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ORIGINAL PAPER

Profitability of agro-forestry based soil fertility management technologies: the case of small holder food production in Western Kenya

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Abstract Persistent food insecurity accompanied by low and declining farm household incomes are a common feature of many small holder maize and bean producers in western Kenya. This has been largely attributed to soil nutrient depletion, among other factors. One way of addressing soil fertility problems in many maize-based cropping systems is the use of agro-forestry based technologies. We carried out a survey in western Kenya (Vihiga and Siaya districts) aimed at analyzing the financial and social profitability of use of agroforestry based (improved tree fallows) and other soil fertility management technologies among smallholder farmers. The Policy Analysis Matrix (PAM) was used to determine the financial and social profitability of different production systems, which were categorized on the basis of the technology used to address soil fertility. Farm budgets were first prepared and in turn used to construct the PAMs for six production systems namely: maize–bean intercrop without any soil fertility management inputs; maize–bean intercrop with chemical fertilizers only; maize–bean intercrop with a combination of chemical fertilizers and improved fallows; maize–bean intercrop with improved fallows only; maize–bean intercrop with a combination of improved fallows and rock phosphate; and maize–bean intercrop with Farm Yard Manure (FYM) only. Results revealed that use of chemical fertilizers with improved fallows was the most profitable technology and thus the study recommended that farmers be encouraged to intensify the use of chemical fertilizers. To make chemical fertilizers more accessible to farmers, the study also recommended that good linkages be made between farmers and micro credit institutions so that small scale farmers are not actually biased against due to lack of collateral when credit is being advanced to clients.

Keywords Food insecurity · Soil nutrient depletion · Improved fallows · Financial profitability · Social profitability · Food production

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Introduction

Background information

Most countries in sub-Saharan Africa are faced with persistent food insecurity accompanied by low and declining farm incomes. This has been attributed to low and declining agricultural production and productivity (World Bank 1996). Agriculture, being the dominant sector in Kenya, plays a big role both as a source of food and for household income. Given that the population growth rate has been substantially higher than the growth rate in agriculture, both per-capita food production and incomes have persistently declined resulting in recurrent food crisis and worsening rural poverty (Republic of Kenya 2002). To meet food security needs of the population, agricultural productivity must grow at a rate that exceeds the population growth. Therefore, in Kenya the determination of strategies, which could steer agricultural and food productivity to higher and sustainable levels are major concerns in agricultural policy and programming.

Soil fertility depletion in smallholder farms is the fundamental biophysical root cause of declining per- capita food production in Africa (Sanchez and Jama 2000). No matter how effectively other constraints are remedied, per-capita food production in Africa will continue to decrease unless soil fertility depletion is effectively addressed. In Kenya for example, studies have shown that low and declining soil fertility due to soil erosion and continuous cropping is behind the current low food production, low land productivity, food insecurity and poverty among most of the rural households (Jama et al. 1999; Sanchez and Jama 2000). Farmers themselves have persistently expressed that low soil fertility is a major constraint to food crop production (Sanchez and Jama 2000).

With the deregulation of fertilizer prices and grain marketing in Kenya in the early 1990s, fertilizer use has been low with smallholder farmers being unable to apply the recommended levels. This was as a result of the drastic price increase resulting from both the withdrawal of fertilizer price subsidies by the government and the devaluation of the Kenyan shilling. In Kenya, fertilizer use patterns to address soil fertility are marked by high concentrations on major cash crops as opposed to food crops. This is partially because average returns to fertilizer use are higher in cash crops than in food crops.

The declining soil fertility has compelled researchers and international organizations interested in agriculture to focus on identifying alternative and/or supplementary strategies for improving soil fertility. Over the last 10 years, the International Center for Research in Agro- forestry (ICRAF) and the Tropical Soil Biology and Fertility institute (TSBF) have carried out research trials on alternative soil fertility replenishment technologies with farmer% in western Kenya. Technologies being actively and vigorously promoted to farmers in the region include; agro-forestry-based technologies (improved tree fallows), *Minjingu* rock phosphate and Farm Yard Manure (FYM). These technologies have been found to be both technically feasible and socially acceptable (Sanchez and Jama 2000; Jama et al. 1999).

Problem statement

In the 1970s and 1980s, expansion of food production especially maize in Kenya relied heavily on use of chemical fertilizers. This is the period when hybrid maize technology was introduced and was accompanied by dependence on chemical fertilizers as part of the recommendation package (Hassan et al. 1998). At that time smallholder farmers had every reason to adopt the hybrid maize and use chemical fertilizers because their prices were kept favorable through government subsidies and controls. Following liberalization of fertilizer prices and grain marketing in the 1990s, prices increased drastically. As a result, use of chemical fertilizers to address soil fertility problems decreased (Heisey and Mwangi 1995). This in turn resulted in decline in food production and productivity leading to chronic food insecurity (World Bank 1996). A lot of questions have then emerged on the economic sustainability of food production by sole and heavy reliance on chemical fertilizers to address soil fertility problems. Additionally, farm sizes have been decreasing due to population pressure inevitably resulting into continuous cropping and as a consequence, leading to soil nutrient depletion.

