). Important variables in these studies are farm size, livestock capital, off-farm income and (access to) cash income and inputs. Hence, this study includes these criteria and uses as proxy for resource level the household's total value (in KSh) of capital and annual current income. The classification of farms into three resource level groups (low, medium and high) facilitated analysis of relationships between land quality and socio-economic factors. An additional subdivision of farms based on land slope was made in this study since large differences in yields, nutrient status and erosion were found between fields on gentle slope and those on moderate slopes.

The results of the soil analysis indicate that significant differences for available P, organic C, sand and silt exist between resource level groups (Table 2). The highest rates of available P and organic C were found among medium resource level farms. The highest maize yield was found among farms with the highest resource levels, except on moderate slopes for 1995 where medium resource farms had the highest output. In the present study, analyses of maize yield corroborates the findings of Tengberg et al. (1998): richer farmers have the highest output while poorer farmers have the lowest output. Tengberg et al. (1998) also indicates that the highest input costs are found amongst the "rich" farmers. Presumably, these farmers have larger possibilities to maintain soil nutrient levels by using fertilisers. This conclusion is also to some extent true for medium resource farmers and could explain the relatively high rates of nutrients in these fields. The higher output of high resource farmers partly explains why the nutrient status of their fields is lower than that for farms of medium resource levels since nutrients are removed with the harvested crop. Farmers' endowment affects farming strategies. Differing farming strategies help explain the differences in both soil nutrient status and farm output (Loiske, 1995; Tengberg, et al. 1998).

Our erosion assessments indicated less erosion on gentle slopes, and slight *(E1)* to moderate *(E2)* on moderate slopes. Conservation of land with steeper slopes requires more labor and this explains the difference in farmers' resources levels between the slope categories. The lower rates of erosion on "rich" farms compared to "poor" farms are explained by the higher availability of labor and farm implements among the rich farmers. Land management practices differ depending on both farmers' resource level and land slope. Both erosion and land management practices depend on labor

Table 4. Erosion and land use management noted, using PLUS classification (N=100).

PLUS Classification	Gentle slope Farm Resource Level			Moderate slope Farm Resource Level		
	High (N=12)	Medium (N=27)	Low (N=14)	High (N=9)	Medium (N=28)	Low (N=10)
Splash erosion						
Class E0	0	0	0	0	0	0
Class E1	9	30	14	0	14	0
Class E2	58	48	43	56	43	60
Class E3	33	22	43	44	43	40
Sheet erosion	*	*[a]	*		[a]	
Class E0	33	30	29	45	25	30
Class E1	50	52	29	11	36	30
Class E2	17	14	21	22	18	40
Class E3	0	4	21	22	21	0
Rill erosion		[a]		*	*[a]	*
Class E0	50	48	29	33	20	20
Class E1	33	45	43	56	63	70
Class E2	17	7	28	11	13	0
Class E3	0	0	0	0	4	10
Land management	*[a]	*[a]	*	*[a]	*[a]	*
Class 0	0	0	0	11	8	0
Class 1	0	15	21	11	52	60
Class 2	42	48	65	67	32	40
Class 3	58	37	14	11	8	0

* indicate significant differences, p= 0.10, of means of rating erosion and land use management between the resource level classes, Kruskal-Wallis test.

[a] indicate significant differences, p=0.10, of means of rating erosion and land use management within resource levels between the slope classes, Wilcoxon test.

requirements and the availability of funds.

Regarding the definition of resource levels, the most important indicators of household wealth seem to be capital assets and cash income. Among households' capital assets, livestock indicates the largest variance, since most farmers operate on a small scale with small differences in farm acreage and land value. It might be argued that all household income is important, but farmers who are less dependent on agricultural income have relatively higher access to other cash incomes, which can facilitate land investments after years of low output. Currently, most farmers have to generate their essential cash needs from their own farms. High costs for public services, such as school fees and health care, reduce the funds available for privately hired labour and farm implements. During years with crop failure the poorest farmers are the ones who suffer the most.

It is thus necessary for agricultural policy makers and practitioners, such as extension workers, to identify the different resource levels among farmers to facilitate better support and targeted advice. In the studied area poorer resource farmers need specific support and advice, especially in the short run, to improve both soil nutrient status and yield, while medium resource farmers need to improve their land management practices to increase yields, and high resource farmers could increase their yield by improving the soil nutrient status. In the long run all farmers need to improve both land management and soil nutrient status to increase today's agricultural production sustainably.

CONCLUDING REMARKS

Our analysis shows that farmers' resource levels affect soil nutrient levels and grain size distribution as well as yields. Poor farmers have relatively low nutrient levels in their fields. They are also more dependent on cash income from the farm. Presumably, this makes them more vulnerable to crop failure compared to richer farmers, who have access to cash income from off-farm work. This study indicated that different farm endowments have different effects on soil properties, yield, and soil erosion and land management. This is important to consider in the design or support of soil and water conservation, land management and crop cultivation. Efficient conservation activities must aim at maintaining soil organic matter, nitrogen, and phosphorus at optimal levels, minimizing nutrient losses, and balancing nutrient output with inputs. To paraphrase Chambers et al. (1989), the priority has to be not only sustainable agriculture, but also sustained livelihoods based on sustainable agriculture.

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