Economic Analysis of Non-Conventional Fertilizers in Vihiga District, Western Kenya

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Abstract

Most farmers in Vihiga district are faced with the problem of low income. Population pressure is high, land sizes are small and the cost of hired labour is high. With the onset of market liberalisation, prices of conventional fertilizers have been rising faster than farm produce prices. There are many available soil fertility technology options but their adoption is subject to farmers' perception of benefits and limitations to their use. The overall objective of this study was to carry out an economic analysis of some non-conventional fertilizer materials used to improve food production in Vihiga district. A random sample of 150 farmers was selected from three of the six divisions of Vihiga district. Primary and secondary data were used. Gross-margins and cost to benefit ratios were used as the main tools in data analysis. Evaluation of the use of the organic matter technologies on maize/ bean production indicated that there were significant profitability differences between them at 95 % confidence level. Among the organic matter technologies considered, use of agroforestry shrubs in food (maize and bean) production gave the highest profitability. Increasing availability of seeds of agroforestry shrubs to farmers can therefore improve food production in the study area.

Introduction

Vihiga is one of the eight districts of western province. It has an altitude range of between 1750 and 2000 meters above sea level. It is characterized by undulating hills and valleys with vast network of streams and brooks that are tributaries of rivers Esalwa and Yala. Its bimodal, reliable, adequate and well distributed rainfall of between 1800 and 2200 mm per annum peaks in April and June for long rains and September and November for short rains. Ninenty five percent (95%) of the District is in the Upper Midland Zone (UM1) while the rest (5%) is in the Lower Midland Zone (LM1).

The district's warm and humid climate supports growing of many crops. However, soils are of low fertility, limited water-holding capacity and are prone to erosion due to their sandy texture, high land use intensity and heavy rainstorms. Widespread N and P deficiencies in soils due to continuous cropping (Niang' *et al.*, 1996) and inability of smallholder farmers to invest on fertilizers to replace the lost nutrients (Okalebo *et al.*, 1996) has led to low agricultural productivity in the district. The high population densities of 1100 people or 294 households (of on average 8 persons) / km^2 has resulted in land subdivision into small units, further lowering agricultural productivity of the area. Vihiga was expected to have 80,000 households in the year 2001. The average land holding is 0.6 ha and this is considered to be below the FAO recommendation for subsistence food purposes of 1.4 ha / household (FAO, 1999).

The problem of persistently low agricultural productivity in Vihiga district has resulted in a vicious cycle of soil degradation and food insecurity. Crop yields have continued to decline despite the existence of a wealth of already developed technologies that farmers could use to improve soil fertility. In 1982 when the Ministry of Agriculture conducted fertilizer trials in various districts of western Kenya, maize yields in Vihiga increased from 3800 kg ha^{-1} (without addition of fertilizer) to 6100 kg ha^{-1} with addition of (60-60-0) NPK fertilizer. The highest maize yields of 14220 kg ha^{-1} with addition of 178 kg N and 104 kg P ha^{-1} was also recorded. This high yield increase realized in the 1980s contrasts greatly with 1990's report of maize yields of on average 122 kg ha^{-1}, (Aritho, 1994). This shows a drastic decline in land productivity in Vihiga over the years.

Adoption rates of chemical fertilizers in western Kenya are low despite farmers knowing the benefits to their use (Hoekstra and Gorbett, 1995). Use of commercial fertilizers on subsistence food crops such as maize and beans in the area has been restricted to only a few farms with high endowment of resources such as cattle and land (Shepherd and Soule, 1998). Fertilizer recommendations as given in the MoA Bulletin are infeasible in most districts in western Kenya (Okello, 1997). This is mainly due to increased prices after SAPs, unavailability of cash, or lack of access to appropriate fertilizer materials that can be reached easily and at the right time (Nandwa *et al.*, 1997). Research has shown that non-conventional fertilizers are major resources available to farmers to manage soil fertility. They are environmentally friendly and provide longer term beneficial effects to the soil than chemical fertilizers. Non-conventional fertilizers refer to soil fertility management technologies other than the exclusive use of chemical fertilizers. They include organic matter of plant and animal origin used alone or fortified with inorganic materials. Non-conventional fertilizers in this study also include Phosphate Rock (PR), a source of P that naturally occurs in some parts of Africa.

