SUSTAINABLE DEVELOPMENT IN AFRICA, THE ROLE OF HIGHER EDUCATION

COMMUNITY ENGAGEMENT

ENGAGING COMMUNITIES IN SOIL FERTILITY MANAGEMENT FOR SUSTAINABLE AGRICULTURAL PRODUCTION: CASE STUDIES FROM KAKAMEGA AND NAKURU DISTRICTS

By

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Executive Summary

Higher institutions of learning including universities have been accused of not responding as they should, to challenges confronting the African continent. These include the escalating poverty, food scarcities, the compounding environmental degradation, diseases, among others. Pedagogies are discipline based and stress intellectual pursuits at the expense of problem solving; the research agenda is equally irrelevant. Efforts to reverse this trend through engaging local communities in participatory research and learning are urgently required in the face of increasing demand for sustainable development. This paper presents preliminary results on an on-going project that is working closely with local communities with a view to empower them to mitigate soil fertility decline in two districts – Kakamega and Nakuru, Kenya. Sustainable agricultural production demands that soils are managed by preventing erosion and replenishing the nutrients. The project is conceived as a partnership between an interdisciplinary team of university based researchers, local communities (read farmers) Ministry of Agriculture extension officers, Kenya Agricultural Research Institute researchers and CBOs/NGOs operating in the two study areas. Participatory Action Research has been used in several stages of the project including soil fertility diagnosis, farmer perception of soil fertility, and capacity building of the participating farmers. The project has so far worked with a small number of nuclear farmers in both study districts in phase one, but will soon be up scaled to cover over 200 others in phase two. Preliminary results indicate that farmers are aware of the declining soil fertility which they describe in qualitative terms based on observations made on crops, soils and farm weeds. Soil analysis reveals that in Kakamega, soils are strongly acidic ($pH < 5.5$), have low organic carbon (< 0.2 %), high bulk density, more sandy in texture and low basic cations than those in Nakuru district. While soils in Kakamega are deficient in nitrogen and phosphorus, those in Nakuru are sufficient in most plant nutrients except phosphorus. Efforts made by farmers to address the declining fertility include among others the use of inorganic fertilizers, manure and terracing. However, poor utilization of inorganic fertilizers in both amounts and types is evident. Moreover, the manure used and terraces constructed are of poor quality. These weaknesses and shortcomings form the basis for current interventions - empowering efforts that focus on provision of the required knowledge and skills by the farmers. Preliminary findings underscore the essence of developing and utilizing synergies between and among experts, local communities, and other stakeholders towards realizing the goal of sustainable agricultural development.

I. BACKGROUND TO STUDY PROBLEM

With only 20% of its land classified as medium to high potential, and serious land degradation, Kenya faces, enormous challenges in attaining food self sufficiency. Increased food production was previously achieved through expansion of the area under crop production, and traditional practices such as fallowing, which allowed soils to regenerate and their fertility sustained. This is no longer possible owing to rapid increase in population and associated decline in land per capita. This coupled with suboptimal land resources management has resulted into soil degradation in Kenya (Nandwa, 2001).

Considerable nutrient losses at a district scale are evident revealing amounts of 112 kg N, 3 kg P and 70 kg K ha^{-1} yr^{-1} (Smaling *et al.* 1993). Estimates in Sub-Saharan Africa show that 320 million hectares of land are affected by human induced soil degradation, 124 million of which are highly degraded (Oldeman *et al*. 1991; Crosson and Anderson, 1995). Other effects include depletion of nutrients, organic matter, and soil erosion (Giller et al., 1997; Sanchez *et al*., 1997; Nandwa and Janssen, 1997). The amounts of nutrients extracted from soil through harvesting of crops, leaching and water erosion normally out weigh those imported naturally through atmospheric deposition, biological nitrogen fixation, and artificially through organic manure and mineral fertilizers (Smaling, 1993). Nutrient loses between 1982 and 2000 in Sub-Saharan Africa were estimated to range between 22-26 kg N, 2.5-3 kg P and 15-19 kg K ha^{-1} yr^{-1} (Stoorvogel *et al*. 1993).

Such losses can, however, be reduced through various management practices including erosion prevention and minimum tillage, use of organic and mineral inputs (Bationo and Buerkhet, 2001, Nandwa, 2001) and use of improved systems that exploit the benefits of biological nitrogen fixation, rotations, intercropping and agroforestry (Rao and Reddy, 2001; Palm *et al*., 2001).