Due to the socio-economic profile of smallholder farmers, soil fertility research needs to address alternative sources of soil fertility management strategies that are not only costeffective but still competitive in terms of productivity and generation of farm income. Most studies done by ICRAF and other organizations have used pilot farmers to look at the financial attractiveness of these technologies using cost benefit analysis (Franzel 1999; Place et al. 2000; Kwesiga et al. 1999; Rommelse 2000). Other studies have also been done looked at both the potential for and factors affecting the adoption of some of these technologies.

This study sought to provide quantitative and empirical evidence of the financial and social profitability (hence the viability) of the above-mentioned emerging technologies for soil fertility enhancement using non-pilot farmers. Financial profitability refers to the difference between total revenues and total costs measured in observed market prices. This concept was used to show whether individual farmers have financial incentives to intensify the use of the soil fertility management technologies being studied. Social profitability on the other hand, refers to the difference between total revenues and total costs measured using efficient (social) prices. This concept was used as measure of whether resources in the region were being used efficiently to produce food under the technologies of interest.

Objectives

The overall objective of the study was to determine the profitability of both agro-forestry based and *Minjingu* Rock Phosphates as soil fertility enhancement technologies for smallholder food production.

The specific objectives were,

- To determine the financial profitability of food production under the use of improved fallow trees, *Minjingu* rock phosphate and farm yard mature as alternative soil nutrient replenishment technologies.
- To determine the social profitability of food production under the use of improved fallow trees, *Minjingu* rock phosphates and FYM as alternative soil nutrient replenishment technologies.

Literature review

Several studies both in and outside Kenya, have been carried out on the subject of soil nutrient depletion (Nekesa et al. 1999; Kamanga et al. 1999). Nekesa et al. (1999) did a study on the economics of improving household food security through targeting the nutrient depleted soils of western Kenya. They considered PREP-PAC, a soil fertility replenishment product specifically designed to ameliorate nutrient depleted "patches" in maize fields. Kamanga et al. (1999), looked at how intercropping perennial legumes purposely for addition of green manure to maize production in southern Malawi. They found out that use of *sesbania* realized the highest maize yields (2,937 kg per ha) followed by *tephrosia* (2,592 kg per ha) and then pigeon peas (2,109 kg per ha). Although at a glance, it is clear that productivity increased, it is unclear whether producing maize under such technologies was profitable. In another soil fertility study by Nyirongo et al. (1999) focusing on compost and igneous phosphate rock amendments in Malawi, it was noted that acid soils contributed to the problem of phosphorus deficiency. The study concluded that rock phosphate was potentially capable of offering an inexpensive source of phosphorus. Several studies have successfully made use of the Policy Analysis Matrix (PAM) developed by Monke and Pearson (1989) to determine the profitability of commodity production systems. For example, Adesina and Coulibaly (1998) used the Matrix to analyze the competitiveness of agro-forestry based soil fertility management technologies for maize production in Cameroon.

Data and methods

The Policy Analysis Matrix (PAM) method, a logical framework for policy analysis was developed in the late 80s and early 90s by Scott Pearson of the Food Research Institute, Stanford University, and explained in details in Monke and Pearson (1989). This framework was used to measure the financial and social profitability of food production under different soil fertility management technologies. Underlying this model (Table 1), is the assumption that prices reflect values or can be adjusted to do so (Gittinger 1982).

Table 1 A schematic presentation of the PAM

	Revenues	Costs		Profits
		Tradable	Domestic	
Private values	A	B	C	D
Social values	E	F	G	H
Divergences	I	J	K	L

Adapted from Monke and Pearson (1989)

Notes:

Private profits (D) = A – (B + C)

Social profits (H) = E – (F + G)

Output transfers (I) = A – E

Input transfers (J) = B – F

Factor transfers (K) = C – G

Net transfers (L) = D – H = I – (J + K)

Observed market prices were used for financial analysis. Since market prices do not always do a good job in reflecting social values due to market failures then shadow (efficient) prices were used for analyzing social profitability.

Besides analyzing the effects of market failures on private profitability, the PAM can also examine the relative social profitability or social optimality of alternative economic activities. Another advantage of the PAM is that, instead of requiring time series data of prices and marketed quantities, which are often difficult to obtain in the developing country setting, it can use data from representative farms. It also allows easy presentation and interpretation of the results to policy makers and other users. The main limitation of the PAM is its static nature (Kydd et al. 1997). This means that it does not incorporate the effects of changes in the important variables over time. For the current study, the above-mentioned shortcoming was overcome by conducting a sensitivity analysis to determine the effects on profitability that would be caused by changes in some key variables.

