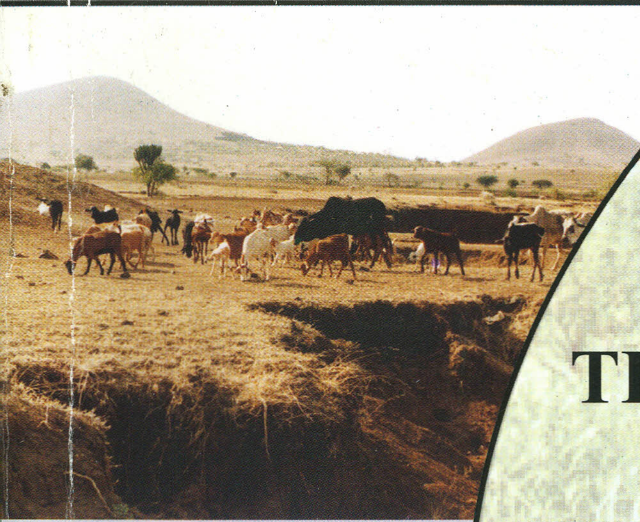


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COST-BENEFIT ANALYSIS OF FARMER-TESTED SOIL FERTILITY REPLENISHMENT TECHNOLOGIES IN KIREGE LOCATION, CHUKA DIVISION, EASTERN KENYA

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ABSTRACT

A study was conducted in Chuka Division, eastern Kenya to assess trends in adoption of soil fertility replenishment strategies. Eighty farmers adopted the soil fertility improvement technologies during the short rains season of 2001. During the subsequent 2 seasons, 163 and 206 farmers representing an increase of 99% and 150% above the initial adopters practiced the soil fertility improvement strategies. Technologies involving use of *Tithonia diversifolia* and *Calliandra calothrysus* alone or in combination with inorganic fertilizer were readily adopted due to the high yields obtained as well as being sources of fodder. During the 1st season of farmer follow-up, tithonia + ½ of inorganic fertilizer gave the highest net benefit of Kshs. 50133 ha^{-1} and was followed by the full rate inorganic fertilizer treatment with a net benefit of Kshs. 39568 ha^{-1}. Tithonia treatment had the highest benefit cost ratio (BCR) of 5.4. Sole manure treatment recorded the lowest net benefit (Kshs. 4601) and hence the lowest BCR of 0.9. However, during the 2nd season, manure plus ½ rate of recommended inorganic fertilizer recorded the highest net benefit (Kshs. 41567) with a BCR of 3.7. Farmer practice involving no input had the lowest BCR of 0.2 with a net sale of Kshs. 9853. Sole tithonia treatment had the highest BCR (4.6) indicating greater benefit per unit investment. Constraints to the adoption of the proposed soil fertility improvement strategies were identified as inadequate labour, poor yield observed from some of the technologies at the demonstration trial, inadequate organic and inorganic resources and laxity due to fear of failure.

The technologies were seen to increase food production at affordable cost at the same time improving the soil quality in the area. Therefore tackling of the mentioned limitations to adoption of soil fertility technologies need priority in any effort to encourage widespread adoption. Timing application of the organic resources needs to be ensured to check on conflicts between labour requirements with other farm or domestic chores.

INTRODUCTION

Food security in the East African Highlands is dependent upon the productivity of lands managed by smallholder farmers who face difficult challenges in maintaining the fertility of their soils. This has resulted in an imbalance between nutrient inputs, harvest removal and other losses and has reached critical proportions (Murage et al., 2000) because these farmers cannot afford frequent and reliable source of replenishing fertilizers.