A range of fertilizers have been recommended to help address soil fertility deficiencies in Kenya (Muriuki and Quresh 2004). However, inorganic fertilizers are expensive and unaffordable by many small scale farmers.. Rock phosphate, manure and *Tithonia diversifolia* locally available alternatives could be used for recapitalizing soil P, reportedly low in soils of western Kenya (Mutuo, 1999). Also, cycling of biomass through animals into manure provides an important link between livestock and soil productivity in many farming systems of Sub-Saharan Africa (Delve and Ramisch, 2004).

In spite of these potential benefits, it is observed that the handling of fresh manure is poor leading to the loss of N through leaching, denitrification and in most cases due to volatilization of ammonia. The quality of the compost can be improved through incorporating rock phosphate, tithonia and fresh manure during composting. Apart from improving the N content of the compost, fresh manure and tithonia have the capacity to lower the usually higher C: N ratio of many crop residues (Misra *et al*., 2003) thereby increasing decomposition rate by microorganisms.

Recent research shows that farmers have a rich understanding of the problems and solutions to soil fertility (Mairura *et al*., 2007; Moges and Holden, 2007). Continued degradation may imply that adoption of corrective technologies is either too slow or limited, probably owing to the nature of the technology itself, socio-economic and institutional factors (Makokha *et al*., 1999).

Enhanced soil fertility management, which is central to increase in food production, will require better access to information, which allows farmers more flexibility in selecting management options, decision making as well as opportunities to diversify their livelihoods or pursue market oriented activities. Research findings however, indicate that technologies and the underlying knowledge have not been disseminated adequately to farmers and therefore still have had little effect at the farm level (Devel and Ramisch, 2004). The need for improved dissemination of knowledge (Semalulu *et al*. 1999), and active participation by farmers, the local administration and the communities in general (Dofoer, 2000), are considered most appropriate.

This paper examines the opportunities and synergies that exist between university researchers and local community for sharing such knowledge and skills for improved decision-making for sustainable soil management, increased food production and reduced poverty.

The organizing framework is the concept of "Empowerment" which embraces participatory problem identification, participatory action learning, and participatory implementation, with the objective of making the farmers more conscious and aware of resources within their reach, as well as building their capacity for better performance. Empowerment seeks to equip farmers with new knowledge and skills, making better able to make informed decisions in improving their techniques in managing their resources for gainful employment and improved livelihoods.

2.0 MATERIALS AND METHODS

2.1 Site Description

The research sites are located in Nakuru and Kakamega Districts in West Kenya. Two distinct agro-ecological zones were selected for each site. In Nakuru one zone is classified as UH2 (Upper Highland wheat-pyrethrum) zones . It ranges in altitude from 2580 to 2800 metres above sea level, annual mean temperatures from 12.0 to 13.7^{o}C and annual rainfall from 1100 to 1400 mm.

The other is classified as LH3 (Lower Highland wheat/maize-barley) zone. It ranges in altitude from 1890 to 2190 metres above sea level, annual mean temperatures from 15.7 to 17.5^{o}C and annual rainfall from 850 to 1100 mm. The soils in both zones were classified by Jaetzold and Schmidt, (1982) using as *mollic Andosols* according to FAO/UNESCO (1974). Developed on ashes and other pyroclastic rocks from recent volcanoes, these soils are well drained, deep to moderately deep, firm clay loam with humic top soil, and high in fertility.

In Kakamega, one zone is classified as LM1 (Lower Midland sugar cane). It ranges in altitude from 1300 to 1500 m. a.s.l, annual mean temperature from 20.8 to 22.0^{o}C, and annual rainfall from 1800 to 2000 mm. The other is classified as LM2 (Lower Midland marginal sugar cane) zone, differing from the first zone only in rainfall that ranges from 1550 to 1950 mm.

2.2 Farmer Selection

Participatory diagnosis workshops comprising farmers, researchers, extension staff and local non government organizations were held in each agro-ecological zone to discuss the project objectives, create ownership and set the criteria for farmer selection and participation. Farmers selected five volunteer "satellite farmers" in each agro-ecological zone. Each satellite farmer in turn selected nine other farmers to make a total of 10 farmers to participate in the research.

