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Soil Fertility Management by Smallholder Farmers and the Impact on Soil Chemical Properties in Sironko District, Uganda

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Abstract

Low crop production on small holder farms in the Mount Elgon region, Uganda is related to a decline in soil fertility. A study was carried out to; determine the major causes of soil fertility decline in Sironko district, quantify crop yields under different soil fertility management practices and to assess the impact of these practices on soil chemical properties. Data were collected from three randomly selected parishes; Bulwala, Bumasobo and Bumasifwa using questionnaire and field observations. Soil samples were taken from the plots, mixed and composite samples were obtained for routine laboratory analysis. Over 95% of the farmers reported a decline in soil fertility, which was caused by soil erosion due to the hilly terrain and poor farming practices. The perceived indicators of soil fertility loss were reduced crop yield, poor crop performance or stunting and yellowing of the crop. As a result of poor soil fertility, yields were low 29−54 bunches acre^{-1} for bananas, 235−348 kg acre^{-1} for beans, 169−329 kg acre^{-1} for coffee and 151−922kg acre^{-1} for maize. In an effort to improve soil fertility smallholder farmers used manures, some mineral fertilizers and other organic nutrient sources, but the quantities used were small and had no significant impact on the soil chemical properties. External assistance is needed to emphasize the importance of the soil conservation measures and the need to improve soil fertility using available and external inputs in order ensure food security and increase household incomes.

Key words: Soil fertility, low crop yields, poverty.

Introduction

Soil fertility reduction on smallholder farms is a major problem in sub-Saharan Africa[1]. The reductions in soil fertility are due to nutrient mining, have been assessed and negative nutrient balances reported in the region[2]. However, soil fertility varies spatially and temporally from field to region scale, and is influenced by both land use and soil management practices of the smallholder farmers[3]. It is reported that differences in fertilization, cropping systems and farming practices are the main factors influencing soil fertility at field scale[4]. Understanding variability of soil fertility, its distribution and the causes of the observed variability are important to improve sustainable land use strategies[5].

Countries in Sub-Saharan Africa (SSA) have high rates of nutrient depletion[6]. Losses of 130kg N, 5kg P and 25kg K ha^{-1} year^{-1} have been reported in the East African highlands[7]. Nutrient depletion in East Africa is due to high outputs of nutrients in harvested products and soil erosion. Majority of the East African population rely on agriculture, and add few inputs to replenish soil fertility and the soil conservation practices are inadequate leading to soil degradation. The Global Assessment of Soil Degradation (GLASOD) reports that degraded soils amount to about 494 million ha in Africa[8]. Many of Africa's soils are derived from granite through millennia of weathering and contain inherently low levels of plant nutrients[7].

Long term experiments are key in understanding the changes in soil fertility status resulting from changes in land management practices[9](Henao and Baanante, 2006). Results indicate that there are positive crop yield responses following application of mineral fertilizers on poor soils. This potential has been recognized by large-scale farmers in East and Southern Africa (Kenya, Zambia, and Zimbabwe) who have been able to sustain relatively high cereal yields for periods of up to 30 years on the same piece of land. Smallholder farmers in Uganda lack financial resources to purchase mineral fertilizers to correct the inherent low fertility levels and replace the nutrients exported with harvested produce. Yet restoring soil N and P are major priorities not only for sustained productivity but also in the rehabilitation of eroded and degraded soils. There is little option to use fertilizers to balance the loss of P and K, but N can also be supplied through Biological Nitrogen Fixation (BNF)[10]. On the other hand, application of organic inputs either as animal manures or crop residues is insufficient to meet the crop nutrient requirements.

Sironko district located in the Mount Elgon region in North Eastern Uganda has a very high population pressure i.e. 500 people km^{-2}. Consequently, the soils have declined in fertility and it is expected that more inputs in form of fertilizers are needed for good yields. Good crop yields are an impetus to attain the national goal of poverty eradication and food security. A study was carried out in the district to i. find out the major causes of soil fertility decline ii. quantify crop yields under different soil fertility management practices and iii. assess the impact of soil fertility management practices on soil chemical properties.

Material and Methods

Study area: This research was conducted in Sironko district, north Eastern Uganda. The main town Sironko is located 01°14'N and 34°15'E. The district has a total area of 421 $km^2$and lies between 1,299 metres and 1,524 metres above sea level. It is a highland area with steep slopes, intensely cropped hillsides and high population densities. The region has experienced out-migration for many years due to the scarcity of land. Erosion and consequent soil degradation have been assumed to be a major problem before independence[11].

