Linking Soil Fertility and Improved Cropping Strategies to Development Interventions

Biophysical Survey

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Executive Summary

Soil fertility depletion in smallholder farms is the fundamental root cause of declining per capita food production in Africa and yet livelihoods of the rural people often depend heavily both upon soil fertility and their ability to maintain and utilize it. In areas around the highland districts of Lake Victoria, National poverty surveys consistently show them to be amongst the poorest in Kenya. Based on agro-climatic conditions, these districts should be a food surplus area. Instead, they are heavily dependent on food imports. Project R7962 aimed to improve the livelihoods of farmers in Western Kenya by expanding their options for resource and crop management and enhancing their capacity to make the relevant management decisions. Its main activities were 1) the establishment of a community-based credit scheme with the aim of enabling a category of poor farmers, identified in earlier studies in SW Kenya to be of intermediate ranking in the scale of poor to very poor, to access limiting inputs (fertilizers, new / improved crops), 2) the development and promotion of three pictorial decision support systems (DSSs) - for better land management, correcting nutrient deficiencies and striga weed control – amongst contact farmers and other development organisations working in western Kenya, and 3) making an improved basket of crops and varieties available to enable farmers to simultaneously improve their economic returns from farming and enhance the soil resource base.

This report mainly concerns a study of maize yield and soil fertility management among the SCOBICS farmers in western Kenya, conducted during late 2004 and early 2005. The study focused on the densely populated food-crop based land use system around Maseno in western Kenya. The objective of the study was to document and quantify: 1) farmers' practices of soil fertility maintenance, 2) the major factors which influence farmers' management decisions, 3) asses the scope for improving existing practices and introducing new ones on maize yield. A questionnaire was developed and administered among 233 SCOBICS households in the project area. The project operates in villages of Yala division (Siaya district), Emuhaya division (Vihiga district), Matayos division (Busia district) and Sigowet division in Kericho district.

The plot sizes varied between 0.31 and 0.97 acres in the whole project area. Almost half of the households owned at least one farming field plot. Kaplelartet field plots were significantly larger and Ebusiloli field plots were relatively smaller. About 81.3 % of the farm plots were owned by 86% of the interviewed farmers and 14% of the farm plots were leased by 14% of the interviewed farmers

SCOBICS farmers use a range of approaches to manage their soil fertility which includes the use of fertilizers and organics. Organics here includes application of animal manure, compost or crop residues, natural fallowing or biomass transfer, as improved fallows and legume (soyabean) cropping are listed separately. About 44% of the farm plots received inorganic fertilizer alone whereas 39% of the plots received both inorganic and organic manures. The most common types of the fertilizers were DAP (diammonium phosphate), CAN (calcium ammonia nitrate), Urea and TSP (triple supper phosphate). In 87% of cases, the fertilizers in question were obtained through the SCOBICS loans scheme. Maize yields realised on plots under inorganic and integrated management were significantly higher than those realised on plots where no inputs or organic technologies only were used. However, no significant difference was found either between no inputs and organic or between inorganic technologies only and integrated management. About 65% of the farms were infested with the striga

weed (*Striga heronnthica)* and the plots with striga incidence gave significantly lower yields than the farm plots without striga Soil fertility perception by farmers showed that striga also contributes significantly to farmers' perceptions: 83% of plots classed as low soil fertility status suffered striga in long rains 2004 compared to only 19% of plots classed as high soil fertility status. farmers appear to differentiate in their input resource allocation according to soil fertility. On poor quality plots they are more likely to cultivate without applying any inputs or using organic technologies only. In contrast, on either medium or good soil fertility status plots, they use predominantly inorganic fertilizers alone or combined with organics.

The multivariate analysis on to crop response to fertiliser amongst SCOBICS borrowers was used to identify factors causing low maize yield. Various specifications of this model were tested, also incorporating management variables such as late planting and the number of times the plot was weeded. The latter was rarely significant, whilst the late planting dummy was too closely correlated with the crop failure dummy for both to register as significant in the same equation. Crop failure was attributable either to purely natural factors or to management failure, most notably failure to plant early and thus points to an important problem in these farming systems. Similarly, a variable recording the incidence of striga in a plot was too closely correlated with the dummy for perceived low soil fertility status for both to register as significant in the same equation. For every kilogramme of nitrogen and/or phosphorus nutrients applied in the long rains 2004 season, maize yield rose by 8.5 kg/ha, *ceteris paribus*. This is a disappointingly low response rate. About 64% of the farm plots top-dressed their maize, but very few farm plots received the recommended total nitrogen to total phosphorous ratio. The value:cost ratio (VCR) realised by the surveyed farmers only ranged from 1.48 to 1.88 (i.e. well below 2), depending on the time at which the crops were valued. This supports the perception that fertiliser application on maize and beans is not a particularly profitable activity for farmers in the project areas under current circumstances.

The multiple regression also records significant area effects with Kaplartet (an area with large plots with less nutrient depletion), Nyamninia and Anyiko giving high maize yield as compared with Ebusiloli (an area with small plots with high nutrient depletion). However, the R^2 of 0.39 for the preferred regression specification means that plenty of yield variation remains unexplained by the model.

We conclude that, for farmers to invest in soils, most households (unless they have a reliable source of non-farm income) need to diversify into higher value crops than maize. However, the combination of small land holdings and existing maize deficits mean that they will only plant other crops if they can simultaneously raise their maize yields. They will only be able to do this if they can access a number of important support services on integrated soil fertility management. They need technical knowledge, on best cultural practices for the new crops and, critically, on how to manage their natural resource base, so as to increase their yields both of maize and of the new crops and for striga control. The existence of soil fertility gradient and perception within the smallholder farms must be considered when providing integrated soil fertility management options.

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Introduction

Soil fertility depletion in smallholder farms is the fundamental root cause of declining per capita food production in Africa (Sanchez and Palm, 1996) and yet livelihoods of the rural people often depend heavily both upon soil fertility and their ability to maintain and utilize it. Over the last decade, Kenya has experienced increasing absolute poverty, reaching 56% of the total population by 1999, with most of the poor residing in rural areas. The worst hit area is the western Kenya highlands. National poverty surveys consistently show the highland districts around Lake Victoria to be amongst the poorest in Kenya. Based on agro-climatic conditions, these districts should be a food surplus area. Instead, they are heavily dependent on food imports. At the root of the problem in these districts are high population densities and, therefore, small land holdings (ranging between 0.5 and 2.0 ha per household). Due to continuous cropping and little investment in soil fertility replenishment, the soils have become severely depleted. Neither phosphorus nor nitrogen levels are sufficient for even moderate agricultural performance. Western Kenya farmers invest very little capital on the purchase of farmer inputs or improved seeds and their farming system is relatively undiversified. Only about 20% of farmers use fertilizer on regular basis (Place et al., 200) and fertilizer use among those who apply it is below recommended application rates (Owour, 1999). This low investment appears to handicap soil fertility replenishment and leads to low productivity and is thus the basis of the household vicious poverty trap. Over 90% of farmers in western Kenya perceive that their soil quality has worsened since the time they acquired their land (Migot-Adholla et al., 1990) and among the 167 plots surveyed by the BASIS/CRSP project in Vihiga District in 2002, 57 % suffered soil quality degradation over the past dozen years.