Traditional farming systems in Africa relied on shifting cultivation practices to replenish soil fertility. According to Sanchez and Leakey (1997) and Vissoh et al. (1998), this traditional approach to soil fertility maintenance in Africa basically involved leaving land to fallow where land was not limiting. However, an increase in population has reduced the number of years farmers can allow land to fallow with consequent negative effects on soil nutrient status and soil productivity (Juo and Lal 1977). For this reason, land users are being encouraged to adopt improved soil fertility technologies, which are readily available, practical and of minimal cost. This paper looks at the several different approaches towards soil fertility replenishment that were introduced to Kirege Location farmers in 2000 and the benefits accrued from them.

The demonstration and on-farm studies were conducted in Meru South District (around Chuka town in Kirege Location, a predominantly maize growing zone (UM2-UM3). The area lies between latitudes and longitudes 00° 03' 47 N and 00° 27' 28" S, 37° 18' 24" E and 28° 19' 12" E respectively (Development Plan 1997-2001). The altitude is approximately 1500 m. The annual mean temperature is about 20°C. The soils are deep, well drained; weathered Humic Nitisols with moderate to high inherent fertility (Jaetzold and Schmidt 1983). Chuka Division has a population of about 53,517 persons with a density of 316 persons km^{-1} while Kirege Location, where the study was conducted, has a total population of 4,718 and a total density of 621 persons km^{-1} (Population and Housing Census 1999). The area is on the eastern slopes of Mt. Kenya with annual rainfall varying from 1200 to 1400 mm and is bimodal, falling in March to June, long rains (LR) and October to December, short rains (SR).

MATERIALS AND METHODS

A trial was initiated at Kirege primary school in 2000 to demonstrate the potential of selected soil fertility improvement technologies to improve soil fertility and crop yields. The selected treatments are shown in Table 1. Herbaceous legumes (*Mucuna pruriens* and *Crotalaria ochroleuca*) were identified as some of most promising legumes in the central highlands of Kenya (Embu) in terms of biomass production, nodulation and nitrogen fixation, ground cover, pests and diseases resistance (Gitari et al 1997). The legumes were intercropped with maize (sown 2 weeks after planting maize) and the resulting legume biomass (after maize was harvested) was incorporated into the soil during land preparation before the onset of the next season's rain.

Cattle manure is occasionally applied on farms for crop nutrients although in small quantities. The recommended rates of manure application in both central and western Kenya vary between 5 and 10 tons ha^{-1} of manure (on dry matter basis) supplying different quantities of N depending on the quality (KARI 1998; Kihanda 1998). Since the quality of manure varied from farm to farm, the rates adopted were aimed at supplying 60 kg N ha^{-1}. During the field days, farmers were advised on the diets to feed to cattle and bedding materials to add to cattle shed in order to increase manure quantity and quality.

Establishment of *Tithonia diversifolia* (from cuttings), *Calliandra calothrysus* and *Leucaena leucocephala* (from seedlings) to be used for biomass transfer took one year in those farms where these resources were not easily obtained along the roadside. The most preferred niches for planting these tree and shrub species was along farm hedges, on contour bunds and along the farm boundaries. Application rates for the organics at the demonstration trial were based on dry weight basis and able to supply 60 kg N ha^{-1}.

Inorganic fertilizer application was based on either the recommended rate (60 kg N) or at ½ of recommended rate (30 kg N ha^{-1}). The ½ rate was to mimic the sub-optimal rates currently applied by some farmers in the region. Absolute control involved no input representing those farmers on the lower end of resource endowment who applied no form of input into their farming systems.

Table1. Technologies experimented at Kirege demonstration site in Chuka Division

No	Treatment	Amount of N supplied (kg ha^{-1})	
		Organic	Inorganic
1	Mucuna	_	_
2	Crotalaria	_	_
3	Mucuna + 30 kg N	_	30
4	Crotalaria + 30 kg N	_	30
5	Cattle manure	60	_
6	Tithonia diversifolia	60	_
7	*Calliandra calothyrsus*	60	_
8	*Leucaena leucocephala*	60	_
9	Cattle manure +30 kg N	30	30
10	Tithonia + 30 kg N	30	30
11	Calliandra + 30 kg N	30	30
12	Leucaena + 30 kg N	30	30
13	Recommended rate of fertilizer	_	60
14	Control	_	_