The first row (private values)

PAM basically consists of three rows and four columns. The first row gives revenues, tradable input costs, domestic factor costs and profits valued using market or private prices. The term ‘‘private'' refers to the observed prices of outputs and inputs. In the first row, the observed market prices are used to value outputs and inputs. These prices contain the effects of any distorting policies and market failures. In this study, the observed market prices were (i) prices for maize and beans in the local markets (ii) input prices for FYM, chemicals for spraying, mineral fertilizers (urea, DAP and rock phosphate), seeds for maize, beans and improved fallow trees, as obtained in the nearest market centre (iii) wage rates for labour inputs into activities such as land preparation, planting, weeding, chemical application, fertilizer application, harvesting and carrying out post harvesting activities.

The letter (A) represents private revenue. Private revenue is a product of private prices and quantities of output produced under a given production system. The letter (B) represents tradable input costs valued at market prices. Tradable inputs such as fertilizers are inputs traded in the world market. The domestic factor costs are represented by letter (C) and are products of observed market prices and quantities of domestic factors employed in the production system under consideration. Domestic factor costs include land, labour and capital. Private profits, also known as financial Profits are denoted by letter (D) and are given by private revenue (A) less private costs of tradable inputs and domestic factors (B + C). Private profits are a measure of the financial competitiveness of the production system. Positive private profits indicate that the production system is financially competitive and producers have incentives to engage in that production system. If private profitability is too low or negative, then use of the particular soil management technology to produce food or a high value crop is expected to decline since farmers would have little or no financial incentives to continue or increase production under that system.

This approach was used to estimate private profitability of maize and bean (food) production under different soil fertility management technologies in western Kenya. Six different food production systems were considered. Each production system comprised of a food crop and a specific soil fertility management technology (Table 2).

Private profits were compared for food production under the six fertility management options being practiced in western Kenya. In

Table 2 Crops and technology packages being studied

Crop	Technology package
1. Maize–bean intercrop	Non-use of external inputs
2. Maize–bean intercrop	Use of chemical fertilizers only
3. Maize–bean intercrop	Use of farm yard manure only
4. Maize–bean intercrop	Use of improved fallows only
5. Maize–bean intercrop	Use of improved fallows + chemical fertilizers
6. Maize–bean intercrop	Use of improved fallows + rock phosphate

Source: Authors' survey, 2002

western Kenya, maize is normally intercropped with beans and therefore maize–bean intercrop was treated as a production system.

The second row (social values)

The entries in the second row are based on "social" prices. "Social" prices of outputs and production factors are the efficient prices that ensure efficient or optimal utilization of resources. This row gives revenue (E), tradable input costs (F), domestic factor costs (G) and net profitability (H) all valued using social prices. The social prices for tradable outputs and inputs are given by world prices, which exclude distorting effects of government policies such as subsidies and taxes, and effects of market failure. Social prices of tradable outputs and inputs were estimated from the world market prices. For example, in the present case maize and fertilizer prices were estimated from the Cost Insurance and Freight (c.i.f.) import prices. Social profitability (H), the difference between revenues (E) and costs (F + G) is a measure of how efficient farmers' resources in the region were being utilized for food production under the different soil fertility management technologies. Financial profitability cannot be used to show whether resources are utilized efficiently because observed market prices are very often distorted. Distorted prices don't reflect scarcity values of resources and therefore cannot lead to optimal allocation of resources.

Positive social profitability implies that the production system is economically attractive and that on the whole, resources are being employed efficiently. Negative social profitability on the other hand implies that the production system in question is not economically attractive. Social profitability was used to show whether resources (land, labour and capital) at the disposal of farmers were being efficiently utilized to produce food using such technologies.

Estimation of social prices for output

The import parity price rather than the export parity price was considered as the most appropriate social price. This was because first, Kenya has been importing maize in the recent past and secondly, Kenya has adopted the policy of import substitution meaning that maize is produced primarily for domestic consumption. The domestic transportation and handling costs were added to the border prices (cost, insurance and freight) to arrive at a social price equivalent for maize at the study area.

According to Morris (1989), decisions based on production levels have a long run perspective, and therefore long term trend c.i.f. and free on board (f.o.b.) prices should be used in calculating import and export parity prices respectively. Long-term price trends prices also reduce the effects of short-term price fluctuations observed in marketing of agricultural produce. Since world prices vary from year to year, the current study estimated the long-term trend world prices by computing the average prices using the 1995–2001 world prices (Table 3).

World prices are usually quoted in foreign currency. An efficient exchange rate is used to convert the prices from foreign to domestic currency equivalent. One approach is to estimate and apply a shadow exchange rate. In 1993, the Kenya shilling exchange rate was allowed to float freely to encourage market allocation of foreign exchange and to promote efficient utilization of scarce resources. Since then, the government has continued to maintain a competitive and a market determined exchange rate policy. It was also noted that in the absence of controls in the foreign

Table 3 World market prices in US dollars per ton for DAP, urea and white maize

Year	DAP	Urea	White maize
1995	208.7	228.0	123.0
1996	219.6	220.5	165.0
1997	200.4	116.4	92.3
1998	198.1	130.2	102.0
1999	199.5	77.4	90.3
2000	150.1	90.0	96.0
2001	165.5	114.6	85.2

Source: FAO, Food outlook statistical supplement (2002)

exchange market, exchange rate moves with the supply and demand forces and thus the prevailing exchange rate was considered to be competitive and therefore used as the social exchange rate. For the current study, a twelve-month average exchange rate of 78.6 for the year 2001 as base year was adopted as the social exchange rate.