2.3 Diagnosis of Soil Fertility Status and Management Practices

Participatory soil fertility diagnosis was carried out during group discussions according to Defoer *et al*. (1996) to identify the broad soil types and enlist farmer perceptions about the fertility status and management practices. The team of researchers and farmers undertook transects of the selected areas to identify indications of soil fertility constraints and potentials as indicated by the farmers during the group discussions. Detailed assessment of soil resources of satellite farmers were then carried out to confirm the soil fertility status, management practices used and farmers' perceptions of the practices.

2.4 Soil Sampling and Analysis

Fourteen (14) composite soil samples from 0-20 cm depth were collected from the satellite farmers' fields in the two study sites. These were analyzed for physical and chemical characteristics at the Kenya Agricultural Research Institute (KARI) Muguga South, based on the methods reported by Okalebo *et al* (1993). Data for soil analysis was entered in an excel spread sheet and subjected to analysis of variance using SAS statistical package.

2.5 Building Farmers' Capacity

During participatory diagnosis, farmers enlisted the soil fertility management practices and prioritized those for which they required extra skills and hence need for training. Composting, use of fresh manure, appropriate utilization of inorganic fertilizers, agroforestry practices and soil conservation were ranked among the top priority practices in this regard. Participatory training of the farmers on the appropriate methods was subsequently carried out on the satellite farmers.

3.0 RESULTS AND DISCUSSION

3.1 Farmers' Perception of Soil Fertility

It is observed from the findings that farmers' perceptions of soil fertility in the two districts do not vary significantly. They perceived soil fertility status based on a number of indicators (Table 2). The indicators included physical characteristics such as soil color, texture, crop vigour and yields, and the types of weeds. The indicators demonstrate the extent and depth of the farmers' knowledge regarding soil fertility. There was a close relationship between the farmers' perceptions, soil fertility and scientific interpretation. This is a demonstration of the usefulness of such perceptions in assisting scientists to understand how farmers manage their soils. Research by Mairura *et al*. (2007) and Tabu (2003) in Eastern and western Kenya respectively, corroborate these findings. The perceptions provide building blocks for further research and university-local community collaborations and interactions.

Table 2: Farmers' Perceptions of Soil Fertility Status

Local Indicator	**Perception of soil fertility**	**Scientific Equivalent**
Yellow plants	Poor	Deficiency of nitrogen
Dark green plants	Good	Adequate supply of Nitrogen
Plant growth-stunted /vigorous	Poor	Low /high supply of plants nutrients
Crop yields (harvest) declining	Declining	Declining supply of crop nutrients
Black soil	Good	High organic matter (good soil)
Light brown soil	Poor	Poor soil
Fine soil	Good water retention	Clay soil

Sandy soil	Poor water retention	Sandy soil
Types of weeds - wondering Jew (*comelina* sps)	Fertile soil	High soil fertility

3.2 Soil Fertility Status

The results of soil analysis showed that the two study sites are significantly different in terms of bulk density, texture, and organic carbon (Table 3). Soils in Kakamega have higher bulk density and sand content while those in Nakuru have higher silt and organic carbon contents. Generally organic carbon and silt contents are higher in Nakuru (LH3 and UH2). The differences in organic carbon observed between LH3 and UH2 could be due to differences in soil management practices. In addition, UH2 falls under the former Mau forest and has not been under cultivation for a long period.

Further differences relate to soil pH and total P. Soils in Kakamega are sandy with lower pH values probably as a result of management (erosion and leaching), and nature of parent material. The high bulk density implies that the soils are compact thus restricting root penetration.

Table 3: Physical and Chemical Characteristics of Soils

Site	AEZ	Local Name	Pb (gCm^{-3})	Silt (%)	Sand (%)	pH	P total (%)	N total (%)	O. C (%)
Nakuru	LH3	Kikapu	1.00[a*]	37.4[a]	38.6[a]	5.76[a]	0.14[ab]	0.31[b]	3.0[a]
	UH2	Sigotik	0.89[a]	46.0[b]	34.0[a]	5.86[a]	0.17[b]	0.48[c]	5.3[b]
Mean			0.95	40.6	36.9	5.8	.016	.0.40	3.9
Kakameg	LM1	Butsots	1.32[b]	15.5[c]	66.5[b]	4.35[b]	0.12[a]	0.20[a]	1.7[a]

a		o						b	
	LM2	Kabras	1.39^{b}	16.0^{c}	63.5^{b}	5.02^{c}	0.12^{a}	0.16^{a}	2.1^{a}
Mean			1.37	15.8	64.5	4.8	0.12	0.18	1.9

* Figures followed by the same letter within a column are not significantly different at $P \leq 0.05$.