An action research project funded by the UK Department for International Development's Natural Resource Systems (Research) Programme has been working within this context since 2001. Building on previous and ongoing research by many institutions, it is exploring the potential for coordinated provision of support services to enhance livelihoods through the promotion of integrated soil and crop management. The project encompasses all four areas of intervention highlighted above. It is producing and testing a range of decision support tools (DSSs) that present accumulated technical knowledge in farmer-friendly ways. The first DSS's to be produced have been about biophysical management of soil fertility. These stress the importance of combining organic and inorganic inputs, given their complementarity in enhancing soil fertility and the lower cost and risk involved when compared with relying on inorganics alone. Other DSS's developed cover the use of credit and aspects of produce marketing. Secondly, the project developed a community based credit scheme for agricultural inputs, known as SCOBICS. Thirdly, initial steps have been taken to link farmers in the pilot areas to new markets, especially in Kisumu. Finally, having identified crops and varieties with potential both at farm and market level - and which preferably contribute to both soil fertility and income-generating objectives – there is the challenge of making those seeds available to producers in adequate quantities.

This report concerns a study of soil fertility management practices on maize yield response among the SCOBIC farmers in Western Kenya. The study focused on the densely populated food-crop based land use system around Maseno in western Kenya. The objective of the study was to document and quantify: 1) farmers' practices of soil fertility maintenance, 2) the major factors which influence farmers' management decisions, 3) asses the scope for improving existing practices and introducing new ones. The report presents the finding from the formal final project survey.

Materials and Methods

Methodology

A questionnaire was developed and administered among 233 SCOBICS households in the project area during late 2004 and early 2005. The project operates in villages of Yala division (Siaya district), Emuhaya division (Vihiga district), Matayos division (Busia district) and Sigowet division in Kericho district. Typically a village contains between 80 and 140 households, a sublocation contains 240-320 households and a location contains 680-750 households or 4-5000 people (Noordin et al., 2001). A total of 454 plots were surveyed. Information on the proportion of farms under different land use in short rains 2003 and long rains 2004, plot sizes, farmers soil fertility perception, amount of inputs applied, striga incidences, farmers source of information on input application, maize yield were obtained from the plot and livestock type and ownership.

Statistical Methods

Chi-square test was used to test the independence of categorical variables. When the observed significance level is low (less than 0.05), the variables are not likely to be independent, i.e they are associated or correlated. Differences in the effect on continuous variables were assessed by analysis of variance and t-test using households in the different groupings (e.g. districts) as blocks. Relationships between continuous variables were examined graphically and by regression analysis. The results from the regression analysis are presented with the regression coefficient with standard errors in parenthesis and with stars denoting the significance of the F-test (*=P<0.1, **=P<0.05, and ***=P<0.001).

Results

Field size distribution and ownership

Farm plot sizes owned and leased by the household were assessed based on farmers' estimates. The plot sizes varied between 0.31 and 0.97 acres in the whole project area. Almost half of the households owned at least one farming field plot. The average farm size distribution by project area is shown in Table 1. Kaplelartet field plots were significantly larger and Ebusiloli field plots were relatively smaller. About 81.3 % of the farm plots were owned by 86% of the interviewed farmers and 14% of the farm plots were leased by 14% of the interviewed farmers (Table 2). There was no significant difference in maize yield between owned and leased plots and farmers applied the same amounts of nutrients (N+P) in longrains (LR) 2004 (Table 2).

Table 1: Field plot distribution by farm size classes (n=454)

		Percentage field plot distribution				
		Plots size in acres				
District	Project area	<0.25	0.25 – 5.0	0.5 -1.0	1.0 – 1.5	>1.5
Siaya	Tatro	2.4	29.3	43.1	18.7	6.4
	Nyamninia	9.1	27.3	36.4	27.3	-
	Gongo	9.6	34.2	41.1	9.6	5.5
Busia	Muyafwa	30.8	33.3	28.2	-	1.7
Vihiga	Ebukhaya	20.0	26.2	35.4	12.3	6.2
	Ebusiloli	32.9	47.1	16.5	2.4	1.2
Kericho	Kaplaratet	2.1	6.4	27.7	53.2	10.6

Table 2: Proportion of plots owned or leased and total amount of nutrients (N+P) applied in long rains 2004 (n=454)

	Percentage of farm plots in LR2004	Average maize yield in LR2004 (kg/ha)	Total nutrients applied (N+P) kg/ha
Owned plots	81.3	1310 (878)	69 (51)
Leased plots	18.7	1213 (675)	71 (46)

Standard deviation in the parenthesis

Farming cropping patterns

Farmers planted a wide range of crops and crop mixtures in their farm plots. However, maize alone and maize and beans intercrop formed an integral part of cropping strategies in both short rains 2003 and long rains 2004 (Table 3). During the short rainy season of 2003, 62% of the farm plots were under maize-legume intercrop, 10% were under maize monocrop, 8% under legume monocrop and 8 % were planted with other crops. During the long rainy season of 2004, 82% of the farm plots were predominantly planted with maize-legume intercrop and 16% were planted with maize monocrop. The common legumes intercropped with maize included beans, soybeans and groundnuts. Natural fallows and improved were common in the short rains of 2003 but not in the long rains of 2004. Improves fallow were common in Muyafwa and Tatro (Table 4). More farmers in Kapleratet planted maize monocrop in in short rains 2003 (31%) and in long rains 2004 (51%) compared to other project areas. However the legume maize intercrop was common in all season in all project areas and legume monocrop and horticultural crops was mostly planted in short rains.

Table 3: Proportion of farmland under different use and average plot size by region in short rains 2003 and long rains 2004 (n = 454)

Type of landuse	Land use in short rains 2003		Land use in long rain 2004	
	Percentage land use	Average land size in acres	Percentage land use	Average land size in acres
Maize monocrop	9.6	0.59 (0.40)	16.3	0.61 (0.36)
Legume monocrop	8.2	0.53 (0.56)	0.2	0.50 (-)
Maize legume intercrop	61.8	0.54 (0.45)	81.5	0.56 (0.47)
Improved fallow	2.0	0.31 (0.46)	-	-
Horticultural crops	1.6	0.37 (0.21)	-	-
Natural fallow	9.1	0.82 (0.50)	-	-
Other crops	7.8	0.60 (0.48)	2.0	0.86 (0.90)

Standard deviation in the parenthesis

Soil fertility management strategies

Farmers in the project area used different soil management strategies (Table 5). These included use of fertilizer, farmyard manure (FYM), compost and crop residues, fallowing, biomass transfer, inorganic fertilizers, soil conservation structures and crop rotation. About 39% of the farm plots received inorganic fertilizer alone whereas 36% of the plots received both inorganic fertilizer and organic manures. The most common types of fertilizers were: DAP (diammonium phosphate) which was used in 95% of the 374 plots, CAN (calcium ammonia nitrate) which was used by 67% of 249 plots, Urea was used by 31 % of 374 plots and TSP (triple supper phosphate) was used by 3% of 374 surveyed plots. All the fertilizers were obtained from the SCOBICS projects suggesting that these farmers would otherwise hardly have invested in soil fertility. About 12% of the farm plots planted their crops using organic manures (farmyard manure or compost) and on average 6% of the plots were planted without inorganic fertilizers or organic manures suggesting that there is further potential for SCOBICS. Fallowing was mainly practiced by 18% of farm plots in Muyafwa but not in other plots areas.