Note:

- The recommended rate of inorganic fertilizer in the area is 60 kg N ha^{-1}
- All the treatments with inputs were designed to supply 60 kg ha^{-1} of N with the exception of the herbaceous legume treatments where the amount of N was determined by the amount of the biomass harvested and incorporated

Purposive sampling was used to select farmers willing to test the proposed technologies on their farms. Every plot was counted as an individual entity regardless of the number of plots on each farmer's farm. Farmers have different circumstances and preferences for soil fertility improvement hence the demonstration trial at Kirege took note of this by availing a wide option of choices for farmers to test. As such, each farmer chose one or more technologies depending on the farm size and interest. Regular farmer follow-up was then conducted to assess the extent of adoption, crop production as well as to evaluate the cost benefit of the adopted technologies. Economic analyses were done by use of partial budget, which was drawn from those practices that had limited impacts on the costs, and returns of an enterprise. Partial budgets help to assess the benefits and costs of a practice relative to not using the practice. It thus takes in to account only those changes in costs and returns that result directly from using a new practice (Upton 1987).

RESULTS AND DISCUSSION

Trends in adoption of soil fertility improvement technologies

Eighty farmers voluntarily accepted to pioneer the adoption of the proposed soil fertility improvement technologies at the inception of the project. A farmer follow-up was thus carried out during the subsequent seasons to assess the trends in the number of farmers willing to adopt the proposed soil fertility improvement technologies. During the subsequent cropping season (long rains 2002), there was however, an increase of about 99% of the number of farmers practicing the various soil fertility improvement technologies as compared to the preceding short rains (SR) 2001. In general, farmer demonstrated a wide range of soil fertility improvement combinations with most of them opting for the combinations of both organic and inorganic nutrient sources.

During the 3rd season (short rains (SR) 2002) after the initial adopters, 206 farmers representing an increase of about 150% of the initial adopters (SR 2001) were practicing the introduced soil fertility improvement technologies. During this season a number of modifications to the proposed technologies were observed with farmers using mixtures of different organic and inorganic nutrient sources. For example, farmers were observed combining tithonia with manure and fertilizer, mucuna with manure, crotolaria with mucuna instead of the ½ recommended rate of inorganic fertilizer as it was demonstrated at the Kirege trial. Reasons given for modifications of the technologies were curiosity by some farmers, lack of enough organic inputs to test and lack of finances to purchase fertilizers.

Maize yields obtained from on-farm trials

Table 2 indicates the maize grain yields on the farmers' fields over the period SR 2001 to LR 2002. Despite farmers testing a wider range of soil fertility improvement technologies, some farmers harvested their crop before drying (green maize) hence no agronomic data of the crop could be collected in those respective farms.

In the SR2001 (1st season), tithonia combined with ½ of the recommended rate of fertilizer gave the highest yields (3.7 tons ha^{-1}) followed closely by full-recommended rate of inorganic fertilizer (3.2 tons ha^{-1}). Cattle manure + ½ recommended rate of fertilizer (2.8 tons ha^{-1}) was the 3rd while mucuna and leucaena all combined with ½ recommended rate of fertilizer were 4th (2.4 tons ha^{-1}). Sole cattle manure had the lowest maize yields followed by the control. The possible reason for low yields in manure technology could be because of low quality materials used to prepare it and poor storage technique. From the demonstration site, Mucheru (2003) reported tithonia combined with inorganic fertilizer to have the highest yields (5.4 tons ha^{-1}) the same season when the on-farm yields were obtained. This was followed by cattle manure with ½ of the recommended rate of fertilizer with a maize yield of 4.9 tons ha^{-1} and sole tithonia and calliandra with ½ of the recommended rate of fertilizer at 4.3 tons ha^{-1} grain yield each. Lower yields at the on-farm trials indicated the diversity and the varied management practices at the farm level as compared to the demonstration site where conditions are nearly optimal.