The soils are Andisols, developed from volcanic ejecta. This rock system is composed of volcanic ash, soda rich agglomerates, and tiny amounts of lava and tuffs, which were extruded by the volcanic activity. Calcareous clays are found especially around river Sironko, Kado and Mahapa, but most of the area is composed of sand clay loams and black soils in the valley basins. The temperature variability in the area is influenced by altitudinal differences, the average maximum temperature 27−32°C, minimum temperatures 15−17°C, with an annual average temperature of 21.5°C. Average annual precipitation is about 1500 mm. The beautiful green scenery has woodlots in the valleys, meandering rivers and streams, escarpments and waterfalls over the cliffs. Over 80% of the green beauty is crop vegetation, bananas, coffee and seasonal crops, maize, beans, and horticultural crops. Most people in Sironko district are mainly peasants living on small farm holdings. Hand tools such as pangas, axes, and hoes play major roles in opening up of fields for cultivation. Due to the hilly terrain and the fragmented nature of the plots, mechanization is not possible in the area.

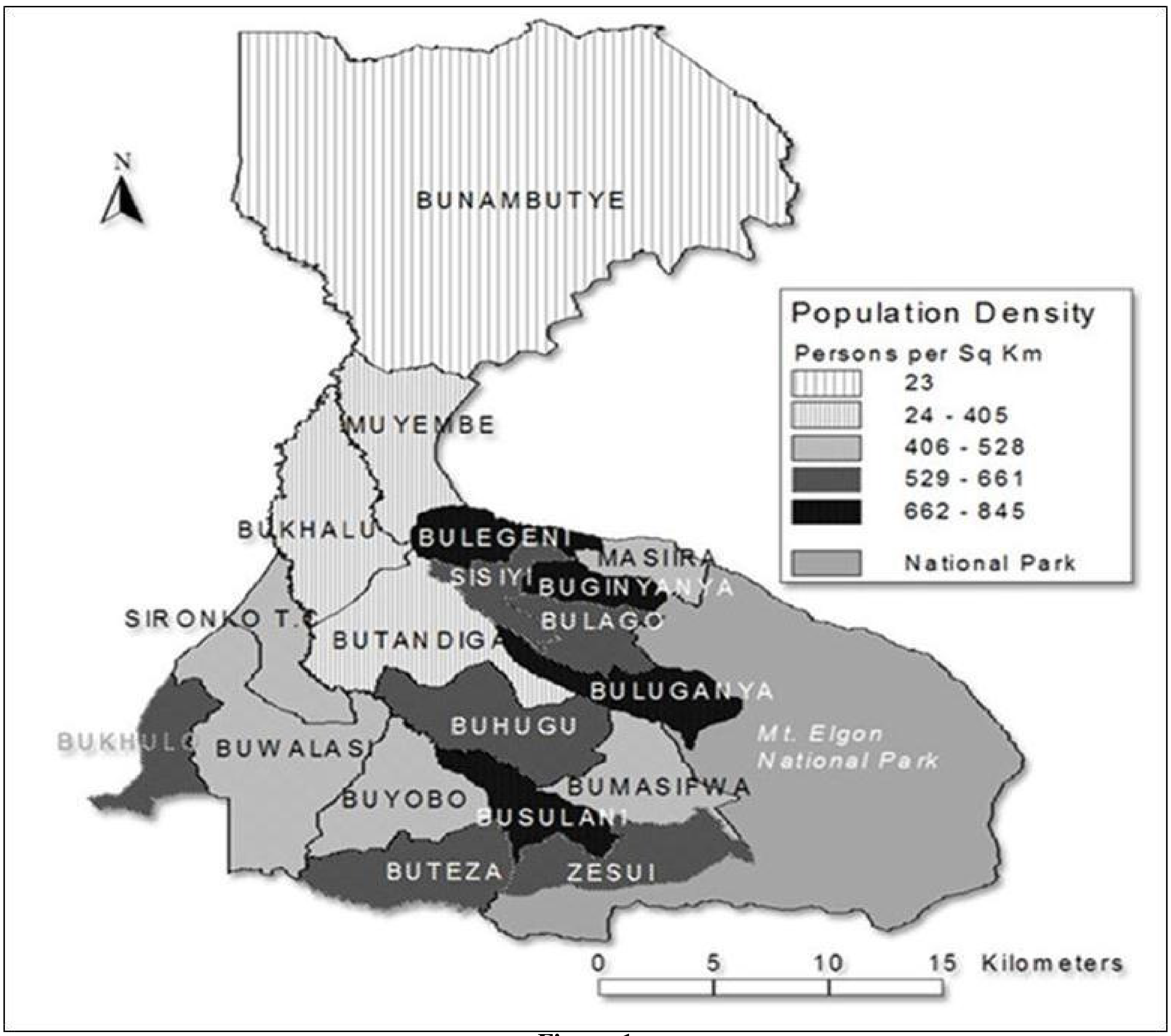

Figure-1

Map of Sironko district showing the study area and the population density

Study design, sample selection, soil sampling and analysis: Qualitative and quantitative data were collected using a questionnaire. Three parishes were randomly selected for data collection namely: Bulwala, Bumasobo and Bumasifwa. In each parish one village was randomly selected for data collection. Thirty households were randomly selected in each village, giving a total of 90 respondents, but some declined and only 86 respondents participatedin the study.

Soil samples were collected from seven different sites in each parish. The sites included maize fields, banana plantations, and coffee gardens where fertilizer was used, mulch and manure applied and the control where no soil fertility management practice was carried out. During soil sampling, information on the previous crops grown, land use practices, amount of crop harvest and the amount of fertilizer / manure applied were recorded.Soils from five random spots in a plot were sampled at a depth of 30cm, put in a basin, thoroughly mixed and a composite sample was obtained. Samples were air dried, packed and taken to the plant andsoil analytical laboratory, Makerere University for analysis. Soils were analysed for nitrogen, available phosphorus, soil PH, soil organic matter and exchangeable potassium, calcium and magnesium using analysis procedures by[12]. Survey data werecleaned, sorted,coded and analyzed using SPSS. Other data were analyzed using Gensat.

Results and Discussion