There is a high potential for using non-conventional fertilizers in Vihiga because farmers are keen on improving the fertility of their soils. They have a long history of using traditional soil fertility improvement strategies such as fallowing and farmyard manure in their fields. Nearly ten years of collaborative research by government institutions and Non Governmental Organizations (NGOs) in western Kenya has addressed soil fertility improvement using non-conventional fertilizers. The crop response trials with the most commonly used non-conventional fertilizers have produced technically good yield responses. It also comes out so clearly from research publications that technologies have been studied for potential yields but comparative economic analysis has not been part of it. Economically speaking, however, output (maize and bean yields) alone does not reflect much about efficiency of production. Research scientists in the past laid more emphasis on the ability of technologies to achieve high crop yield responses than on the performance of the technologies based on economic considerations. This explains why some technologies that appear superior in improving crop yields under research conditions are not always the most adopted in farmers' fields. This has resulted in problems of determining the superiority of the existing non-conventional fertilizer technologies based on efficiency of use of the productive resources. Health conscious consumer groups are also lobbying for the use of organic materials but the viability of the option has not been assessed economically.

Non-conventional fertilizers when used in the right amounts have as high yield responses as those of chemical fertilizers used at required levels. The overall objective in this study was to economically evaluate some of the commonly used non-conventional fertilizer materials, namely, agroforestry shrubs, farmyard and compost manure and *Tithonia diversifolia* on improved and sustained maize and bean production in the populous Vihiga district. The hypothesis that was held in this study was that there is a significant profitability difference in maize-bean intercrop when the selected organic matter technologies are used. This implies that farmers need to consider profitability of use of the technologies in adoption. The technologies have comparable yield responses but the cost of adoption vary from technology to technology resulting in profitability differences.

Methodology

The study was based on three out of the six divisions of Vihiga district, namely Sabatia, Emuhaya and Luanda. According to Vihiga District Development plan 1997-2001, Emuhaya has a total area of 75 km^2, of which 60 km^2 is arable land. It has a population estimate of 89,952 persons and 11,244 households, farm sizes of on average 0.4 ha and a population density of 1,199 persons km^{-2}. Sabatia has an area of 115 km^2 with 101 km^2 of arable land expected to be supporting 150,000 people. It has 21,428 households with average farm sizes of 0.5 ha. Luanda has a population estimate of 114,936 people and 14370 households in an area of 104 km^2, of which 68.5 km^2 is arable. Like the rest of the district, Luanda, Emuhaya and Sabatia divisions have generally good climate for production of most crops but soils are depleted of N and P.

Primary and secondary data was used in this study. Primary data was collected through administration of structured questionnaires in some purposively selected households. Secondary data was mainly from research institution and government publication such as agricultural annual reports. Information collected included those on operation costs of use of the selected technologies in maize and bean intercrop, input and output prices, application rates of the specified non-conventional fertilizers by farmers and the associated average maize and bean intercrop yields. The average output and input prices were obtained from time series data in the study area divisional Agriculture Offices. Operational costs considered included costs such as those of crop management (planting, pest control, harvesting, shelling and collecting, preparing, carrying and application of organic materials) and marketing of produce. The opportunity cost of second season maize and bean crop was considered as a cost in case of improved fallows because no crop was planted in the second rainy season as agroforestry shrubs were left growing in the crop field during the season. The value of labour used on various operations in the production was based on survey of farmers estimation, while the cost of land included the land rent in the area. Costs were arrived at after grants and subsidies on agricultural products have been excluded. The benefits included increased maize and bean yields and wood fuel (in case of agroforestry shrubs). Information on use levels of fortified or unfortified organic materials and associated crop yields were obtained from some selected farmers, who were known to enumerators employed in this study as using the organic matter technologies considered in this study on maize and bean intercrop. Interview of farmers who did not use fertilizer in subsistence food (maize and bean) production provided data that was used as control.

The population was divided into three sampling units represented by three selected divisions (Sabatia, Emuhaya, and Luanda). The selection was based on agro-ecological zones and prevalence of organic matter technologies under consideration. The three divisions provided the survey sites for the study. From the selected divisions, households that were known to the enumerators as using the selected organic matter technologies were selected randomly from each location. The exact number of farmers selected in each location depended on prevalence of organic matter technologies that the study focussed on in the location. At least two farms were selected from each sub-location and this study collected data from 20 sub-locations in which a total of 150 households were interviewed.

Data collection exercise was done between August and December 2000. Ten enumerators were appointed, trained for the enumeration exercise and provided with questionnaires. Single visit formal surveys that were conducted using structured questionnaires were orally administered to farmers with the help of the enumerators who knew and were conversant with the farmers' local language and customs. During the survey the enumerators made arrangements to meet the sample farmers in farmers' fields.

