Chapter 4

Organic Resources for Soil Fertility Management in Eastern Kenya

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Soil erosion, decline in soil fertility and insufficient fodder production are some of the major problems facing agricultural production in Kenyan smallholder farms today. These problems are more pronounced in the densely populated highlands of central Kenya with over 700 persons km^{-2} (Government of Kenya, 2001). The soils in this area are Humic Nitisols with moderate to high inherent fertility (Jaetzold and Schemindt, 1983). However, with an annual net nutrient depletion exceeding 30 kg N (Smaling, 1993) as a result of soil erosion and continuous cropping, soil fertility has markedly declined over time. The use of inorganic fertilizers is generally low, less than 20 kg N ha^{-1} (Murithi *et al.,* 1994) which does not meet the optimal crop nutritional requirement. Maize yields achieved by smallscale farmers in the region are less than 1.5 t grain ha^{-1} compared to the potential of 6 to 12 t ha^{-1} (Wokabi, 1994).

Surveys conducted in the area indicate that farmers are fully aware of the declining soil fertility (as expressed by declining crop yields), but in most cases do not have readily available resources to replenish the soil fertility (Murithi *et al*., 1994). Research results reported by Gachengo (1996), Gitari *et al.* (1997), Mugendi *et al.* (1999) and Mutuo *et al.* (2000) describe a positive effect due to the use of biomass from mucuna, crotalaria, manure, tithonia, calliandra and leucaena for soil fertility improvement in the Kenyan highlands. These organic inputs and tree hedges are important components in soil fertility replenishment and need to be evaluated by farmers. A participatory trial was therefore established in maize growing areas of Meru South District in 2000 with the main objective of examining and extending nutrient replenishment and conservation technologies intended for the small-scale farmers.

Study Area and Field Approach

The study was conducted in Meru South District, which is characterized by complex farming systems dominated by perennial cash crops, food crops and livestock (Micheni *et al.,* 1999). The area is in the main coffee/dairy/maize Land Use Systems (LUS) with an altitude of approximately 1500 m above sea level, annual mean temperature of 20^0 C with an annual rainfall varying from 1200 to 1400 mm (Jaetzold and Schemindt, 1983). The rainfall is bimodal, falling in two seasons, the long rains (LR) lasting from March through June and short rains (SR) from October through December. The average farm size is about 1.5 ha per household.

An off-station soil fertility trial was established in March 2000 on a farm with degraded soils and arranged as a randomised complete block design (RCBD) with three replicates. The trial was researcher-designed and researcher-managed, and the test crop was maize (*Zea mays* L, var. H513). Thirteen external soil fertility amendment inputs were applied to give an equivalent amount of 60 kg N ha^{-1} except for the herbaceous legume treatments where the N quantity was determined by the amount of biomass harvested and incorporated in the respective treatments. The fourteenth treatment received no nutrient inputs. One row of the herbaceous legumes was planted between the maize rows, two weeks after sowing. The legumes remained in the field after maize was harvested until land preparation the next season. Then, they were harvested, weighed, chopped and incorporated into the soil.

Farmers' field days were held during each season at the grain filling stage. Farmers toured the experimental plots and treatment effects were discussed in an informal setting. They were then requested to select the treatments they wished to test on their farms. During the 2001/2002 short rains, farmers established many of the technologies in their own farms. The trials established in the farmers' fields were of two types: researcher-designed but farmer-managed, and farmer-designed and farmer-managed. The farmers applied the organic inputs as explained during the field days though some of them adapted the technologies to fit their more specialized conditions. Data collected from both off-station and on-farm trials were statistically analysed using spreadsheet and statistical computer programs.

Maize Grain Yield

The off-station average maize grain yields in the different treatments across the four seasons are presented in Table 1. Tithonia with half the recommended rate of inorganic fertilizer recorded the highest maize grain yield of 4.8 t ha^{-1} followed closely by sole tithonia (4.7 t ha^{-1}). The absolute control treatment recorded the lowest maize grain yields across the treatments and seasons with 1.5 t ha^{-1} followed closely by the sole crotalaria with 1.7 t ha^{-1}.