For maize, world market price equivalent was estimated and used as the social price. The observed domestic transportation and handling costs were added to the border prices of imported maize to obtain the social price equivalent to its import parity price (Appendix 1). The internal handling costs were costs at the port of Mombasa mainly related to related to off loading and storage before clearing and transportation. An average of such costs was got from the customs department. Transport costs were considered all the way from the port of Mombasa to the market (Luanda) where farmers commonly bought maize for domestic consumption.[1] The following formula was applied to derive its social price;

$$P_{\mathrm{m}} = (P_{\mathrm{cif}} * \mathrm{ER}) + \mathrm{IC} + \mathrm{TC}$$

Where;

P_{m} = the social price of maize;
P_{cif} = the cif (trend) price for maize at Mombassa;
ER = foreign exchange rate;
IC = internal handling costs;
TC = transportation costs from the port of Mombasa to western Kenya

[1] Farmers in western Kenya were found to be net buyers of food. They consumed almost all the maize produced and supplemented the same by buying from the market.

Since Kenya some times imports yellow maize, a factor of 1.1 was used to correct for quality differences between yellow maize (which Kenya imports sometimes) and white maize (which is normally grown in Kenya).

Estimation of social prices for tradable inputs

Production inputs were first classified into tradables, non-tradable inputs and domestic factors. Social prices were determined differently for these tradables, non-tradable production inputs and domestic factors. Social prices of tradable inputs (imported fertilizers—urea and DAP) were estimated using a similar procedure like that used for maize. Unlike the case for maize, whereby the transport costs considered were from the port of Mombassa, up to the central market in western. Kenya, for chemical fertilizers the transport costs were considered all the way up to the farm (past the central market). This is because fertilizers are used at farm level (Appendix 2). Similarly, the official exchange rate was assumed to represent the social exchange rate. The import parity price was used as the efficient price because Kenya is a net importer of inorganic fertilizers.

Estimation of social prices for non-tradable inputs

Concerning non-tradables, there is no particular method of arriving at their social prices. Non-tradable inputs contain both tradable and domestic factor components. One way of arriving at the social price equivalent of a non-tradable input is by adding subsidies and subtracting taxes from its private price (Morris 1989). In the current study, improved fallow seeds and FYM were considered to contain a tradable component and a capital component and to arrive at their social prices, a rule of thumb was employed. This rule of thumb presupposes that private market costs be decomposed evenly into one third labour, one third capital and one third tradable. The social price for beans was taken as the opportunity cost (cost of the next best alternative crop) which was maize while the social price for *Minjingu* Rock Phosphate was taken as the opportunity cost (cost of the next best alternative fertilizer) which was DAP (Table 5).

Estimation of social prices for domestic factors

The social prices for domestic factors (land, labor and capital) are represented by opportunity cost (Morris 1989). In principle the social value of land should be equal to its highest alternative production use (Gonzales et al. 1993). It could also be estimated from its rental value where a competitive market for leasing or renting land exists. The current study did not factor in the cost of land during both private and social valuation because it is a permanent asset and its inclusion over estimates the costs and under estimates the profits. For capital items, the social price was the opportunity cost of capital, which was estimated by the real interest of borrowing from lending institutions (Monke and Pearson 1989). The interest rate is the payment for use of capital. The social price of capital is the opportunity cost of money i.e. the marginal productivity of additional investment in the best alternative use (Gittinger 1982). The real interest rate is nominal interest rates (observed interest rate) less the rate of inflation in the country. The following formula was used to estimate the real interest rate;

$$\mathrm{Ir} = \{(1 + \mathrm{In})/(1 + f)\} - 1$$

Where,

Ir = real interest rate;
In = nominal interest rate;
f = inflation rate

The current study used 14.5% as the real interest rate for the 2001 base year (Table 4).

Table 4 Estimation of real interest rate on commercial bank loans and advances

Year	Nominal interest rate	Inflation rate	Real interest rate
1997	30.4	11.2	19.2
1998	27.1	6.6	20.5
1999	25.2	3.5	21.7
2000	19.6	6.2	13.4
2001	22.5	8.3	14.5

Source: Authors computations, 2002

In general, the shadow price for farm labour is simply the marginal value product, which is the marginal output of labour foregone elsewhere because of its use in the production activity under consideration (Monke and Pearson 1989). In a perfectly competitive economy, the shadow price of labour would be equal to the wage rate. Past studies have shown that agricultural labour market in Kenya is highly competitive, that is, the wage rate reflects supply and demand conditions (Place et al. 2000). As such, the current study retained the observed daily wage rate (Ksh 101) as the shadow price of labour.