Whereas available calcium, magnesium and potassium differ significantly between the two sites, available P and N (both NH_4^+ and NO_3^-) are similar (Table 4). Available cations in Kakamega were extremely low and deficient compared to those in Nakuru. Being predominantly *Ferralsols* and *Acrisols*, the soils in Kakamega are low in inherent fertility compared to the *Andosols* found in Nakuru. The results for soil characteristics are corroborated by Shepherd *et al*. (1992) in western Kenya.

Table 4: Available Soil Nutrient Content

Site	AEZ	Local Name	Available nutrients (ppM)					
			Ca	Mg	K	P	$N\text{-}NH_4^+$	$N\text{-}NO_3^-$
Nakuru	LH3	Kikapu	1930^{b*}	344^{b}	878^{b}	39^{a}	21^{a}	13^{a}
	UH2	Sigotik	2361^{b}	370^{b}	756^{b}	19^{a}	7^{a}	46^{b}
Kakamega	LM1	Butsotso	161^{a}	58^{a}	156^{a}	11^{a}	11^{a}	9^{a}
	LM2	Kabras	234^{a}	27^{a}	95^{a}	14^{a}	23^{a}	9^{a}

* Figures followed by the same letter within a column are not significantly different at $P \leq 0.05$.

Soils in Kakamega are acidic, low in nutrient reserves and high potential to fix P hence calling for management practices that address the constraints. In contrast, soils in Nakuru require management that targets improvement in soil P, N and C content. The difference in pH across zones could be attributed to differences in management. For example in Kakamega, it could be the result of continued use of acidic fertilizers like Diammonium Phosphate (DAP) as observed by Mwangi *et al*. (2007).

3.3 Soil Fertility Management Practices

Farmers in the two sites use different practices to manage their soils. Legume intercropping, inorganic fertilizers and farm yard manure were the most commonly used practices (Table 5). The inorganic fertilizers used largely included DAP, CAN and Urea. Sixty seven (67) percent and 100% of the farmers in Kakamega and Nakuru, respectively, used DAP. This implies that in spite of the differences in soil characteristics, farmers use the same type of phosphatic fertilizer in Kakamega and Nakuru. The use of DAP an acidic fertilizer in Kakamega is inappropriate since it is less efficient and further lowers the soil pH. Long term application of acidic fertilizers has been reported to cause soil acidification and decrease exchangeable bases (Ca and Mg) in soil (Lungu and Dynoodt, 2008).

Table 5: Soil Fertility Management Practices

Practice	% Farmers Using		Comments
	Nakuru	Kakamega	
Composting	25	17	EM used in a few cases in Nakuru
Fresh farm yard manure	25	8	Mainly used on Napier
Dry farm yard manure	63	83	Mainly used on maize
Legume intercropping	100	92	Mainly maize and beans
Inorganic fertilizer (DAP, CAN & Urea)	100	67	Mainly on maize & very low amounts
Agro-forestry practices	13	0	More predominant in Nakuru
Terraces	25	33	Poorly established and maintained
Cut-off drain	13	33	Predominant in Kakamega probably

			because of high rainfall and tenure system
Fallowing	0	17	Less productive natural fallows used
Confined/zero grazing	38	25	Predominant in Nakuru
Grass strips	38	33	Mainly of Napier grass
Trash-lines	13	0	Using crop residues
Zero tillage	13	0	In Nakuru under conservation agric project

EM is commercially sourced Effective Microorganisms used to enhance composting

Table 5 further shows that manure is the most commonly used organic resource. In most farms, manure is collected from kraals and piled in selected places, but it is exposed to rain and the sun. .The practice compromises the quality of the manure (Lekasi *et al*., 2003). This could be improved through proper composting and storage methods of on-farm organic wastes as observed by Misra *et al.* (2003). In addition to providing nutrients, organic fertilizers are important for improving CEC, organic carbon and soil health (Nalivata 2007). In spite of these benefits, few farmers use the resource because of socio-economic constraints (Somda *et al*, 2002). For instance, according to Kipsat *et al*. (2005) labour costs account for more than 60% of the total variable costs involved in composting.

3.4 Interventions for soil fertility management

This project seeks to contribute towards the improvement of the farmers' skills and practices for sustainable soil management. A number of technologies for soil fertility management using the Integrated Nutrient Management Systems (INMs) framework at a farm level exist (Woomer et al.