In the LR 2002 (2nd season), a wider number of technologies were practiced. Crotalaria + fertilizer yielded 3.3 tons ha^{-1} of grain followed by manure + fertilizer ½ rate and full rate fertilizer with 3.0 tons ha^{-1} each.

Tithonia + fertilizer ½ rates (2.8 tons ha^{-1}) and sole tithonia (1.3 tons ha^{-1}) performed much lower than observed at the demonstration trial. Mucheru, (2003), reported high yields of 5.6 tons ha^{-1} and 6.5 tons ha^{-1} for tithonia + fertilizer ½ rates and sole tithonia respectively during the same period. The reason for the low yields was lack of adequate green biomass. To overcome the problem of limited availability, Mutuo et al (1998) suggested that farmers be encouraged to plant tithonia on their farms and boundaries for use as green manure. Control and mucuna gave the same maize yields of 0.4 tons ha^{-1}. The lower yields observed in mucuna treatment could be due to competition from the climbing mucuna plant that tended to choke the maize plants.

Farmers modified treatments (tithonia + manure, calliandra + leucaena, crotalaria + manure, mucuna + manure + fertilizer, and calliandra + manure) and the resultant yields were better than the control. The greatest yield from the modified technologies was that of mucuna + manure + fertilizer (4.3 tons ha^{-1}). This was followed by calliandra + leucaena treatment with a grain yield of 3.6 tons ha^{-1}.

Table 2: Average maize grain yields from the on-farm trial in Kirege Location, Chuka Division

Treatment	Grain weight (tons ha^{-1})		
	1st season	2nd season	Mean
Mucuna	nd	1.6	1.6
Crotalaria	nd	0.4	0.4
Mucuna + fertilizer	2.4	1.2	1.8
Crotalaria + fertilizer	nd	3.3	3.3
Cattle manure	0.3	2.1	1.2
Cattle manure + fertilizer	2.8	3	2.9
Tithonia	1.9	1.3	1.6
Tithonia + fertilizer	3.7	2.8	3.3
Calliandra + fertilizer	nd	1.2	1.2
Leucaena	nd	0.2	0.2
Leucaena + fertilizer	2.4	2.1	2.3
Recommended rate of fertilizer	3.2	3	3.1
Control	1.0	0.4	0.7
Tithonia + Manure	1.8	nd	1.8
Calliandra + leucaena	nd	3.6	3.6
Crotalaria + manure	nd	0:9	0.9
Mucuna + manure + fertilizer	nd	4.3	4.3
Half recommended rate of fertilizer	nd	2.5	2.5
Calliandra + manure	nd	0.6	0.6

nd = no data

Cost benefit analysis of the demonstrated technologies

One of the reasons that leads to the acceptance of any new technology by farmers is its profitability. The farmer will adopt the technology that will offer more net benefit. The farmer will only go for a technology with lesser net benefit if he/she considers other factors such as climate or social and cultural needs rather than the economic aspects. The information used for the cost benefit analysis was collected at specific time of each activity in the course of each season. These data were mainly from farmers and agro-input stockists.

Table 3 indicates the cost-benefit analysis (CBA) for the 1st season (October-December 2001) of on-farm experimentation. During this season tithonia + half fertilizer gave the highest net benefit, Ksh. 50133 and was followed by full rate inorganic fertilizer treatment with a net benefit of Kshs. 48568. Sole manure treatment recorded the lowest net benefit (Kshs. 4601). On the other hand, manure + half fertilizer, mucuna + half fertilizer, sole tithonia and leacaena + half fertilizer gave a net benefit of Kshs. 36953, 34301, 29589 and 29621 respectively.