Table 4: Percentage landuse pattern used by farmers in different project areas (2003 = short rains, 2004 = long rains) (n = 454)

		Maize monocrop		Maize legume intercrop		Legume monocrop		Horticultural crops		Improved fallows		Natural fallow		Others	
District	Project area	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
Siaya	Tatro	10.7	25.2	57.9	74.0	13.2	-	1.7	-	1.7		9.1	-	5.8	0.8
	Nyamninia	-	-	65.0	100.0	15.0	-	-	-	-		10.0	-	10.0	-
	Gongo	4.1	4.1	69.7	90.4	11.0	-	2.7	-	-		9.6	-	2.7	5.5
Busia	Muyafwa	12.8	23.1	35.9	74.4	2.6	-	-	-	17.9		7.7	-	23.1	2.6
Vihiga	Ebukhaya	1.5	4.6	86.2	93.8	-	-	3.1	-	-		3.1	-	6.2	1.5
	Ebusiloli	7.1	4.7	76.5	94.1	8.2	1.2	1.2	-	-		-	-	7.1	-
Kericho	Kapleratet	31.9	51.1	19.1	44.7	4.3	-	-	-	-		34.0	-	10.6	4.3
	Average	**9.6**	**16.3**	**61.8**	**81.5**	**8.2**	**0.2**	**1.6**	**-**	**2.0**	**-**	**9.1**	**-**	**7.8**	**2.0**

Table 5: Average soil fertility management strategies for farm plots by region (n=454). Values are respective percentage of all fields on a farm

District	Project area	No inputs	Organic only	Fertilizer	Fertilizer + Organics	Improved fallows + fertilizer	Legume + fertilizer
Siaya	Tartro	11.4	17.1	36.6	27.6	0.8	6.5
	Nyamninia	-	18.2	40.9	27.3	-	13.6
	Gongo	2.7	2.7	46.6	39.7	-	8.2
Busia	Muyafwa	7.7	7.7	46.2	17.9	17.9	2.6
Vihiga	Ebukhaya	1.5	4.6	50.8	48.1	-	-
	Ebusiloli	4.7	17.6	27.1	44.7	-	5.9
Kericho	Kapleratet	6.4	12.8	57.4	23.4	-	-
	Average	**6.2**	**11.7**	**39.4**	**35.9**	**1.8**	**5.1**

*Legume monocrop of soybeans and /or groundnuts planted in SR2003
Organics = farmyard manure and compost

Soil fertility perception

Farmer's perception of the status of soil fertility of their fields was based on how well maize grew and the grain yield obtained. About 19% of the farm plots were classified as of good fertility status, 54% of medium fertility and 27% as poor (Table 6). Comparison between maize yield and soil fertility status showed that significant differences in yields between soil fertility perception groups. The distinction between farmers knowledge on soil fertility perception was reflected by the maize yield obtained in the different soil fertility groups.

Table 6: Farmers' perception on soil quality of their farm plots (n=454)

Soil fertility perception	Percentage of plots	Maize yield (kg/ha)	Nutrient (N+P) inputs (kg/ha)
Poor	26.7	889 (598)	76 (51)
Medium	54.0	1385 (818)	77 (48)
Good	19.4	1590 (1005)	50 (50)

Standard deviation in the parenthesis

There were some differences in between soil fertility management strategies and soil fertility perception suggesting that farmers applied soil fertility management strategies equally amongst the three soil fertility perception groups (Table 7). On poor quality plots they are more likely to cultivate without applying any inputs or using organic technologies only. In contrast, on either medium or good soil fertility status plots they use predominantly inorganic fertilizers alone or combined with organics although these differences are very strong. In relation to the amounts of nutrients applied per unit area large variations were observed and no significant differences between soil fertility status occurred (Table 6).

Table 7: Comparing farmers soil fertility perception with soil fertility management strategies (n=454)

Soil fertility perception	No inputs	Organic only	Fertilizer	Fertilizer + Organics	Improved fallows + fertilizer	Legume + fertilizer
Good	5.7	5.7	38.6	39.8	2.3	8.0
Medium	3.7	6.5	43.7	39.6	1.6	4.9
Poor	11.6	26.4	31.4	25.6	1.7	3.3

Striga incidence

About 65% of the farms were infested with the striga weed (*Striga heronnthica)* and the plots with striga incidence gave significantly lower yields than the farm plots without striga (Table 8). Farm plots perceived to be poor were linked with high striga incidences (90%) as compared to farm plots of good soil fertility status. However, soil fertility management strategy used in different fields was not influenced by striga incidences (Table 9).

Table 8: Striga incidence across regions (n=454)

Striga incidence	Percentage of the plots	Maize yield (kg/ha)
With striga	64.8	1190 (791)
Without striga	35.2	1479 (908)

Standard deviation in the parenthesis

Table 9: Comparing striga incidences with soil fertility management strategies (n=454)

	No inputs	Organic only	Fertilizer	Fertilizer + Organics	Improved fallows + fertilizer	Legume + fertilizer
No striga	6.5	13.9	39.5	34.0	0.7	5.4
With striga	6.2	11.7	39.4	35.9	3.8	4.4

Maize yield by different soil management strategies

Farmers grew a wide range of crops in pure monocrop and in mixtures in their farm plots. However, maize was predominantly planted in all the farm plots in the long rains of 2004. Therefore, maize grown in pure monocrop or intercropped with legume intercrop was selected for analysis of maize yields in the long rains of 2004. There was no significant difference between maize monocrop and legume-maize intercrop. There was an overall significant difference in mean maize yield between various soil fertility management strategies (no inputs, organics, inorganic and combined organics and inorganic) as shown in Table 10. The average maize yield varied between 657 kg/ha for control and 1420 kg/ha with combined inorganic and organic fertilizers. At the same time, average maize grain yield in the farmer managed demonstration plots varied between 2159 Kg/ha and 5242 kg/ha depending on variety and farm site (Table 11). In the survey, Turkeys LSD multiple comparison test showed that maize yield from no inputs and organic alone were not significant differently different but were significantly different from inorganic alone and combined organic and inorganic (Table 10). Use of organics alone was significantly different from inorganic and combined organics and inorganic. There were no significant differences in maize yield between inorganic and combined organics and inorganic fertilizer treatments. Maize yields in the long rains of 2004 adjusted for planting of fallows or soybeans in SR 2003 gave a similar yield response pattern.

Table 10: Soil management strategies and associated maize yield in project area (n=454)

Soil fertility management strategy	Maize yield (kg/ha)	Adjusted* maize yield (kg/ha)
Control (no inputs)	658 (452)	748 (560)
Organics (FYM and compost)	951 (657)	928 (637)
Inorganic	1352 (896)	1420 (894)
Organics + Inorganic	1420 (819)	1334 (803)

*Maize yield in long rain adjusted for planting of fallows or soybeans in SR 2003 (n=454)
Standard deviation in parenthesis

Fertilizer application to different plots

The majority (93%) of farm plots received less than the recommended rate of 60 kg/ha of nitrogen as compared to 7% of the plot that received the recommended rate (Figure 1). Most of the nitrogen applied was from Diammonium phosphate (DAP), which was applied at maize planting. DAP provides only a third of the nitrogen requirement for maize production. About 37.4 % of farm plots used ammonium sulphate (CAN) for top-dressing whereas 17 % of farm plots used Ureas. Figure 3 shows that only a tiny minority of plots received twice as much nitrogen (kg) during topdressing as during basal dressing, which is the recommend ratio.

In contrast, the median application rate of phosphorous from inorganics and organics (animal manure) was almost exactly the recommended rate of 21 kg P/ha (Figure 2). Diammonium phosphate (DAP) was used by 79.7 % of farm plots and 3.7 % of plots used Triple super phosphate (TSP).