1999 and Table 4). The success of these technologies however, depends upon farmers' willingness and capacity to embrace the new and innovative ideas.

In view of the farmer deficiencies observed, this project earmarked composting, soil and water conservation, improvement of the agro-ecosystem health (agro-forestry) and striga control as priority technologies. De Jager *et al*. (2004) in a participatory analysis in Kenya and Uganda identified composting, manuring and phospho-composting as priorities for soil fertility management.

3.4.1 Compositing

The participatory learning exercise on composting, involved an initial group of 14 satellite farmers (8 in Nakuru and 6 in Kakamega). These were trained in phospho-composting using Rock Phosphate. The training/learning focused on the importance, materials and procedure for compositing. This initial group considered as "trainers of trainees" will assist in the cascading of the knowledge and skills on composting to an initial 200 farmers within the research sites. Already two groups have been identified are ***Abakoko*** (Women Group), and **Retirees' Club** in Kakamega**.** These groups are preferred as entry points because they enjoy a strong sense of belongingness, and shared vision, are cohesive and they appreciate their unique weaknesses and strengths (Plate 1)

Table 7: Nutrient Composition of Fortified and Unfortified Composts from Mukoshi's farm

NUTRIENT TYPE	FORTIFIED	UNFORTIFIED
N (%)	1.08	0.85
P (%)	1.08	0.42
K (%)	0.81	0.38
Ca (%)	1.61	0.81
Mg (%)	0.61	0.35
Organic carbon (%)	10.80	8.45
Available P (mg/Kg)	2495.8	700.29
Available ammonium (mg/Kg)	3.48	5.56

Table 8: Nutrient Composition of Fortified and Unfortified Composts from Mr. Musiomi's farm

NUTRIENT TYPE	FORTIFIED	UNFORTIFIED
N (%)	0.86	0.66
P (%)	0.50	0.41
K (%)	1.11	0.99
Ca (%)	0.71	0.62
Mg (%)	0.37	0.26
Organic carbon (%)	9.06	6.64
Available P (mg/Kg)	904.4	640.5
Available ammonium (mg/Kg)	24.5	38.6

During the composite-making participatory learning, it became evident that many farmers did not understand the process of composting and the type of materials required. The training thus sought to overcome these constraints through providing appropriate knowledge and new skills. It is important to observe that farmers participated keenly in the compositing exercise; taking charge of the collection, assembling, and turning activities.

The analysis of the compost despite being restricted to only two on-farm trials shows that the material was fully composted i.e. the C: N ratio was less than 20 compared to a ratio of about 75:1 for the original (Tables 7 & 8). The nutrient status of the compost is comparable to those of Nalivata (2007) and Kuba *et al.* (2008). Compositing therefore has a demonstrated positive impact on improving the soils' nutrient status.

3.4.2. Soil and Water Conservation

To demonstrate the efficacy of SWC related technologies, a number of soil conservation structures were constructed jointly by farmers and researchers (Plate 2). Farmers were also trained on appropriate methods of laying out soil conservation structures including terraces. It is noted that construction of the structures is both labour intensive, and costly. In recent farmer training meetings, it became clear that whereas women farmers were keen on embracing soil and water conservation techniques, their spouses who would normally be expected to provide the labour and money, to facilitate the structures, were reluctant to make the contributions.

3.4.3 Improvement in the Agro-ecosystem health

The third technology on which farmers were trained focused upon the planting of agro-forestry trees and napier grass. These additional technologies were believed to assist in enhancing nutrient cycling, and in stabilizing terraces constructed to check water/soil erosion.

4.0 CONCLUSION AND WAY FORWARD

This paper provides a preliminary assessment of the on-going work on empowering farmers for sustainable agricultural production through better management of their soils in Kakamega and Nakuru. It has been shown that decline in the fertility of soils is a major and growing problem, not only in the study sites, but also over much of Kenya and the rest of the African continent. Although they are aware of the decline in the fertility of their soils, most of the farmers in the two study sites do not have adequate knowledge and skills to manage the soils in practical and cost effective ways. Mechanisms of delivering information, knowledge and skills in cost effective ways are needed to help farmers increase their production, and means of livelihood.

Participatory action learning that brings together university researchers on the one hand, and farmers, local CBOs/NGOs, have capacity to ameliorate these challenges. Our experiences further demonstrate that farmers are receptive to well conceived and executed innovations. Synergies already developed will be critical in up scaling our activities for target more farmers for increased and sustainable agriculture.

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