For the same period tithonia treatment yielded the highest benefit cost ratio (BCR) of 5.4 and was followed by the tithonia + fertilizer treatment with a CBR of 4.4 while sole manure treatment had the lowest BCR of 0.9. Treatment involving integration of organics and with inorganics fertilizer also recorded appreciable BCR as indicated in Table 3.

Studies indicate that combination of organic and inorganic nutrient sources ensures greater synchrony between nutrient release and plant uptake and hence greater crop yields. This explains the observation that integrating tithonia + ½ rate of recommended fertilizer, as to manure + ½ rate of recommended fertilizer, mucuna + ½ rate of recommended fertilizer gave high net benefits. Although use of inorganic fertilizer resulted in the 2nd highest net benefit, the use of fertilizer may not be affordable especially for these smallholder farmers of Kirege. The lowest net benefit observed in manure treatment could be attributed to the low quality of manure used by farmers. As discussed earlier, farmers tended to use napier grass which has low nutrient contents as major feed for livestock. Application of such low quality manures results in low yields of net nutrient immobilization in the short-term but could contribute to long-term build-up of soil organic matter.

Inorganic fertilizers tend to be a high investment for small-scale farmers although it can result in high BCR. On the other hand, application of high quality organic resources such as tithonia can result to high returns to investment. Considering that farmers may not be able to afford the high costs of purchasing inorganic fertilizer then the use of organic fertilizers or combinations of organic and inorganic may form a major supplement or complement to replenishing nutrient deficiencies and ensuring high crop yields.

Table 4 indicates the CBA for the 2nd season (March-June 2002) of on-farm technology experimentation. During this period, a wider number of soil fertility improvement technologies were tested. Manure + ½ rate of recommended fertilizer recorded the highest net benefit (Kshs. 41567). This was followed by crotalaria + ½ rate of recommended fertilizer which recorded a net benefit of Kshs. 40434. The farmer practice yielded at least net benefit of Kshs. 9853. Application of organic resources resulted in greater benefits as compared to farmer practice.

Over the same period, tithonia treatment recorded the highest BCR (4.6) indicating greater benefit per unit investment. Despite the full rate of inorganic fertilizer treatment having fairly high net benefit (Kshs. 27717), the BCR was low (1.8) as compared to sole tithonia, mucuna, crotalaria and manure indicating that inorganic fertilizer is a capitalintensive investment that may not be sustainably managed by the farmers.

Farmers tend to practice soil fertility improvement technologies that ensure immediate high benefit at a minimal cost. Despite inorganic fertilizer having high net benefit, the cost of fertilizer is unaffordable to most smallholder farmers. On the other hand organic technologies have appreciable net benefit and involve less capital investment. As a result of fewer alternative sources of income, farmers in Kirege were ready to invest all their labor into testing some labor-intensive organic technologies. The situation implies that selection of technologies with highest BCR is subject to affordability of nutrient sources.

Table 3: Cost benefit analysis of growing maize under different soil fertility improvement technologies in Chuka Division during the 1st season of farmer adoption

Variables/Activities/inputs/Unit cost (Ksh)	1	2	3	4	5	6	7	8	9
Fixed cost (FC)	4000	4000	4000	4000	4000	4000	4000	4000	4000
Purchase of soil fertility inputs	0	9000	800	4500	4500	400	4500	4900	0
Storage dust @ Kshs. 20 per bag	422	710	66	532	822	400	532	622	222
Empty bags @ Kshs. 50	1050	1778	167	1334	2056	1000	1334	1556	556
Total variable cost (TVC)	1472	2488	1033	6366	7378	1800	6366	7078	778
Total cost (TC) =TVC+FC	5472	6488	5033	10366	11378	5800	10366	11078	4778
Maize grain (Tons ha^{-1})	1.9	3.2	0.3	2.4	3.7	1.8	2.4	2.8	1.0
Stover (Tons ha^{-1})	9.3	13	4.2	12	13.6	6.6	8.9	11.3	5.8
Grain sales @ Kshs. 1000 per 90 kg bag	21111	35556	3334	26667	41111	20000	26667	31111	11111
Stover (@ Kshs. 1500 Tons ha^{-1}) *	13950	19500	6300	18000	20400	9900	13350	16950	8700
Total sales	35061	55056	9634	44667	61511	29900	40017	48061	19811
Net Benefit	29589	48568	4601	34301	50133	24100	29651	36983	15033
Benefit/cost ratio (BCR)	5.4	7.5	0.9	3.3	4.4	4.2	2.9	3.3	3.2