Putting the results for nitrogen and phosphorous together, Figure 4 shows that very few farm plots achieved the recommended ratio of total nitrogen to total phosphorous of three.

Figure 1: Average amount of nitrogen used by farmers on different plots (n=454)

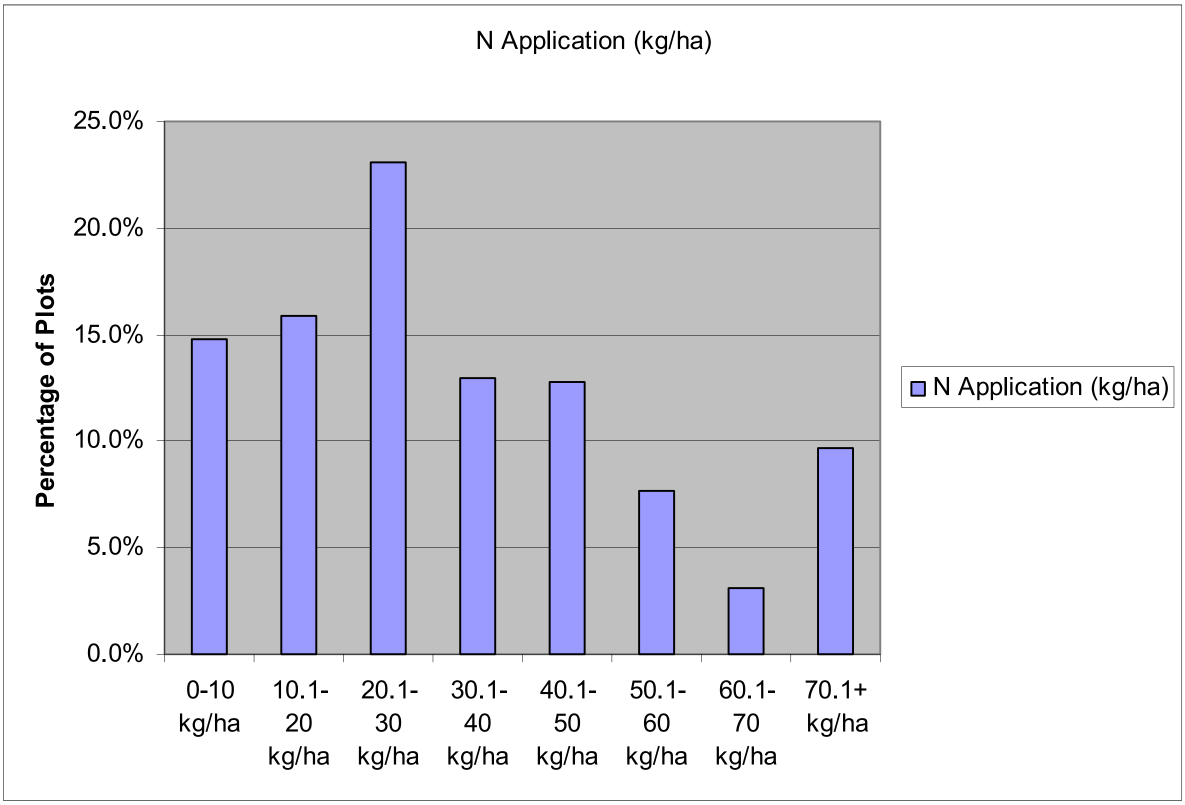


Figure 2: Average amount of phosphorus used by farmers on different plots (n=454)

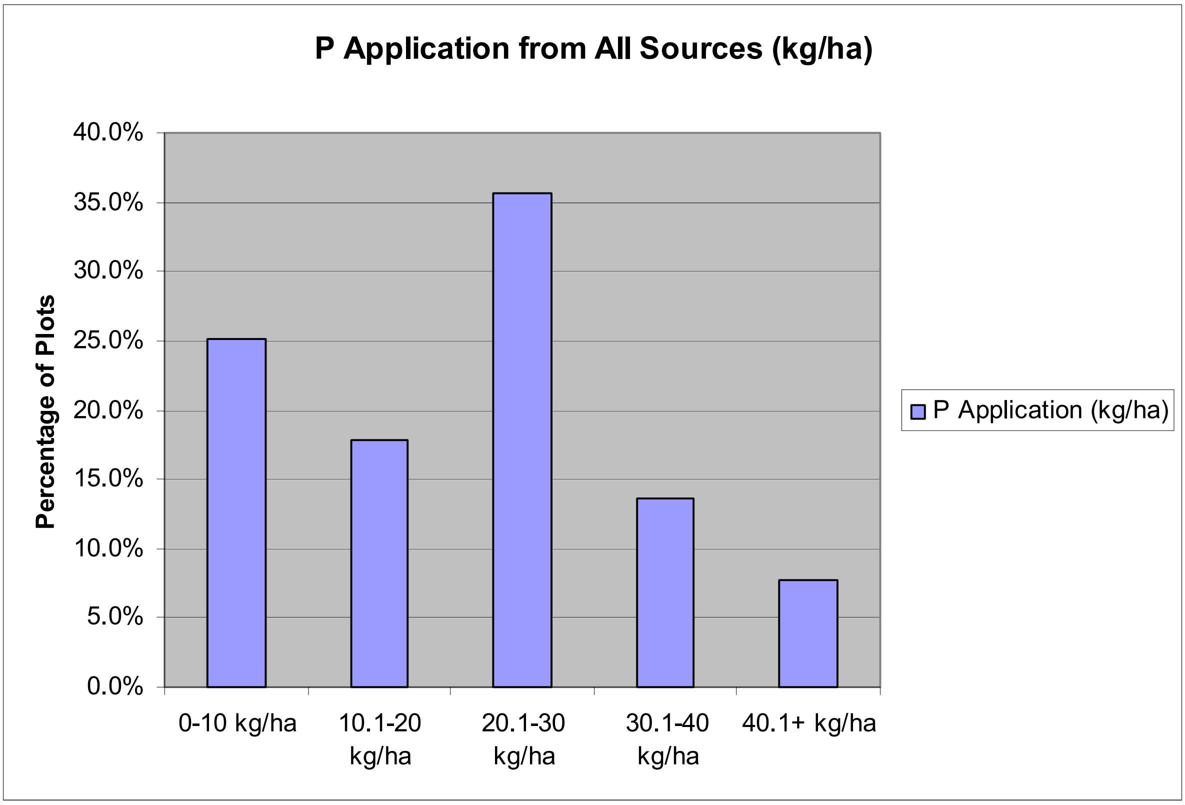


Figure 3: Ratio of nitrogen (kg) in topdressing to nitrogen (kg) in the basal dressing as used by farmers (n=454)