Sensitivity analysis

As noted earlier on, PAM framework gives results that are static in nature. To overcome this shortcoming, a sensitivity analysis was carried out. This analysis provides a way of assessing the impact of changes in key assumptions on profitability. It is usually useful in any ordinary profitability analysis to have an idea of whether the economic optimum value of interest represents a relatively large positive balance between small costs and benefits. Additionally, it is good to know these economic optimum values represent a relatively small balance between very large costs and benefits. In a liberalized economy, the value and costs of the output and the inputs are most likely to fluctuate. The stability of economic optima values of interest were noted by observing the effects of varying output values and input costs up and down within a range of about 10%. The price of improved fallow seeds was increased by 10% and profitability level before and after the increase compared. Similarly, the prices of maize and beans were decreased by 10% and profitability before and after the decrease compared.

Study area

This study was carried out in western Kenya. This part of the country was chosen because of its high population, which has lead to continuous cropping. Additionally, these areas have experienced serious soil fertility problems (Jama et al. 1999). It is also in the same areas where the Tropical Soil

Table 5 Prices used for the valuation of outputs and inputs

	Private	Social
Output/inputs	Ksh/kg (1US$ = Ksh 78.6)	Ksh/kg (1US$ = Ksh 78.6)
Maize (average price)	10.00	15.10
Beans (average price)	20.00	10.00 (the price of maize)
Maize (highest price)	12.50	–
Beans (highest price)	35.60	–
Maize (lowest price)	8.40	–
Beans (lowest price)	18.06	–
DAP	28.00	28.10
Urea	24.00	24.00
Farm Yard Manure	25.00 per wheelbarrow	Was decomposed
Improved fallow seeds	100.00	Was decomposed
Rock phosphate	15.00	28.00 (the price of DAP)
Labour (daily wage)	101.00	101.00 (competitive market)

Source: Authors' survey and computations, 2002

Biology Fertility (TSBF) Institute and International Centre for Research in Agro forestry (ICRAF) scientists have been doing research and on-farm trials together with vigorously promoting the various technologies under consideration to non-pilot farmers.

The specific areas of study are located around Maseno town (0° 00' N 34° 35' E) and include adjacent portions of Siaya and Vihiga districts i.e. Yala and Emuhaya divisions. These represent humid parts of the food-crop based land use systems of western Kenya. The area has high agricultural potential (high rainfall and well structured soils) but the land is nutrient depleted. There are two cropping seasons, the long rains that run from March to July and the short rains, which run from August to November. The rainfall amounts range between 1,500 and 1,900 mm per annum, the altitude ranges between 1,250 and 1,600 m above sea level while the mean temperature is 21.0° C (Rommelse 2000).

Farm sizes vary from 0.5 to 2.0 ha with a median of 1.2 ha while main soil types are Ferrasols, Acrisols, and Nitisols. Population densities range from 300 to over 1,000 persons per square kilometer while main ethnic groups in Siaya and Vihiga districts are Luo and Luhyia respectively (Rommelse 2000). The main food crop in the study area is maize, which is usually intercropped with beans. Other common food crops include tomatoes, bananas, kales, cassava and sweet potato.

Data sources and sampling

The study used both primary and secondary data for maize, beans and soil fertility management technologies. The primary data that was collected using structured questionnaires was about output prices and quantities as well as prices and quantities of soil fertility management technologies such as improved fallow trees, chemical fertilizers and Minjingu rock phosphates. This primary data was obtained through interviewing randomly selected farmers. The secondary data was about exchange rates, nominal lending interest rates, inflation rates and f.o.b. prices for tradables (maize and fertilizers). This secondary data was collected from Food and Agricultural Organization (FAO) publications (food outlook and statistical abstracts), publications from the planning and farm management division of the Ministry of Agriculture and Rural Development (MoARD), statistical bulletin, annual reports and monthly economic reviews from the Central Bureau of Statistics/Central Bank of Kenya.

The sample for this study was drawn from Yala and Emuhaya administrative divisions of Siaya and Vihiga districts respectively. To scientifically arrive at the specific farmers to be interviewed, a two-stage sampling procedure was used. In the first stage, the abovementioned divisions were purposively chosen because that's where most of the ICRAF and TSBF sites are located. In the second stage, two lists of farmers for both divisions were obtained from the division officers. Both ICRAF and TSBF staff helped in ensuring that the lists comprised of farmer who had tried to use the agroforestry based technologies once. These two lists were combined together giving a sampling frame of 363 farmers. Numbers were allocated against each of the farmers comprising the sampling frame and to get the actual respondents, the numbers were picked from a box one at a time. From the sampling frame, a total of one hundred and twenty farmers (120) were selected, sixty (60) coming from each of the two administrative divisions.

Results and discussion

Farm budgets

Farm budgets were developed for the six different soil fertility replenishment technology packages. The wage paid for casual labour in western Kenya did not vary per activity or per season. The average daily wage was Ksh 101 and includes a meal approximated at Ksh 30. Table 5 shows both the private and the social prices used for the valuation of output and inputs. All costs and returns are presented on per hectare basis for one year (2 seasons).

The food production system (maize–bean intercrop) which recorded the highest total revenue (Ksh 20,936) was the use of a combination of chemical fertilizers alone followed by use of chemical fertilizers in combination with improved fallows whose total revenue was Ksh18,401 (Table 6). The production system that registered the highest total revenue similarly had the highest net private profits.