The integration of organic and inorganic nutrient sources of N gave higher maize grain yields as compared to the sole application of organic materials during the four seasons of the study. Integration of inorganic and organic nutrient inputs can be considered as a better option in increasing fertilizer use efficiency and providing a more balanced supply of nutrients (Palm *et al.,* 1997; Vanlauwe *et al.,* 2002).

Table 1. Off-station maize yields under different technologies during the various rainy seasons at Chuka, Meru South District

Candidate management	-------------------------Seasons-----------------------				
	2000 LR	2000/2001 SR	2001 LR	2001/2002 SR	Mean
	----------------Grain weight (t ha^{-1})-----------------				
Control	0.6	2.6	1.2	1.5	1.5
Crotalaria	0.9	2.1	1.9	1.8	1.7
Mucuna	1.3	4.0	2.4	3.7	2.6
Crotalaria + 30 kg N ha^{-1}	1.4	3.4	2.4	3.2	2.6
Mucuna + 30 kg N ha^{-1}	1.4	4.4	3.2	2.7	2.9
Calliandra	0.7	6.0	2.8	4.5	3.5
Manure + 30 kg N ha^{-1}	1.2	6.5	4.9	2.9	3.9
Leucaena + 30 kg N ha^{-1}	1.3	6.1	3.7	4.4	3.9
60 kg N ha^{-1}	1.4	6.3	5.0	3.2	4.0
Cattle manure	1.2	6.7	3.7	4.6	4.1
Calliandra + 30 kg N ha^{-1}	1.1	5.8	4.3	5.1	4.1
Leucaena	1.0	6.1	4.0	5.8	4.2
Tithonia	1.2	6.6	4.3	6.5	4.7
Tithonia + 30 kg N ha^{-1}	1.3	6.8	5.4	5.6	4.8
SED	0.2	0.4	0.7	0.7	0.5

The lower maize grain yield in the 2000 and 2001 LR season may be attributed to the low precipitation, averaging only 126 mm in the 2000 LR season. During the 2001 LR season, 431 mm of rainfall was recorded but 86% of the rains fell within the first two weeks. This insufficient and unevenly distributed rainfall reduced the availability of nutrients to the maize plants. Fortunately, the 2000/2001 and 2001/2002 SR seasons were characterized by higher precipitation (average 698 and 806 mm, respectively) that was well distributed throughout the season.

Technology Adoption

Five well-attended farmers' field days were held at the grain filling stage during each season. Many farmers (24%) were willing to try the sole tithonia management probably because of its local availability and because they did not need to be educated on how to handle it. To overcome the problem of limited availability (as 30 t of fresh biomass is required to provide 60 kg N ha^{-1}), farmers said they would plant tithonia hedges, and most of them knew how to propagate it through cuttings. Calliandra was also highly rated because of its supplementary role as an animal feed. The farmers with animals said that they would use calliandra as an animal feed to improve the quality of their manure; however the ones with no animals wished to use it as a direct source of soil fertility.

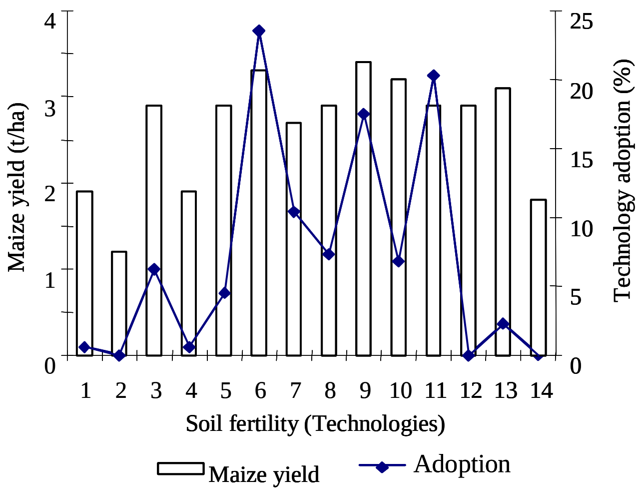

Figure 1. Average maize grain yield across the seasons and the % adoption of the technologies at the beginning of the 2001/2002 SR season in Chuka, central Kenya. Technologies (1= mucuna; 2 = crotalaria; 3 = mucuna + ½ fert; 4 = crotalaria + ½ fert; 5 = manure; 6 = manure + ½ fert; 7 = tithonia; 8 = calliandra; 9 = leucaena; 10 = tithonia + ½ fert; 11 = calliandra + ½ fert; 12 = leucaena + ½ fert; 13 = rec fert; 14 = control).