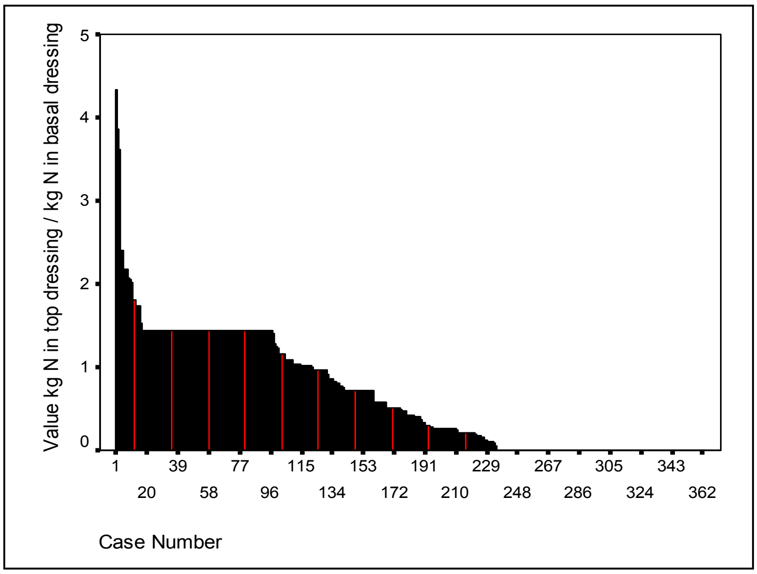
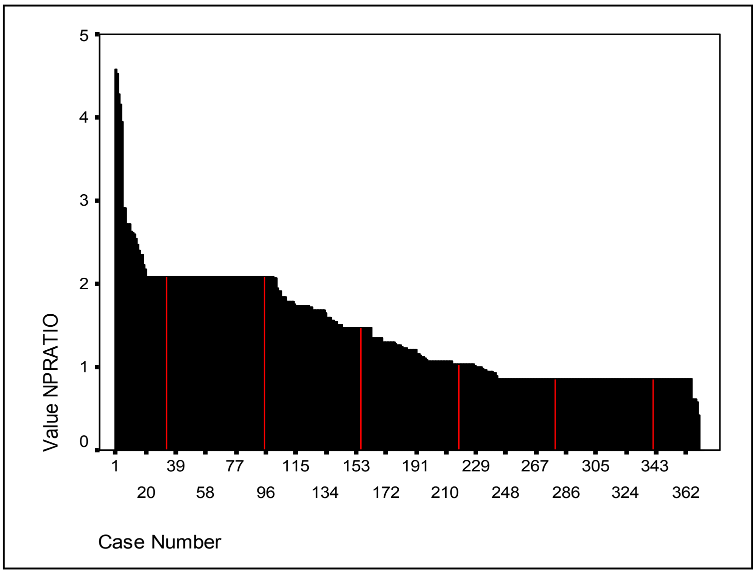


Figure 4: Total nitrogen to total phosphorus ratio (n=454)



Multivariate analysis of factors influencing maize yield

Table 11 presents a regression analysis of plot-level maize yield and Table 12 regression for beans in the long rains 2004 season. Various specifications of this model were tested, also incorporating management variables such as late planting and the number of times the plot was weeded. The latter was rarely significant, whilst the late planting dummy was too closely correlated with the crop failure dummy for both to register as significant in the same equation. (Crop failure was attributable either to purely natural factors or to management failure, most notably failure to plant early and thus points to an important problem in these farming systems). Similarly, a variable recording the incidence of striga in a plot was too closely correlated with the dummy for perceived low soil fertility status for both to register as significant in the same equation. Surprisingly, a seed type dummy (distinguishing hybrid seed from local) was never significant, whilst a variable capturing seed application rate was only significant in a minority of model specifications.

Table 11 and Table 12 reinforce the point made earlier that farmers try to achieve higher yields when they have less land available to them (although note that these tables use plot-level and not farm-level data). It also shows the significance of soil fertility gradients across plots, with plots of low soil fertility status recording yields of 341 kg/ha (171 kg/acre) for maize and 52 kg/ha for beans *less* than plots of medium or good fertility, *ceteris paribus*. The multiple regression also records significant area effects. Farm plots in Anyiko, Nyamninia and Kaplelartet had significantly higher maize yield as compared to other project areas, whereas plots in Ebusiloli had significantly lower maize yield. We attribute this to two things:

- better agronomic practices: farmers in Anyiko (members of Tatro farmers' organization) receive intensive monitoring input from organization committee members to ensure that they make good use of inputs obtained through the SCOBICS loan scheme, whilst defaults on SCOBICS loans in Nyamninia in previous years mean that only the most committed farmers were members of the scheme in 2004;
- levels of soil fertility depletion[1]: farmers in Kaplelartet often have sufficiently large land holdings to fallow a proportion of their land during the short rains season, whilst farms in Ebusiloli are the smallest in the whole sample and thus have been exploited most heavily over time, with insufficient investment in maintaining soil fertility.

Finally, we note that the R^2 of 0.38 for maize and R^2 of 0.12 for beans means that plenty of yield variation remains unexplained by the models.

[1] Note that assessments of soil fertility status were made by individual farmers and are not necessarily comparable across areas.

Table 11: Determinants of maize yield in long rains 2004 (n=454)

Variable	Coefficient	Significance
Constant	1191	.000
Total Nutrients (N+P) in Inorganic Fertiliser (kg/ha)	8.5	.000
Available Land Area (acres)	-284	.000
Dummy if Perceived Low Soil Fertility Status	-340	.000
Dummy if Crop Failure	-211	.004
Dummy if Anyiko, Nyamninia or Kaplelartet	620	.000
Dummy if Ebusiloli	-528	.000
F =	46	.000
R^2 =	0.38	

Table 12: Determinants of beans yield in long rains 2004

Variable	Coefficient	Significance
Constant	229	.000
Total Nutrients (N+P) in Inorganic Fertiliser (kg/ha)	1.02	.000
Available Land Area (acres)	-77	.000
Dummy if Perceived Low Soil Fertility Status	-52	.020
Dummy if Anyiko, Nyamninia or Kaplelartet	103	.000
F =	13	.000
R^2 =	0.12	

Turning to fertiliser application, the variable used in Table 11 was the total quantity of nitrogen and phosphorus nutrients supplied through inorganic fertiliser application. Table 11 shows that, for every kilogramme of nitrogen and/or phosphorus nutrients applied in the long rains 2004 season, maize yield rose by fractionally over 8.5 kg/ha for maize and 1.02 kg/ha for beans. This is a disappointingly low response rate.

Table 13 converts these physical response rates into an assessment of the economic profitability of fertiliser application, using the value:cost ratio (VCR). The VCR is the value of additional yield obtained from fertiliser use, divided by the cost of the fertiliser used. As a rule of thumb, “a ratio equal to two [is generally considered] as the minimum requirement for a farmer to adopt fertiliser and a ratio of three or four to be necessary when production or price risk is high” (Kelly, V.A. *et al.*, 2005, p14).

According to Table 13, the value:cost ratio realised by the surveyed farmers only ranged from 1.48 to 1.88 (i.e. well below 2), depending on the time at which the crops were valued. This supports the perception that emerged from participatory budgeting workshops, conducted during the project, that fertiliser application on maize and beans is not a particularly profitable activity for farmers in the project areas under current circumstances. However, what Table 13 does not capture is the benefits that are gained from fertiliser application if the resulting higher yields allow him or her to free up scarce land for planting to other crops. Fertiliser application may thus still be profitable as part of a broader strategy of diversification beyond maize.

Table 13: Value:Cost Ratio (VCR) for fertilizer application on maize and beans, long rains 2004

Maize Response per kg Nutrient	8.5	
Beans Response per kg Nutrient	1.02	
Weighted Price per kg Nutrient (KShs)[2]	103	
	After Harvest	Peak Price
Maize Price (KShs / kg)	15	18
Revenue per kg Nutrient	128	153
Beans Price (KShs / kg)	25	40
Revenue per kg Nutrient	25.3	40.8
Total Incremental Revenue (KShs)	153	194
VCR	1.48	1.88

Discussions

Why was maize yield response to soil fertility interventions so poor?