*Stover was sold outside the farm

1= Tithonia 2= Fertilizer full rate 3= Manure 4= Mucuna + half rec 5= Tithonia + half rec 6= Tithonia + manure 7= Leucaena + half rec 8= Manure + half rec

9=Control

Table 4: Cost benefit analysis of growing maize under different soil fertility improvement technologies in Chuka Division during the 2nd season of farmer adoption

Variables/Activities/inputs/Unit cost (Ksh)	1	2	3	4	5	6	7	8	9	10	11	12	13
Fixed cost (FC)	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
Purchase of soil fertility inputs	0	0	9000	0	0	800	4500	4500	4500	4500	4500	4900	0
Storage dust @ Kshs. 20 per bag	288	390	666	88	44	466	266	732	622	266	466	666	88
Empty bags @ Kshs. 50	750	900	1700	250	150	1200	700	1850	1600	700	1200	1700	250
Total variable cost (TVC)	1038	1290	11366	338	194	2466	5466	7082	6722	5466	6166	7266	338
Total cost (TC) =TVC+FC	5038	5290	15366	4338	4194	6466	9466	11082	10722	9466	10166	11266	4338
Maize grain (Tons ha^{-1})	1.3	1.6	3	0.4	0.2	2.1	1.2	3.3	2.8	1.2	2.1	3	0.4
Stover (Tons ha^{-1})	9.4	6.7	6.5	8.9	4.6	6.1	7	9.9	8.1	6.3	10.2	13	6.5
Grain sales @ Kshs. 1000 per 90kg bag	14444	17778	33333	4444	2222	23333	13333	36666	31111	13333	23333	33333	4444
Stover (@ Kshs. 1500 Tons ha^{-1}) *	14100	10050	9750	13350	6900	9150	10500	14850	12150	9450	15300	19500	9750
Total sales	28544	27828	43083	17794	9122	32483	23833	51516	43261	22783	38633	52833	14194
Net Benefit	23506	22538	27717	13456	4928	26017	14367	40434	32539	13317	28467	41567	9856
Benefit/cost ratio (BCR)	4.7	4.3	1.8	3.1	1.2	4.0	1.5	3.6	3.0	1.4	2.8	3.7	0.2

NB: *Stover was sold outside the farm

1= Tithonia 2= Mucuna 3= Fertilizer full rate 4= Crotalaria 5= Leucaena 6= Manure 7= Mucuna + half rec 8= Crotalaria + half rec 9 = Tithonia + half rec 10= Calliandra + half rec 11= Leucaena + half rec 12= Manure + half rec 13= Control

CONCLUSION

The demonstration trial at Kirege Primary School has served as an eye opener into the adoption of improved soil fertility technologies that could help increase food production at affordable cost at the same time improving the soil quality. The willingness of some farmers to adopt some of the technologies being demonstrated is commended. The study revealed that the proposed soil fertility improvement technologies were able to increase food production and tended to be more profitable as compared to the farmer practice. Tackling of some of the limitations to the adoption of such soil fertility improvement technologies such as scarcity of organic resources need to be given priority in any effort to encourage widespread adoption. Considering the scarcity of land, proper identification of niches, such as farm boundaries, hedges and contour bunds, for the planting of the organic resources need to be identified where farmers can produce the organic resources. Further, proper timing for application of the organic resources needs to be ensured to check on conflicts between labour requirements with other farm or domestic chores.

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