On-farm Maize Yields

Farmers participating in the field days selected some of the technologies that were demonstrated to them and started testing them in their farms during the following 2001/2002 short rains (Table 2). The results indicate that their crop yields improved as a result of using the introduced technologies, however the yields varied among farms. This could be as result of the inherent variability within each farm and the differences in day-to-day management. For instance, applied cattle manures varied in quality depending on the feedstuff, storage and decomposition duration. Tithonia did not perform exceptionally well on-farm as it had done in the off-station trial. This could be due to the lower amount of tithonia applied by farmers.

Table 2. Average on-farm maize yields (t ha^{-1}) under different technologies during the 2001/2002 SR, 2002 LR and 2002/2003 SR seasons at Chuka, Meru South District

Candidate management	-----------------Cropping Seasons-----------------		
	2001/2002 SR	2002 LR	2002/2003 SR
	---------------Grain weight (t ha^{-1})-----------------		
Control	1.0	0.4	1.4
Tithonia	1.9	1.3	2.4
Leucaena + 30 kg N ha^{-1}	2.4	2.1	--
Crotalaria	--	0.4	2.5
Mucuna	--	1.6	2.7
Manure + mucuna + 30 kg N ha^{-1}	--	4.3	3.3
Tithonia + 30 kg N ha^{-1}	--	2.8	3.4
60 kg N ha^{-1}	3.2	3.0	3.9
Manure + tithonia	1.8	--	4.2
Cattle manure	0.3	2.1	4.2
Calliandra + 30 kg N ha^{-1}	--	1.2	4.4
Crotalaria + 30 kg N ha^{-1}		3.3	4.5
Leucaena	3.7	0.2	4.7
Cattle manure + 30 kg N ha^{-1}	2.8	3.0	4.8
Mucuna + 30 kg N ha^{-1}	2.4	1.2	5.3
SED	1.1	1.2	1.5

Figure 2. A farmer participating in the trials explains a new technology to others during a visit to his farm.

The participating farmers observed better performance of crops using the organic resources and that the cost of production had been reduced and soil fertility improved. Soil erosion had also been reduced where the tree hedges were established. Milk production had also improved after feeding cattle with calliandra. Farmers also observed that soil pests were reduced with the organic resource use additions especially where tithonia was applied. In the 2002 LR season, 84% of the farmers who had started to work with these technologies continued with them and there were 25 additional new farmers examining the technologies during this season. In the 2002/2003 SR season, another 43 new farmers started working with these technologies. A total of 206 farmers evaluated these technologies during the 2002/2003 SR season.

Farmers who were already practicing the new technologies initially mentioned lack of sufficient biomass (tithonia, calliandra and leucaena) and finances to purchase manure and fertilizer in the required quantities. Over time, many farmers have established hedgerows along fences and on terraces. For example, by the 2001/2002 SR season 25, 40 and 45 farmers had started planting tithonia, calliandra and leucaena, respectively. They also learned how to manage manure more effectively, leading to lower nutrient losses. Some of the farmers have modified the technologies to better suit their own conditions in very innovative ways. For example, though the test crop was maize, some farmers started growing vegetables using tithonia. Other farmers' modifications include the different inputs, for example, tithonia + manure or tithonia + manure + fertilizers. Currently, a bag of tithonia is retailed at KSh 50, unlike two years earlier when it did not have an economic value within the community.

Figure 3. Farmers visiting a field trial in Chuka in Eastern Kenya.

Conclusion

Prunings of tithonia added to the soil, and tithonia prunings combined with half the recommended rate of inorganic fertilizer resulted in impressive yields over four cropping seasons and many farmers have adopted these new practices. Attempts to expose farmers to improved, locally-available technologies through field days has resulted in positive impacts within the project area, particularly where farmers are acutely aware of their farming constraints and are willing to test and adopt new solutions to their problems. Indeed, farmers are trying some of the technologies in their own farms and indication of improved crop yields in these farms has been observed, although the magnitude of yield improvement varies between locations. The largest challenge that is facing farmers in adoption of these cut-and-carry technologies is the labour required pruning the hedges and transferring the prunings to their fields.