Socio economic characteristics of the farmers: The gender distribution in the three sampled villages of Bumasola, Gibumbuni and Lolobi was 47.3% male and 52.7% female. Marital status of the respondents was single 4.7%, married 70.9%, divorced 7% and widowed 17.4%. Marriage commits individuals to directly engage in productive farming to raise enough crop produce for domestic use and for sale to meet other cash needs. In terms of religious affiliations, majority were catholics (52.3%), Protestants (32.6%), seventh day Adventists (2.3%), Pentecostals (5.8%) and Muslims (7%). Up to 77% of the population sampled had houses made of mud and iron sheets, 4% mud and grass, bricks and iron-sheets 17%. Regarding age distribution, 30% were aged between 18–35years, 48% were aged between 36–55years, 20% were between 56–75 years and about 2% were above 75 years. This shows that people who are actively engaged in farming (18–55years) were captured in the study.

In reference to level of education, 6% had received no education at all, 38% attained primary education, 37% secondary and 19% received tertiary education. The low education levels highlight the need for agricultural education and training, in order to impart farmers with skills and knowledge about proper soil fertility management in order to increase productivity. The high drop out of school at the primary level may also be attributed to labour shortage because mainly family labour is used in production, with parents forcing their children from school to help them in farming. This implies that with limited education, the children will not be able to access better employment opportunities, hence the poverty trap[13]. Forty seven percent (47%) of the farmers inherited land; 31% had both inherited and bought land. The high level of land inheritance from parents exaggerates the problem of land fragmentation where by even the smallest piece of land must be divided among the children. Another cause of land fragmentation is the sale of land due to high poverty levels. Land pressure implies no fallowing for land to regain fertility[14]. Maize, bananas, coffee, onions and cabbage are cash crops, while the other crops are mainly grown for domestic consumption include; cassava, potatoes, yams and groundnuts.

Table-1
Socio-economic characteristics of respondents (n = 86)

Variable	Category	Frequency	Percentage (%)
Gender	Male	41	47.3
	Female	45	52.7
Marital status	Single	4	4.7
	Married	61	70.9
	Divorced	6	7
	Widowed	15	17.4
Religion	Catholic	45	52.3
	Protestant	28	32.6
	Seventh-day Adventist	2	2.3
	Pentecostals	5	5.8
	Muslims	6	7
Agedistribution	18–35	26	30.2
	36–55	41	47.7
	56–75	17	19.8
	>75	2	2.3
Housing	Mud and grass	3	3.5
	Mud and iron sheets	66	77
	Bricks and iron sheets	15	17
	Other	2	2.5
Education level	None	5	5.8
	Primary	33	38.4
	Secondary	32	37.2
	Tertiary	16	18.6

Farmer perceptions and causes of soil fertility decline: In this study, 95.3% of the farmers reported that soil fertility had declined and only 2.3% reported that their soils were still fertile and hence any need to apply manures and fertilizers in their crop fields. Farmers reported the following signs of soil fertility decline; stunted (poor growth) 10.5%, low produce (yield) 70.9%, and a combination of poor growth and low yields 15.1%. Reasons for the soil fertility decline were; soil erosion coupled with heavy rainfall 22.1%, poor farming practices 31.4%, hilly terrain 3.5%, a combination of soil erosion, poor farming practices and hilly terrain 31.4%, soil erosion and hilly terrain 8.1%.