Financial profitability

PAMs for the different soil fertility management technologies were constructed. Values in the first row of the PAM, which gives the net private profitability, were computed using observed market prices. Financial profits, also known as net private profits are equal to the total revenue less total costs. Financial profitability shows the profitability of a production system, given the current technology, output values, and input costs. In regard to food production, the highest financial profits of Ksh 11,735 for use of a combination of chemical fertilizers alone (Table 7). Futher, the total costs were decomposed into both tradable inputs (in this case chemical fertilizers) and domestic factors.

Farm budget analysis showed all production systems for food production had positive private profits. Therefore, all the systems were all financially profitable at observed market prices. Since net private profitability is a direct measure of the incentives for farmers to produce a commodity under a given technology, the results of this study suggest that farmers in western Kenya have financial incentives to expand food production by use of all the technology packages that were considered. In general, technology packages that comprised of chemical fertilizers appeared to be more attractive financially to farmers relative to other soil fertility management options for the production of food.

Social profitability

Social profitability, which is equal to social revenue minus social costs, is a measure of how efficiently resources are utilized. Both output and

Table 6 Total revenue, costs and profits (Ksh/ha)

Technology	Farmers	Total revenue (average)	Total costs (average)	Profits
M/B + 0	10	15,226.00	8,200.50	7,025.50
M/B + F	23	20,936.20	9,201.33	11,734.87
M/B + F + IF	35	18,401.26	8,613.97	9,787.29
M/B + IF	17	13,099.00	9,102.00	3,997.00
M/B + IF + RP	23	14,870.00	9,213.50	5,656.50
M/B + FYM	12	16,990.00	8,600.00	8,390.00

Source: Authors computations, 2002

Notes: M/B = maize–bean intercrop; M/B + 0 = maize–bean intercrop with no external inputs; F = Chemical fertilizers; IF = Improved fallows; RP = Rock phosphate; FYM = Farm Yard Manure

Table 7 Financial profitability (Ksh/ha)

Technology	Total revenue	Tradable inputs	Domestic factors	Profits
M/B + 0	15,226.00	–	8,200.50	7,025.50
M/B + F	20,936.20	1,597.16	7,604.17	11,734.87
M/B + F + IF	18,401.26	931.34	7,682.63	9,787.29
M/B + IF	13,099.00	–	9,102.00	3,997.00
M/B + IF + RP	14,870.00	330.00	8,883.50	5,656.50
M/B + FYM	16,990.00	–	8,600.00	8,390.00

Source: Authors computations from the first row of the PAM model, 2002

Notes: M/B = maize–bean intercrop; M/B + 0 = maize–bean intercrop with no external inputs; F = Chemical fertilizers; IF = Improved fallows; RP = Rock Phosphate; FYM=Farm Yard Manure

inputs are valued at prices that reflect opportunity costs. The results are taken directly from the second row of the PAM. Social prices which were used for tradable inputs and output were, Ksh 20.10/kg, Ksh 28.10/kg and Ksh 15.10/kg for urea, DAP and maize respectively.

Results of social profitability analysis in regard to food production revealed that the most socially profitable system was use of a combination of chemical fertilizers with improved fallows (Ksh 8,131) followed by use of FYM manure only (Ksh 6,977). All the production systems had positive social profits meaning that all the systems utilized resources efficiently (Table 8).

Sensitivity analysis

The stability of economic optima values of interest were noted by observing the effects of varying output values and input costs up and down within a range of about 10%. Both the private and social parameters for the production of food (maize and beans) were subjected to sensitivity analysis. The cost of improved fallow seeds was increased by 10% and profitability levels before and after the increase compared. For ease of understanding the results for all the categories of sensitivity analyses are presented separately.

Increasing the cost of improved fallows by 10% (from Ksh 100 to Ksh 110) decreased the profits by Ksh 10 since the seed rate (spacing) was the same across different systems. Farmers were using one kilogram of improved fallow seeds per hectare. For the combination of improved fallows with chemical fertilizers, use of improved fallows alone and a combination of improved fallows with rock phosphate, profits decreased by 0.10%, 0.25% and 0.18% respectively (Table 9). This means that the cost of improved fallow seeds is insignificant in terms affecting profitability thus use of such seeds is not a risky venture.

Decreasing the prices of maize and beans by 10% is equivalent to decreasing maize price by one shilling and that of beans by two shillings. Re-computing profitability using Ksh 9 instead of Ksh 10/kg and Ksh 18 instead of Ksh 20/kg changed profits by 10% (Table 10). This gives an indication that an increase in the cost of production could impact on profitability by the same magnitude.