References

Gachengo, C. 1996. Phosphorus Release and Availability on Addition of Organic Materials to Phosphorus Fixing Soils. M.Ph.Thesis, Moi University, Eldoret, Kenya.

Genstat. 1995. Genstat 5 Release 3.2 for Windows 95. Lawes Agricultural Trust, Rothamstead Experimental Station, UK.

Gitari, J.N., Dyck, E.A., Maina, P. 1997. Legume Screening for Potential Soil Improvement in Medium Altitude Areas of Mt. Kenya. Paper presented at the Legume Screening Network Workshop at Mombasa, 24-26 March 1997.

Government of Kenya. 2001. The 1999 Kenya National Census Results. Ministry of Planning and National Development. Nairobi, Kenya.

Jaetzold, R., and Schmidt, H. 1983. Farm Management Handbook of Kenya. Natural Conditions and Farm Information. Vol. 11/ C. East Kenya. Ministry of Agriculture. Nairobi, Kenya.

Micheni, A.N., Rees, D.J., Kariuki, Matiri, F.M., and Manyara, F.R. 1999. An Overview of the Farmer Participatory Regional Program of Regional Research Center, Embu Mandate Region. In: Micheni, A.N., Kariuki, Gethi and Rees, D.J. (Eds.). Participatory Rural Appraisals of the Farming Systems of Eastern Kenya. Kenya Agricultural Research Institute, Nairobi. pp 1-8

Mugendi, D.N., Nair, P.K.R., Mugwe, J.N., O'Neill, M.K., and Woomer, P.L. 1999. Calliandra and leucaena alley cropped with maize. Part 1: Soil fertility changes and maize production in the sub-humid highlands of Kenya. *Agroforestry Systems* 46: 39-50.

Murithi, F.M., Thijssen, H.J.C., Mugendi, D.N., Mwangi, J.N., O'Neil, M.K., and Nyaata, O.Z. 1994. Report of a Survey on Agroforestry Technologies Used for Fodder Production and Soil Fertility Improvement in Meru District, Kenya. National Agroforestry Regional Project, Regional Research Centre, Embu, Kenya.

Mutuo, P.K., Mukalama, J.P., and Agunda, J. 2000. On-farm testing of organic and inorganic phosphorous source on maize in Western Kenya. In: The Biology and Fertility of Tropical Soils: TSBF Report, Nairobi, Kenya. p 22.

Palm, C.A., Myers, R.J.K., and Nandwa, S.M. 1997. Organic-inorganic nutrient interactions in soil fertility replenishment. In: Buresh R.J., Sanchez, P.A., and Calhoun, F. (Eds.) Replenishing soil fertility in Africa. Soil Science Society of America Special Publication 51, Soil Science Society of America, Madison Wisconsin, USA. pp 193-218.

Smaling, E. 1993. Soil nutrient depletion in sub-Saharan Africa. In: Van Reuler, H., and Prins, W. (Eds.) The Role of Plant Nutrients for Sustainable Food Crop Production in Sub-Saharan Africa. VKP, Leidschendam, The Netherlands.

Vanlauwe, B., Diels, J., Aihou, K., Iwuafor, E.N.O., Lyasse, O., Sanginga, N. and Merckx, R. 2002. Direct interactions between N fertilizer and organic matter: Evidence from trials with ^{15}N-labelled fertilizer. In: Vanlauwe, B., Diels, J., Sanginga, N., and Merckx, R. (Eds.) Integrated Plant Nutrient Management in Sub-Saharan Africa: From Concept to Practice. CAB International Wallingford, Oxon, UK.

Wokabi, S.M. 1994. Quantified Land Evaluation for Maize Yield Gap Analysis at Three Sites in the Eastern Slopes of Mt. Kenya. International Institute for Aerospace Survey and Earth Science (ITC), The Netherlands.