Table-2
Perceptions of farmers and causes of soil fertility decline (n = 86)

Category	Response	Frequency	Percentage (%)
Decline in soil fertility	Stunted or poor growth	9	10.5
	Low yields	61	70.9
	Poor growth and low yields	13	15.1
	No attempt	3	3.5
Causes of soil fertility decline	Soil erosion coupled with heavy rainfall	19	22.1
	Poor farming practices	27	31.4
	Hilly terrain	3	3.5
	Soil erosion, poor farming practices and hilly terrain	27	31.4
	Soil erosion and hilly terrain	7	8.1
	No attempt	3	3.5

Due to the wide perception that soil fertility had declined, soil fertility management practices used by farmers were; manure 1.3%, fertilizer application on a small scale 24.1%, mulching 11.4%, planting of cover crops 6.3%, a combination of fertilizer application and mulching 11.4%, fertilizer and manure 17.7%, a combination of cover crops, manure and fertilizers 12.7%, a combination of fertilizer, mulching and manure 11.4% and about 3.8% gave no response. Farmers use cow urine on bananas and coffee purposely to kill pests and to also provide nutrients to the crops. All farmers who had animals like cows, goats, sheep, and poultry at least applied manure in their fields and those who didn't have any animal either bought manure or used only fertilizers on a small scale. Farmers reported increased production after applying manures depending on the amount applied. This was attributed to the fact that 76.5% of the farmers buy improved seeds with a good yield potential, but the low yields obtained are probably due to soil fertility constraints. A few farmers used the following methods to control soil erosion; ditches, cover crops, mulching, terracing, fanya juu and fanya chini, contour bands, terraces, and tunnels. Some farmers were aware of the above practices but lack the manpower to implement them. The government of Uganda has put in place the National agricultural advisory services (NAADS), but majority of the farmers didn't receive any extension services[15]. Farmers stressed that their soils continue to decline in fertility because they are not sensitized about the most appropriate measures to curb it down.

Quantification of crop yields on smallholder farms: Table 3 shows that the quantity of manure and fertilizer applied differed significantly between the different farm sizes (P value <0.001). Smaller farms applied less manure. The number of bunches of banana harvested also differed significantly but there was no significant difference in number of bunches of banana harvested from farm size of 1.5–2.9 and >3 acres. This could be attributed to shortage of manure to fertilize larger plantations, because bananas take up large quantities of nutrients and probably shortage of labour[16]. Nonetheless, farmers who preferentially applied manure on bananas reported an increase in number and size of bunches harvested.

There was no significant difference in amount of beans harvested in the different land sizes (P value =0.118). Beans slowly respond to fertilizer and manure application this explains no significance in bean yields among the different land sizes. There was a significant difference in amount of coffee harvested by farmers with land area <1.4 acres and 1.5–2.9 acres, but there was no difference in coffee yield between farmers with farm size 1.5–2.9 acres and >3 acres. This is probably due to limited manure and mineral fertilizer use. Maize yields differed significantly among the land sizes (P value <0.001), probably because the crop is considered a source of cash. Farmers therefore tend to buy more fertilizer for this crop and reported higher yields.

Table-3
Manure, fertilizer use and crop yields among smallholder farmers in Sironko district, Uganda

Treatment / category (size of land, acres)	Variables					
	Dry manure (kg acre^{-1})	Fertilizer applied (kg acre^{-1})	Bananas (bunches acre^{-1})	Beans yields (kg acre^{-1})	Coffee yields (kg acre^{-1})	Maize yields (kg acre^{-1})
< 1.4	10.5	4.9	29.6	235	169	151
1.5–2.9	23.2	17.2	54.0	324	311	415
>3	47.9	42.6	52.7	348	329	922
Mean	27.6	21.9	45.5	303	271	504
P-value	<0.001	<0.001	0.009	0.118	0.025	<0.001