Table 8 Results of social profitability (Ksh/ha)

Production system	Revenue	Tradable inputs	Domestic factors	Profits
M/B + 0	10,926	301	5,609	5,016
M/B + F	11,969	732	4,799	6,438
M/B + IF + F	16,244	1,086	7,021	8,131
M/B + IF	11,000	580	7,789	2,631
M/B + IF + RP	12,210	1,001	6,161	5,048
M/B + FYM	13,100	701	5,422	6,977

Source: Authors computation from the second row of the PAM model, 2002

Notes: M/B = maize–bean intercrop; M/B + 0 = maize–bean intercrop with no external inputs; IF = Improved fallows; F = Chemical fertilizers; RP = Rock phosphate; FYM = Farm Yard Manure; M/B = maize–bean intercrop

Table 9 Comparison of initial profits with profits obtained after a 10% increase in the cost of improved fallows seeds (Ksh/ha)

Technology	Revenue	Initial costs	New costs	Initial profits	New profits	% Change
M/B + 0	15,226.00	8,200.50	8,200.50	7,025.50	7,025.50	0.00
M/B + F	20,936.20	9,201.33	9,201.33	11,734.87	11,734.87	0.00
M/B + F+IF	18,401.26	8,613.97	8,623.97	9,787.29	9,777.29	–0.10
M/B + IF	13,099.00	9,102.00	9,112.00	3,997.00	3,987.00	–0.25
M/B + IF+RP	14,870.00	9,213.50	9,223.50	5,656.50	5,646.50	–0.18
M/B + FYM	16,990.00	8,600.00	8,600.00	8,390.00	8,390.00	0.00

Source: Authors computations, 2002

Table 10 Comparison of initial profits with profits obtained after a 10% decrease in the price of beans and maize (Ksh/ha)

Initial profits	New profits	% Change
15,226.00	13,703.40	–10.00
20,936.20	18,842.58	–10.00
18,401.26	16,561.13	–10.00
13,099.00	11,789.10	–10.00
14,870.00	13,383.00	–10.00
16,990.00	15,291.00	–10.00

Source: Authors computations, 2002

Conclusions and recommendations

Use of chemical fertilizers alone was the most financially profitable technology (Ksh 11,735) while a combination of chemical fertilizers with improved fallows was the most socially profitable (Ksh 8,131) technology. Use of FYM gave the second highest social profits (Ksh 6,977). One clear observation from the production systems is that use of chemical fertilizers enhanced both financial profitability while use non-chemical fertilizers enhanced social profits.

Whereas chemical fertilizers are beyond the reach of small-scale farmers due to their high prices, chemical fertilizers inevitably remain to be the main solution to soil nutrient depletion. This is partially because it is normally in a form that enables quick release of nutrient into the soil unlike organic fertilizers. In a resource poor setting, like that of smallholder farmers, the faster or sooner the benefits from a technology are realized, the better so as to address their current food or financial needs. In this light, policy should focus on making fertilizers affordable or even accessible through credit.

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Appendices

Appendix 1 Estimation of import parity price in Ksh of Maize in Western Kenya, 2002

F.o.b. Gulf ports (Long term world price-six year average from 1996)	91.29
Yellow–white premium (10%)	9.13
Freight rate to E/Africa (US$/ton)	10.30
Insurance (1% of C and F)	1.12
c.i.f. Mombasa (US$/ton)	111.84
Exchange rate	78.56
Estimated c.i.f. Mombasa (Ksh/ton)	8,786.15
IDF fees (2.75% of Cand F) (Ksh/ton)	239.20
Stevedoring (Ksh/ton)	674.48
KPA shore handling (Ksh/ton)	408.65
Bagging (Ksh/ton)	317.40
Transport to warehouse (Ksh/ton)	245.19
Storage and handling charges (Ksh/ton)	98.08
Fumigation charges (Ksh/ton)	119.03
Agency fees (Ksh/ton)	81.73
Incidental charges (1% of C and F) (Ksh/ton)	86.98
Ports and customs overtime (Ksh/ton)	19.84
Trade levy (Ksh/ton)	11.11
Landed into store Mombasa (Ksh/ton)	11,087.84
Cost per 90 kg bag	997.90
Road haulage to Luanda market, western Kenya (Ksh/bag)	357.98
Import parity price; western Kenya (Ksh/90 kg bag)	1,355.88
Import parity price; western Kenya (Ksh/kg)	15.10

Source: Authors computations, 2002

Notes:

f.o.b = free on board

c.i.f. = cost, insurance and freight

IDF = import declaration form

KPA = Kenya ports authority

Appendix 2 Derivation of import parity prices in Ksh for chemical fertilizers at farm level in western Kenya, 2002