The economic analysis of the technologies involved the Net Present Value (NPV) or the net worth and Benefit- Cost Ratios (BCR). NPV is defined as the present worth of the benefits less the present cost of a project. In this study each of the four organic matter technologies is taken as a project. BCR is a discounted measure of project worth. It is given as the present worth of the benefit stream divided by present worth of the cost stream. The NPV and B/ C analyses were used in economic evaluation of non-conventional fertilizer technologies in this study to ensure that the residual effects of use of organic matter technologies are captured. Mathematically NPV is given as:

$$\sum_{t=1}^{t=n} (B_t - C_t)(1+i)^{-t}$$

B_t = benefits in year t,
C_t = cost in year t,
t =1,2,....n, time in years
n = year n/last year under consideration
i = interest/compounding rate, taken as the interest rate in commercial banks.

Results and Discussions

Evaluation of soil fertility technologies in terms of maize and bean yields

Farmers interviewed in this study fortified organic materials with half the recommended levels of inorganic materials mainly DAP and CAN. Very few farmers used Phosphate Rock (PR) due to its limited availability in retail shops in the area. Table 37.1 shows the three-year (1998-2000) average maize and bean yields among the farmers interviewed in Vihiga district when the specified soil fertility technologies are used. The yields considered in this study refer to averages obtained when maize and beans were intercropped. Control is taken as the current crop yields obtained in a maize-bean intercrop in the study area when no fertilizer is applied.

Table 37.1: Average yield responses to soil fertility management technologies

Soil Fertility Management Technology	Fertilizer use level/ Seed Rate	Maize Yield kg ha^{-1}	Bean Yield k g ha^{-1}
Zero fertilizers added (control)	-	970	100
Tithonia diversifolia alone	5 t ha^{-1}	1674	165
Fortified Farmyard manure	2.5 t ha^{-1}	2025	182
Fortified Compost manure	2.5 t ha^{-1}	2109	180
Use of *Tephrosia vogelii*	2.5 t ha^{-1}	2174	185.5
Fortified *Tithonia diversifolia*	2.5 t ha^{-1}	2270	193.7
Use of *Crotalaria grahamiana*	2.5 t ha^{-1}	2490	212.5
Inorganic fertilizer (DAP and CAN)	DAP 2.5 Bags CAN 2.5 bags 1 bag = 50 kg	2700	225

Table 37.1 shows that yields of both maize and beans were higher with application of conventional fertilizers than with non-conventional fertilizers. Using fortified organic materials however, also improves crop yields. Fortifying tithonia for example increased maize yields by 36% relative to tithonia applied on its own and 134% compared to maize produced under conditions of no fertilizer. Table 37.2 shows the % change in crop yields arising from the use of the specified soil fertility technologies in the study area compared to the control of no fertilizer use. Applying

organic materials results in substantial crop increases of between 72 and 157 %. Fortifying organic materials is thus recommended because of the low levels of N and P in organic materials. Table 37.2 indicates the % crop yields increases arising from use of fortified organic materials.

Table 37.2: Yield Increases with Use of Fortified Organic Materials in Vihiga District

Soil Fertility Management Technology	Percent (%) improvement in crop yield	
	Maize	Beans
Zero fertilizers added (control)	0	0
Use of *Tithonia diversifolia* alone	72	65
Use of fortified farmyard manure	109	82
Use of fortified Compost manure	117	80
Use of fortified *Tephrosia vogelii*	124	85.5
Use of fortified *Tithonia diversifolia*	134	93.7
Use of fortified *Crotalaria grahamiana*	157	112

Table 37.2 shows that *Crotalaria* is the best of the organic matter technologies in improving yields of both maize and beans in Vihiga by on average 157 and 112 % respectively. This means that based on crop yield responses, organic materials are the best alternatives to inorganic materials in crop production in Vihiga district. A single factor ANOVA carried out to make comparative yield analyses indicate significant maize and bean yield differences arising from the use of the organic matter technologies at 5% level.

Economic evaluation of soil fertility technologies in vihiga

Cost of labour form a major part of the total cost in the use of organic materials in western Kenya, particularly in Vihiga district (Kipsat, 2001). Table 37.3 gives a comparative analysis of the total variable and labour costs of using the reviewed technologies in maize and bean intercrop production in the study area. The table indicates that labour form more than half of the total variable cost of production when the organic matter technologies are used. This is because use of organic materials is labour intensive.