Plots were classed into four management categories – no inputs, organic only, inorganic only and integrated (organic + inorganic). In long rains 2004 the mean maize yields realised on plots under inorganic and integrated management were significantly higher than those realised on plots where no inputs or organic technologies only were used. However, no significant difference was found either between no inputs and organic or between inorganic technologies only and integrated management.

The majority of farmers who got fertilizer on credit applied the nutrients to maize. However, the maize yield obtained in using various soil management strategies were on average between 0.6 to 1.4 tons/ha and were far below the maize yield potential of 4 to 6 tons/ha obtained with proper agronomic practices in the region. Access to fertilizer through credit increased maize yield by 694 kg/ha when used alone and 762 kg/ha when inorganic fertilizer was combined with organics. Across the project areas, the median application rate of phosphorous from inorganics and organics (animal manure) was almost exactly the recommended rate of 21 kg P/ha. However, the rate of nitrogen

[2] This was calculated taking into account the quantities and prices of different types of fertiliser used, and the N and P composition of each.

application to the different plots was in most cases below the recommended amount of 60 kg N/ha (of which a third should be applied at planting and two thirds applied as topdressing four week weeks after planting). More than 93% of the farm plots received less nitrogen than the recommended. Moreover, this was applied mainly at planting, such that, even where farmers top-dressed their maize, only a minority of their total N input was applied at this stage. The imbalances in phosphorous and nitrogen application mean that the full potential of fertilizer for maize production was not realized and signifies also a waste of financial resources, as phosphorous fertilizer is not fully exploited. Nevertheless, we note that, when variables capturing the degree of imbalance in nutrient application were included in the regressions to explain maize yields (Table 11), they either came out as insignificant or had the wrong sign.

Comparison between the maize yield obtained from plots which applied inorganic fertilizer alone and those plots which combined organics and inorganics were similar. Those farmers who planted maize with farmyard manure, the manure quality was presumably poor because of poor preparation method and the animals are fed with poor quality feeds. This suggests that the poor quality manure did not contribute significantly to maize nutrition. Depending on the variety and application of the recommended rate of P and N, maize yields from farmer designed demonstration trials varied between 1.5 – 2.8 tons/ha on the striga infested farm, 4.1 – 6.2 tons/ha on the farm previously under *Crotalaria grahamiana* fallow and 2.2 to 6.7 tons/ha on the farm previously under natural fallow. This demonstrates the potential of yield production in the area and highlights that that farmers' returns from soil fertility management investments were often very low. Farmers appear to differentiate in their input resource allocation according to soil fertility. On poor quality plots they are more likely to cultivate without applying any inputs or using organic technologies only. In contrast, on either medium or good soil fertility status plots, they use predominantly inorganic fertilizers alone or combined with organics. In relation to the amounts of nutrients applied per unit area large variations were observed and no significant differences between soil fertility status occurred.

Apart from poor soils, insufficient N supply and striga problems various other factors contributed to low yield in the farmer's fields. Farmers' reported in 40% of the cases problems during the cropping season. These can be classified, both natural causes (12%) (eg drought stress risks, hailstones, poor health of the farmer) and mismanagement (27%) (eg late planting, insufficient weeding). The reduction in maize yield due to late planting was estimated by multiple regression to be on average about 180 kg/ha. The same multiple regression suggested, that, the increasing the frequency of weedings did not strongly (<100 kg/ha) improve maize yield. The large variation between maize yield and applied N+P (Figure 3) suggested that maize yield on farmers' fields is determined by many factors and not fertilizer alone. This suggests that it may not be possible to obtain reliable yield response estimates to fertilizer application from farmers' assessment because of the high degree of heterogeneity in soil fertility status, fertilizer application, striga incidence and agronomic practices. Thus it is difficult to compare yield across farms because of the high degree of non-experimental variables required to measure biophysical responses. Promotion and provision of understandable information coupled with on-farm experiments seems to be the best way of changing farmers' attitude in adopting good farming practices that will lead to high maize yield and high returns to farmers investment. Although farmers had access to decision support systems provided by the project, not all the recommendations were taken up and further evaluation and improvements are necessary.

Integrated soil fertility management

Soil fertility management by smallholder farmers seems a complex process that was only partly determined by recourses endowment. Although all the farmers that participated in this study obtained inputs from SCOBICS to implement various soil fertility improvement strategies their success varied greatly. The use of fertilizer and combinations of organic and inorganic manures resulted in higher yields compared to control and use of organics alone. The use and availability of farmyard manure on farmers will unlikely to be sufficient to overcome soil fertility problems as indicated by low maize yield obtained from organic manures and compost alone. Combination of farmyard manure and inorganic fertilizer did not improve the maize yield compared to inorganic fertilizer alone. However, the majority of farmers applied high amounts of phosphorous-based fertilizer but often-lower amounts of nitrogen based fertilizer than recommended rate of 60 kg N/ha applied in split, a third at planting and two third at maize knee height. Farmers also applied the fertilizers on larger area of land rather than targeting the available fertilizer on the optimum field size. Farmers should target fertilizer application to relatively fertile fields with no striga so that they can obtain high yields on relatively smaller field sizes and 'open up' (and thereby leaving) more land to grow high value crops. Indeed a multiple regression analysis suggested that farmers on smaller fields realized about 300 kg/ha more maize yield. Farmers should be encouraged to invest more on commercial enterprises on their farms through diversified agriculture. Better knowledge of farmers on the use of organic and inorganic fertilizers needs further attention. The majority of farmers used organics organic and inorganic fertilizer for soil fertility improvement without proper knowledge on guidelines and recommendation. Manure was either collected and applied daily or heaped in piles and spread in the field when dry. Limited availability and lack of knowledge among the farmers about preparing and use of compost and manure are some of the main limitations to their use. Likewise farmers applied inorganic fertilizers obtained from SCOBICS without prior knowledge of the plot size and proper agronomic practices that are required in order to maximize on maize yield.

It is also worth commenting upon the extremely limited use of fallows (either natural or "improved" tree fallows). The one exception to this is Muyafwa, which is a drier area than the others, such that other crops do less well in the short rains season. This is notable given the efforts made by ICRAF to promote improved fallows during the 1990s and their prominence within the UN Millennium Project report (UN Millennium Project, 2005) based in some part on experience in western Kenya. Feedback from field demonstrations conducted during the life of the project indicated that, where land holdings are very small, farmers are reluctant to put land under improved fallows, despite the benefits in terms of future yields. The dual purpose soyabeans promoted by the project (in collaboration with TSBF) appear to have more potential for adoption by farmers looking to enhance the fertility of their soil on very small holdings, because they generate nutrition and cash benefits, in addition to their contribution to soil fertility. These two observations reinforce our proposed strategy 'diversification beyond maize' as a viable entry point.

Linking local indigenous technical knowledge on soil fertility to technologies

Local innovation and knowledge on soil fertility perception offer points for linking indigenous technical knowledge (ITK) and scientific knowledge in community adoption of technologies. In the project site the linkage of farmers' distinction between farmers' indigenous technical knowledge on soil fertility and farmers practices was encouraged by the use of decision support systems on appropriate cropping patterns, for nutrient deficiency diagnosis and corrective measures and striga control. We recognized that farmers' knowledge alone without technical support on possible interventions obtained from various research organizations to counter farmers' constraints does not lead to action because of the farmers' economical situation and farmers' access to extension information. DSS can play an important role in augmenting their knowledge with the current farming practices. Farmers are now able to link soil fertility perception to soil fertility improvement and on diversification. Farmers are now diversifying beyond maize through the use of DSS for nutrient deficiency diagnosis and corrective measure, and DSS on and better land management for improved returns.