Fertilizer type	DAP[a]	Urea[b]
Long term world price (six year average: from 1996 to 2001)	188.85	124.85
Sea freight to E/Africa (US$/ton)	33.00	24.00
Insurance @ 1% of f.o.b	1.88	1.25
Cost c.i.f. Mombasa (US$/ton)	223.73	150.10
Exchange rate	78.56	78.56
Cost c.i.f. Mombasa (Ksh/ton)	17,576.23	11,791.74
IDF levy @ 2.75% of c.i.f price	483.35	324.27
LC @ 2%	351.52	235.83
KBS levy @ 0.2%	35.25	23.58
Stevedoring and bagging charges @ Ksh 1771/ton DAP and	1771.00	668.00
668/ton Urea Clearing and forwarding @Ksh6O/ton	60.00	60.00
Transport to warehouse @ Ksh 290/ton	290.00	290.00
Storage costs/ton for 2 months (warehouse)	96.00	96.00
Port to warehouse handling costs @Ksh116/ton	116.00	116.00
Warehouse handling @Ksh260/ton	260.00	260.00
Transit loss @ 0.5% c.i.f/ton	87.88	58.96
Cost of bags (rebagging)	25.00	25.00
Miscellaneous/incidental costs@0.5% c.i.f-	87.88	58.96
Total Mombasa ex-warehouse/ton	21,240.21	14,008.10
Total Mombasa ex-warehouse/ 50kg bag	1,062.00	700.40
Road transport from Mombasa to Luanda in western Kenya	170.00	170.00
Per 50kg bag Parity price equivalent at Luanda per bag	1,232.00	870.40
Retailing margin (10% per bag)	123.20	87.40
Social price at Luanda	1,355.20	957.40
Transport to the farm	50.00	50.00
Parity price equivalent at farm level/bag	1,405.20	1,007.40
Parity price equivalent at farm level/kg	28.10	20.10

[a] DAP is imported in bulk and bagged in Mombasa

[b] Urea is imported in 50 kg bags

Source: Authors computations, 2002

Key:

f.o.b = free on board;

c.i.f = cost, insurance and freight;

LC = letter of credit;

KBS = Kenya Bureau of Standards;

IDF = import declaration form

References

Adesina A, Coulibaly ON (1998) ''Policy and competitiveness of agro-forestry based technologies for maize-production in Cameroon'': An application of Policy Analysis Matrix. Agricult Econ 19:1–13

Franzel S (1999) Socioeconomic factors affecting the adoption potential of improved tree fallows in Africa. Agro Forest Syst 47:305–321

Gittinger JP (1982) Economic analysis of agricultural projects. The Johns Hopkins University Press, Baltimore and London

Gonzales LA, Kasryno F, Perez ND, Rosegrant MW (1993) Economic incentives and comparative advantage in indonesian food crop production. International Food Policy Research Institute, Washington, DC

Hassan RM, Murithi F, Kamau G (1998) Determinants of fertilizer use and the gap between farmers yields and potential yields in Kenya In: Hassan RM (ed) Maize technology development and transfer, a GIS application for research planning in Kenya. CABI International, pp 175–192

Heisey PA, Mwangi W (1995) Fertilizer use and maize production in sub-saharan Africa. International Maize and Wheat improvement (CIMMYT). CIMMYT, Mexico

Jama BA, Niang IA, Amadalo B, De wolf J, Rao MR, Buresh RJ (1999) The potential of improved fallows to improve and conserve the fertility of nutrient depleted soils of western Kenya In: Proceedings of the 6th Biennial KARI Scientific Conference (KARI) pp 133–144

Kamanga BCG, Kanysma-Phiri GY, Minae S (1999)Intercropping perennial legumes for green manure additions to maize in southern Malawi. Afr Crop Sci J 7(4):355–365

Kwesiga FR, Franzel S, Place F, Phiri D, Simwanza CP (1999) Sesbania sesban improved fallows in eastern Zambia. In: Jama B, Buresh RJ, Place FM (eds) Sesbania tree fallows on phosphorus sites: maize yield and financial benefits. Agron J 90:717–726

Kydd J, Pearce R, Michael S (1997) Economic analysis of commodity systems: extending the policy analysis matrix to account for environmental effects and transaction costs. Agricult Syst 55(2):323–345

Monke AE, Pearson RS (1989) The policy analysis matrix for agricultural development. Cornel University Press, Ithaca, USA

Morris ML (1989) Guideline on determining the comparative advantage through DRC (Domestic Resource Cost) Analysis. Working paper No. 89/10, CIMMYT Economic Program, Mexico.

Nekesa P, Maritim HK, Okalebo JR, Womer PL (1999) Economic analysis of maize–bean production using a soil fertility replenishment product (PREP-PAC) in Western Kenya. Afr Crop Sci J 7(4):585–590

Nyirongo CV, Mughogho SK, Kumwenda SD (1999) Soil Fertility studies with compost and igneous phosphate rock amendments in Malawi. Afr Crop Sci J 7(4):415–422

Place F, Wangila J, Rommelse R, de Wolf J (2000) Economics of Agro-forestry technologies in the pilot project area in Western Kenya. ICRAF, Nairobi, Kenya

Republic of Kenya (2002) Interim poverty Reduction strategy paper for the period 2002–2003. Government printer, Nairobi

Rommelse R (2000) Economic Assessment of Biomass Transfer and Improved fallow trials in Western Kenya. Natural Resource Problems, Priorities and Policies Programme Working Paper 2001-3. International Centre for Research in Agroforestry, Nairobi, Kenya

Sanchez PA, Jama BA (2000) Soil fertility replenishment takes off in East and Southern Africa. ICRAF, Nairobi, Kenya

World Bank (1996) African development indicators. World bank, Washington, DC