The figures in parentheses in Table 37.3 indicate the proportion that labour costs make of the total variable costs of using the specified technologies in maize/ bean production in Vihiga. The cost of labour forms over 60% of the total variable costs in all cases. Labour contributes less to total variable costs (60.74%) when inorganic fertilizers are used than it does in use of organic fertilizers, where it contributes between

65.71 and 74.76% of the total costs in maize and bean production. This is explained by the differences in labour requirements for using organic and inorganic materials in crop production.

Table 37.3: Costs associated with soil fertility technologies in Vihiga District

Soil Management Practice	Total costs (Kshs ha^{-1}) of Maize and Bean Inter-crop	Cost of labour (Kshs ha^{-1}) of Maize and Bean Inter-crop
Inorganic Fertilizer	47031.10	28565.00 (60.74 %)
Fortified Crotalaria	43126.00	28337.80 (65.71%)
Fortified *Tephrosia vogelii*	42304.55	27972.50 (66.12%)
Fortified *T. diversifolia*	46231.70	30861.10 (66.75%)
Fortified Compost Manure	44220.80	29897.50 (67.61%)
Fortified Farmyard Manure	42996.35	28897.50 (67.21%)
Unfortified *T. diversifolia*	44995.80	33639.10 (74.76%)
Zero fertilizer (control)	35560.70	26630.50 (74.88%)

In economics the goal or standard for return to labour and management should be an amount at least as great as the opportunity cost of owner's labour and management in a non-farm occupation. The minimum standard or goal for return to capital is that the rate of capital return should approximate the interest rate of borrowed capital. The above goals though desirable are not achievable in farmers' production conditions as seen in Vihiga district. The aim should therefore be that farmers select technologies that are more economically efficient than others in the use of resources. Table 37.4 shows the economic evaluation of organic matter technologies.

Table 37.4: Results of economic evaluation of organic matter technologies

Soil Fertility Management Technology	Net Present Value NPV ha^{-1} in (Ksh ha^{-1})	Benefit to Cost Ratio	Rank based on NPV
Fortified Crotalaria	33 568.20	1.27:1	1
Fortified Tephrosia	13745.90	1.13:1	2
Fortified Tithonia	11047.20	1.08:1	3
Fortified Compost Manure	6020	1.05:1	4
Fortified Farmyard Manure	4592.10	1.036:1	5
Tithonia alone	-2130	0.87:1	6
No fertilizer (control)	-11719	0.61:1	7

Table 37.4 indicates that the use of agroforestry shrubs (Crotalaria and Tephrosia) on maize and bean production gives the best profitability in relation to the other non-conventional fertilizers considered. Although

tithonia is associated with high crop yield, the net worth is lowered by the high labour demands that translate into high cost of using it. Fortified farmyard and compost manures have relatively low crop yields and high labour costs lowering the returns to their use. The NPV of using unfortified tithonia and production under conditions of no fertilizers are negative. This means that those farmers who produce under the two systems are incurring losses in maize and bean production and should be advised to find alternative use of the invested labour, land and capital. The two production systems result in very low BCR while the rest of the soil fertility management technologies under consideration have favourable (greater than one) BCR values. This means that apart from using tithonia, a farmer can make positive returns by using the rest of the Non-Conventional fertilizer technologies in maize bean production although the relative returns vary from technology to technology.

To test the null hypothesis that there are no significant profitability differences arising from the use of the four organic matter technologies on maize and bean production, a single factor ANOVA was carried out. The results indicate that there are significant profitability differences between the Non-Conventional fertilizers at 95 % confidence level and therefore agricultural extension agents should consider profitability differences in choice of technologies to promote in Vihiga district.

Conclusion and Recommendations

Resource limitations are a major hindrance to adoption of soil fertility improvement technologies in Vihiga district. The district is characterized by high cost of land, labour and capital. To improve food security in the district, policy makers should focus more on measures to improve the resource base of the resource poor farmers than on aspects of generating more technologies in the area.

Promotion of agroforestry can improve food production in the study area. From the survey, it was realized that farmers have a problem of accessing agroforestry shrubs' seeds to use in their fields. To promote agroforestry as a technology, therefore, involves providing agroforestry shrubs' seed to the farmers and teaching them on how to propagate and manage the plants for soil fertility improvement. The economic analysis of other soil fertility management technologies not covered in this study should be made and information availed to the farmers to enable them make informed decisions. The benefits of using organic materials can be improved by fortifying it with PR that is a cheaper source of P than inorganic P fertilizer. The availability of PR in retail shops should thus be improved. From the research, it was realized that farmers were aware of the benefits in the use of PR but complain of the material not being available.

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