Linking striga control to fertilizer use and varieties/technologies

In western Kenya, striga is a serious and persistent problem for maize production especially for farmers whose farms are heavily infested. Striga infestation and yield reduction of the susceptible crops increases with declining soil fertility. Striga was common in nutrient poor soils and fields that are exhausted by continuous cropping. Various technologies and crop varieties exist and have been promoted for striga control and management in the project area. Studies have shown less striga infestation and increased crop yield with high levels of nitrogen application in the striga-infested field. But in this study the majority of farmers in the region who got fertilizers from SCOBICS applied less nitrogen-based fertilizers in their fields and this led to poor development of the maize crop. It is thus recognized that escaping striga impact by high N doses is not a feasible approach for most farmers in the region.

The use of organic manures and compost, which are also known to reduced striga infestation, did in this study not have any major impact on maize yield as compared to control plots clearly showing that the manure being used by farmers is of low quality and therefore less effective on striga. A number of crops (soybean and groundnuts) and improved fallows species (sesbania and desmodium) are widely know to act as false host to striga, and rotation of maize with such crop should be encouraged as one of the strategy for striga management especially during short rains when majority of farmers are planting less maize. Farmers with small fields can benefit by intercropping striga false host legumes with maize and planting striga resistant maize varieties. Development and promotion of integrated striga management strategies for use by smallholder farmers in the region seems to be the best way forward for reduction of striga control and management. Provision of decision support system (DSS) and capacity building of the farmers on striga control technologies and striga tolerant varieties is an important strategy to reduce striga and increase food productivity.

Fertilizer use profitability

We suggest four reasons why the VCRs reported in Table 13 are low:

- Most obviously, the price of fertiliser is high in western Kenya. Moreover, the prices used for calculating the VCRs reported include the 20% interest charged on SCOBICS loans. (Without this interest charge, i.e. making the unrealistic assumption that farmers could obtain the inputs on a cash basis and ignoring the opportunity cost of their capital, the VCR under the peak price option rises to 2.26);
- As mentioned earlier, the need for continual applications of phosphorus because of the nature of soils within the project areas adds to cost – and hence reduces VCRs – compared with a situation where mostly nitrogen needs to be supplied through inorganic fertiliser application;
- Related to this, the fertiliser variable was a simple aggregation of kilogrammes of nitrogen and phosphorus applied, with no reference to the balance of nutrients that farmers were applying.. Whilst a majority of farmers applied phosphorus at or above recommended levels, only a small proportion of farmers applied nitrogen at or above recommended levels. Thus, relatively speaking, too much phosphorus was applied relative to nitrogen, limiting the response to the phosphorus applications. On almost all plots (96%) where fertiliser was applied, DAP was applied as a basal fertiliser. This could often supply all the recommended phosphorus. However, in only 64% of cases was any top dressing (CAN or Urea) applied, meaning that many plots received insufficient nitrogen relative to phosphorus. This behaviour is partly the legacy of years of promotion of DAP by the Ministry of Agriculture in western Kenya. ICRAF also promoted primarily phosphorus fertilisers (rock phosphate and TSP) on the assumption that farmers could obtain the required nitrogen inputs from organic sources - something that our data suggests that they do not do. However, even Project R7962 only first included top dressing fertiliser (CAN and Urea) within the SCOBICS credit scheme in 2004, although draft decision support tools had highlighted the importance of top dressing fertiliser prior to this. Thus, the majority of farmers surveyed for the biophysical survey in 2004-05 had had relatively little exposure to messages about the importance of top dressing;
- Finally, although farmers were less likely to apply inorganic fertiliser on plots considered to have poor soil fertility, where they did apply fertiliser on such plots, they sometimes did so at higher rates than they used on plots with good soil fertility[3]. Given the problems of striga in most of these low soil fertility plots – and the resulting low yields achieved – this represents something of a wasteful application of fertiliser (reinforcing the earlier point about considering extension advice differentiated by plot type). If a separate regression is run to explain yields only on plots of medium or good soil fertility status, the maize response to nutrient application rises fractionally to 8.9 (still only enough to give a VCR of 1.95 in the high crop output price scenario).

[3] It is commonly thought that application of N helps to 'outgrow' striga damage.

Overcoming farmers production constraints

The need for P inputs

Insufficient P in smallholder farms can only be accomplished with replenishment with P fertilizer inputs. It appears the message of P deficiency is well known to the farmers but the need for N topdressing seems not well understood. Phosphorous replenishment must usually be accompanied by N replenishment in order to be effective, because most P-deficient soils also are deficient in N. Lack of topdressing leads to unbalanced application of N and P for maize production. This imbalance also means a waste of financial resources as P fertilizer is not fully exploited. More information on nitrogen use and better access of N fertilizer and high quality organic resources will be necessary to ensure that there is significant crop response to P input. Fallowing with N_2-fixing plants, use of high quality manure and fertilizer use improve nutrient cycling. Overcoming P deficiency usually tightens the nutrient cycles and reduces erosion. Therefore, integrated nutrient management, improving nutrient cycling and soil conservation at the farm levels as well as regional levels will be necessary.

Efficient use and targeting of fertilizer use

It is evident that farmers are combining different kinds of soil fertility management strategies according to their resources. However, information of efficient resources allocation of soil fertility management strategies to different soil fertility classes seems to be not well understood by farmers. Too much fertilizer is spent on poor and striga infested soils thus giving low returns to fertilizer investment by farmers. Inappropriate agronomic practices on field where fertilizer have been used have also led to low maize yield. This are factors within farmer control and more training is require to ensure change in attitude. The technical aspects of fertilizer use, highlights the need for appropriate extension messages and further improvement of the DSS and their dissemination.

Provision of information and agricultural technologies

Provision of information and options of agricultural technologies should further be widely disseminated among partners and mechanisms to manage information should be put in place. The reason why different DSSs were not sufficiently taken up by farmers needs further investigation. However further training of various stakeholders and farmers is necessary to equip them with all necessary tools to effectively disseminate agricultural technologies and link with other partners through establishment of information contact points in the existing partner information resource centres, conduct field days and technology demonstrations.

Capacity building of individuals and institutions

Capacity building of individuals and institutions in management and utilization of natural resources need to be further strengthened. Empowering communities and individual farmers to experiment with and fine-tune suitable technology interventions is a prerequisite for sustainability of innovations.

Capacity building of farmers and other partners to train other farmers and scale-up the adoption of the agricultural technologies will be necessary to ensure continuity.

In conclusion, fertiliser application on maize and beans is at best a marginally profitable activity for farmers in the project areas under current circumstances, and this only if adopted as part of a broader strategy of diversification beyond maize. High fertiliser prices obviously reduce profitability of use, whilst the inherent soil characteristics of the area mean that more fertiliser is required to generate a crop response than in some other areas. It also has to be noted that soil fertility problems in the area are not only due to P and N deficiencies, e.g. some 20% of soils also suffer from potassium deficiency and it has been noted in other projects and experiments that there are soil degradation effects relating to other less well defined problems (soil structure, pH, etc). However, there are also improvements that could be made to on-farm fertiliser management, so as to raise the profitability of fertiliser use. These include achieving a better balance between phosphorus and nitrogen application through sufficient top dressing and concentrating fertiliser application on plots where crops are better able to respond (especially plots free of striga, unless the maize variety used is striga resistant). These insights should feature in future advice provided to farmers in the area.