The differences in amounts of dry manure and fertilizer applied per acre among the land sizes can be attributed due to differences in incomes, farmers with more land applied more manure since they are wealthy and can afford to keep slightly more animals. Table 3 shows that the amounts of manure and fertilizer applied are still low, consequently resulting in low crop yield. In Uganda, average banana yields are 15−32 Mg ha^{-1}[17], beans (1.0−2.0 Mg ha^{-1}), maize 1.5 Mg ha^{-1}[18] and coffee 486−748 kg acre yr^{-1}[19]. This situation calls for concerted efforts among the extension workers and non-governmental organisation working in the area to increase efforts aimed at encouraging the use of manures and mineral fertilizers to replace lost nutrients. This will help to increase the crop yields to a satisfactory level. In addition, farmers mainly have one farming season which runs from March to August, but this has been altered by changes in weather and sometimes the rains come in April instead of March. In the second farming season, most farmers are reluctant to plant, because the crops in this season do not give good yields. Climate change is likely to exacerbate the already fragile situation. This calls for joint efforts that allow adaptation to climate change and as well increase crop yields and the income of the farmers.

Impact of soil fertility management practices on soil chemical properties: There was no significant difference in the soil pH (P value = 0.141), organic matter (P value = 0.239), available phosphorus (P value = 0.541), exchangeable potassium (P value = 0.285), exchangeable sodium (P value = 0.780), exchangeable calcium (P value = 0.226), exchangeable magnesium (P value = 0.893), and percentage nitrogen (P value = 0.253) among the different treatments. Soil organic matter (SOM) content is higher than the 3% threshold for good crop growth[20], but low yields could be attributed to a low proportion of active SOM as noted in other parts of Uganda[21]. Nitrogen was low (below the 0.2% threshold) except fields that received manure, but available P was below the 11 mg kg^{-1} threshold for crop growth[20].

Table 4 shows that the soil fertility management practices of the small scale farmers had little impact on the soil chemical properties. This is evidenced by the high poverty levels in the district as farmers cannot afford to buy fertilizer/manure in large quantities to apply in their fields. From the results, average soil pH is 5.2, which shows that the soils are moderately acidic therefore farmers need to be sensitized about the practices that can lower the soil acidity such as liming, application of ash and organic materials. Available phosphorus was low, so farmers should be encouraged to use P-containing fertilizers or rock phosphate, which is available from the rock phosphate deposits in Busumbu, Mbale district and Sukulu, Tororo district. Given the soil fertility problem in the district, the Ugandan government should introduce subsidies on fertilizers to increase access to inputs for increased agricultural production. Subsidies do lower the price and relatively improve the availability of fertilizer to farmers in ways that encourage its efficient use and can stimulate private input market development. In addition, more investment is needed to support adoption of sound soil fertility management practices by smallholder farmers[22]. It is critically important to empower farmers with basic principles of crop nutrition and management since simple techniques such as mulching, fanya juu, fanya chini, cover crops, terracing, contour bunds, establishing clear drainage channels and more precise fertilizer placement can increase crop yields. In order to ensure their adoption, government and the local government should develop policies that encourage sustainable land use and management and assist in the use of land resource information for sustainable agriculture to increase food security in Sironko district and the country at large[22].

Conclusion

The major causes of soil fertility decline in Sironko district were soil erosion accelerated by hilly terrain, heavy rainfall and poor farming practices. Therefore farmers need more sensitization about proper soil fertility management to ensure increased crop production for poverty alleviation and better rural livelihoods.Crop yields varied between farmers with cultivated land size <1.4 acres and 1.5−2.9 acres but generally there was no significant difference in yield between farmers with cultivated land size 1.5−2.9 acres and >3acres, due to increasing shortage of inputs needed to increase yields. The reported yields on the smallholder farms were very low, as compared to yields reported in other parts of the country. The different soil fertility management practices by the smallholder farmers did not affect soil chemical properties. This calls for more application of manures and mineral fertilizers in order to increase crop yields.

Table-4
Soil fertility management practices and their impact on soil chemical properties in top soil (0−30 cm) in Sironko district, Uganda

Treatments (management practices)	pH	%OM	Available P (mg kg^{-1})	%N	K	Na	Ca	Mg
					$cmol_c\ kg^{-1}$			
Control	5.10	3.37	5.1	0.172	1.188	0.117	1.258	0.881
Fertilizer	5.38	3.28	9.5	0.167	0.933	0.118	1.783	0.992
Manure	5.30	4.05	7.9	0.215	0.860	0.125	1.517	0.860
Mulching	5.03	4.18	7.2	0.187	0.704	0.126	1.700	0.930
Mean	5.20	3.72	7.4	0.185	0.921	0.122	1.564	0.916
P value	0.141	0.239	0.541	0.253	0.285	0.780	0.226	0.893

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