Outlook

More work is needed particularly on the marketing front before the action research project can say that it has tested its hypothesis about the impact of coordinated service provision on small farm crop management, livelihoods and poverty. However, let's assume that - with access to remunerative markets plus the credit necessary to invest in the fertility of their soils and to obtain improved seeds - farmers are able *both* to increase their maize production *and* to sell other crops for cash. (We call this diversifying *beyond* maize, as opposed to *out of* maize). How might provision of the necessary coordinated set of services to poor farmers in western Kenya be ensured after the life of the project? A mechanism is needed to bring together output buyers, credit providers and seed suppliers (all from the private sector) with researchers and extension workers (mainly public sector) to support farmers in particular communities or sub-locations to diversify beyond maize. The COSOFAP consortium of organisations involved in development in western Kenya may be able to encourage the necessary coordination. Alternatively, district development planning processes may be the appropriate mechanism for encouraging such coordination. Our observation is that this is an issue that has yet to receive serious policy consideration. However, it could be central to assisting poor farmers in western Kenya to escape the maize-focused poverty trap in which they currently find themselves.

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QUESTIONNAIRE.

Biophysical Monitoring, Crop and Livestock Management Practices for LONG RAINS 2004

1. **Make a quick tour of the farm making observations**

2. **Sketch the map of the farm**

Name of enumerator ____________________

Date of interview ____________________

Farmer code ____________________

Name of HH head [ ]

Name of farmer	Village	Sub-location	District

On farm land use

a) **Indicate the size of your plots and the crops planted in each plot in the short and long rain seasons of year 2003 and 2004 respectively. What are your perceptions of the soil quality in each plot?**

Field No.	Size (Acres)	Owned or Leased?	Land use/cropping strategy (including fallow)		Perception of soil quality	Striga in LR 2004?	Order of planting in LR 2004
		1 = owned 2 = leased	Short rain 03	Long rain 04	1 = Good 2 = Medium 3 = Poor	1 = yes 2 = no	1 = first 2 = second etc.
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
Total							

Land use Codes

1=maize	8=millet	15=kales
2=beans	9=sorghum	16=tomatoes
3=maize+beans	10=improved fallow	17=fruits
4=groundnuts	11=natural fallow	18=simsim
5=soyabeans	12=sweetpotatoes	19=cowpea
6=maize+soyabeans	13=cassava	20=others
7=maize+groundnuts	14=onion	

Did you work on others' fields before planting your own? Yes / no

Did you have to delay planting for any other reasons? Yes / no If yes, please give details …………………..

b) Indicate which purchased inputs and organic manures you used during the 2004 long rain season and on which plots
(N.B. You may need to record more than one type of seed or fertilizer applied to a given plot. Here and in all subsequent tables, the field numbers used should be the same as in Table a)
Please also identify one "control" plot where maize was grown without fertilizer and indicate the seed quantity used at planting on this plot (if not already indicated under Purchased Inputs)

Field No.	**Purchased Seed**			**Inorganic Fertiliser**			**Organic manure used at planting**			**Identify Control Plot**
	Type	Qty (kg)	1 = Cash 2 = Credit 3 = farmers	Type	Qty (kg)	1 = Cash 2 = Credit	Type	Qty (kg)	Did you buy? 1 = Yes, 2 = No	(Seed qty used if retained seed)
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Codes

Note: Indicate in brackets for hybrid seed varieties e.g beans hybrid = (2), local = 2

Fertilizer
1 = DAP
2 = CAN
3 = Urea
4 = TSP
5 = Rock P

Seed
1 = maize
2 = beans
3= groundnuts
4= soyabeans
5 = collards
6 = Cal J tomatoes
7 = sweet potatoes
8 = sorghum
9 = millet
10 = cassava

Organic manures (wheel barrow, debe?)
1=compost
2= farm yard manure
3= biomass transfer
4= improved fallow
5= mulching (crop residues)
6=animal manure

c) **Please tell me about weeding practices and the yield that you harvested from your fields in the *long rains 2004*?**
(N.B. Here we want information on all fields where inputs from the credit scheme were used, plus the maize plot identified as a control in Table b)

Field No.	No. of times plot was weeded	Actual Harvested yield (specify units)	Weight of unit (kg)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Units: 90kg bag, 50kg bag, gorogoro, debe, etc shelled maize

Glossary for actual harvested yield

1 gorogoro = 2 kg
8 gorogoro = 1 debe
5 debe = 1 (90 kg) bag

(d) Where in your fields do you start carrying out land preparation and input application activities and give reasons why?

Where do you start cultivating **(Tick as appropriate)**			Reasons why the farmer does this
Good	*Medium*	*Poor*	
			-
			-
			-
			-
			-
			-

REASONS: 1=Reduce labor costs of using tithonia, compost manure, etc, 2= closer to homestead, 3 Insufficient input amounts (seeds fertilizer, etc), 4=poor soil fertility of fields, 5= Improve crop yields, 6= Limited land area, 7= to achieve better input combination(Organic and inorganic) 8= Due to water logging, 9= Fields had improved fallow, 10= No informed reason, 11=others (specify)

(e) How do you evaluate if the inputs used have improved your yields? (Tick appropriately)

Other/Control fields	Past experience	Comparison with the neighbors	Other (specify)

(f) Indicate the problems/challenges or reasons for the observed yield trends in your plots over the last 5-10 years. Tick as appropriate and give reasons

Plot classification	Increasing	Constant	Decreasing	Reasons
Good				
Medium				
Poor				

Reasons

1 = no striga weed problem
2 = striga weed problem
3 = high seed quality
4 = poor seed quality
5 = use of animal manure
6 = use of biomass transfer
7 = use of improved fallow
8 = good agronomic practices
9 = poor agronomic practices
10 = fertilizer use
11 = no fertilizer use

(g) Where did you obtain the information on the application rates for each of the indicated fields?

Field No.	Source of information
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Source of information: 1=KEFRI/ICRAF; 2=KARI-Kakamega; 3=Ministry of Agriculture; 4=Group; 5=Others

(h) Do you need more information on what type and how much to apply on each field? Yes/No (tick appropriately)

(i) Do you need more information on how to apply for each field? Yes/No (tick appropriately)

(j) Which alternative crops do you know, their fertilizer recommendations? And give reasons for and not for planting the alternative crop type?

	Alternative crop type	Have you ever planted (1=yes or 2=no)	Fertilizer Recommendation known? (1=Yes; 2=No)	Reasons for and not for planting the alternative crop
1	*Millet*			
2	*Sorghum*			
3	*Tomatoes*			
4	*Kales*			
5	*Cowpeas*			
6	*Groundnuts*			
7	*Soybean*			
8	*Bananas*			
9	*Sweet potato*			
10	*Simsim*			
11	*Indigenous vegetables*			
12	*Napier grass*			
13	*Onions*			
14	*Cassava*			
15	*Passion*			
16	*Tea*			
17	*Other (specify)*			

Reasons

1. **Home consumption**
2. **Income generation**
3. **Limited land area**
4. **No available seeds**
5. **Lack of enough knowledge**
6. **High prices of seeds**
7. **Low prices of products**
8. **Pest/birds incidences**
9. **Others (Specify)**

2. Farmers' opinion

Farmers' opinion on the interview on the biophysical monitoring, crop and livestock management practices?

………

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