

Ex-ante Economic Impact Assessment of Green manure Technology in Maize Production Systems in Tanzania

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Abstract
In maize-based farming systems, intercropping of maize with green manure have been increasingly been one of the strategies to revive the declining maize production caused by increasing pests' infestations and low soil fertility. This study analyzed the potential impacts of adoption of green manure technology on yield, cost, and profitability of maize production in the Eastern Zone of Tanzania. To assess the income and costs effects of maize production using green manure, a farm level budget was constructed from primary and secondary sets of data and information using a with-and-without framework of analysis. A partial budget was constructed to determine the incremental benefits from costs of adopting the green manure technology in managing noxious weeds such as Striga. Results showed that the adoption of green manure technology has a high potential to increase marketable yield, reduce costs and increase net profits. The partial budget analysis showed that green manure would give a net incremental benefit of Tsh. 478 654/acre compared to the chemical fertilizers used by farmers. These additional benefits were realized from increased marketable yields and savings from reduced chemical fertilizers and labour costs. Future research should strive to further develop and strategize dissemination channels to reach more of the smallholder population to increase their knowledge base on the alternative values of green manures.
Keywords: Green manure, ex-ante impact assessment, investment in technology, partial budgeting

1.0 Introduction

Soil productivity has declined in many areas of Sub-Saharan Africa (SSA) (FAO, 2001a). About 494 million hectares of land are affected by soil degradation and of this, 25% is highly degraded with a loss in the productive capacity. An additional 39% is moderately degraded and faces a deforestation threat if there is no replenishment of depleted resources and sustainable use in the future (Ayoub, 1998). Nitrogen is among the major nutrients limiting crop production (URT, 2000). Some parts of Tanzania there is a negative nitrogen balance valued at about

$27Kg^{-1}hayr^{-1}$ (URT, 2000). This decline has been attributed to many causes, for example, continuous cropping, cultivation of marginal areas, inadequate replenishment of nutrients (Kaizzi *et al.*, 2002). This has led to the decline in soil organic matter, the degradation in the soil structure and loss of other bio-physical soil processes and consequently, low soil fertility (Bekunda *et al.,* 1997).

According to Graene and Casee (1998), most sustainable method of soil fertility improvement is the integrated nutrient management approach. Chemical fertilizers are important soil fertility management inputs, however, organic inputs also serve as compliments in fertility management. Soil organic matter increases the efficiency of use of chemical fertilizers. In SSA, however, structural adjustment due to budgetary concerns has been responsible for the removal of inorganic fertilizer subsidies (FAO, 2001b). Without these subsidies, resource poor smallholder farmers have been unable to afford chemical fertilizer purchase and they are thus experiencing increasing negative nutrient imbalances at the farm level (Kaizzi *et al.,* 2002).

Farmers have also, often perceived chemical fertilizers as substitutes to additions of soil organic matter rather than as compliments (FAO, 2001a). This is not surprising in case where the use of chemical fertilizers is constrained by the lack of financial resources. According to Place and Dewees (1999) however, these are not substitutes because inorganic fertilizers are incapable of producing the benefits associated with organic inputs, such as increasing the water holding capacity of soils or buffering low pH soils. Kaizzi *et al.* (2002) agree that the improvement in the balance of N sources can be achieved through the combination of biological nitrogen fixation (BNF) and the use of inorganic nitrogen. However, combining chemical fertilizers and organic soil amendments has been shown to reduce the quantity (of either amendment) needed to supply the required levels of Nitrogen as opposed to the situation when each is used in isolation (Kimetu *et al*., 2004).

Incorporation of soil nitrogen enriching herbaceous legumes in isolation into the cropping system should be among the strategies of sustainable Nitrogen replenishment under small scale farming (Ali and Narciso, 1996; Charan, 2000; Rao and Mathuva, 2000; Marshall, 2002; Mbwaga *et al*., 2003; Cherr, 2004). Green manure cover crops (GMCCs)–fast-growing, typically leguminous plants with high biomass production can improve the productivity and sustainability of smallholder farming. Green manure species of interest in this study are Mucuna (*Mucuna puriens*), Canavalia (*Canavalia ensiformis*) and Marejea (*Crotalaria ochroleuca*). Any program that attempts to introduce a new set of technologies is often confronted with questions such as: how profitable is the technology? What are the impacts or benefits? What is its return on investment? Answers to these questions are needed by farmers (technology users) who desire information on field levels. This study will be undertaken to understand the economic potential of changing from continuous cropping system (maize after maize) to green manure intercropped with maize against noxious weeds (Striga). The results of this study will serve as a basis of recommending to farmers an effective strategy to manage Striga weeds in maize production system in Tanzania.

2.0 Literature review

The literature review presents background information on the analytical tools used in this study. It reviews empirical evidence and results of the partial budgeting tool of analysis from other authors in sections 2.1. The the determinants of technology acceptance are presented in section 2.2. Section 2.3 presents the framework of analysis for this study.

2.1 Economic Assessment of Soil Improvement Technologies

Input-output relationships must be appropriately defined and structured to be used when considering various alternatives (Harsh *et al*., 1981). This creates the need for basic budgeting techniques to organize inputs, outputs and price information. Enterprise budgeting therefore states the income, expenditure and resource utilization on a per unit basis of a productive activity of a farm. The partial budget examines the costs, income and resource requirements that change with a proposed adjustment. It is an enterprise budgeting tool, which enables comparisons between enterprises by generating gross margins of each enterprise (Harsh *et al*., 1981). Budgets form the basis of other types of analysis such as linear programming, cost-benefit analysis and the net present values. The cost-benefit analysis produces ratios that enable the comparison between costs and benefits within each enterprise, whilst the stream of costs and benefits can be discounted to produce the net present values (NPV's). According to Nyirenda *et al*., (2001), in order to consider the farmers' preference regarding when consumption should occur, the cost benefit analysis uses a discount factor to measure the stream of benefits given time. This particularly applies to the multi-year or multi-season enterprises. The partial budget can also be subjected to a sensitivity analysis to determine which key parameters affect enterprise performance.

Previous studies on the economics of integrated soil fertility management technologies have predominantly used the partial budgeting and Economic Rate of Return (ERR) analytical tools. For example, researcher managed trial in Kenya using tithonia biomass showed increased maize yields. Moreover, these yields were even higher where tithonia was supplemented with phosphorus inorganic fertilizer (Place *et al*., 2000). Using the partial budgeting technique, results show that returns to land and labour were US $ 863 ha^{-1} and US $ 3.98 $ man-days with the addition of 1.82 t ha^{-1} dry weight tithonia and 50 kg ha^{-1} of phosphorus.

Studies conducted in northern Honduras on the other hand found that the relative profitability of a *Mucuna pruriens* system was not solely dependent on the higher maize yields, labour costs and lower production risk but also on the seasonally high prices that favoured the second season maize crop (Place *et al*., 2000). Maize yields were reported to be twice as high and labour costs 17% lower, on average, owing to the weed suppression properties of mucuna. The yield losses associated with drought stress were also lower due to the moisture conservation characteristic of mulch in the mucuna system.

2.2 Determinants of Acceptance of Technologies

According to Babigumira (2001), labour availability is a key characteristic of farmers' decision in technology adoption. Thus labour demanding technologies may coincide with the seasonality of labour and in turn affect acceptance. Franzel (1999) reported that peak labour constraints might not have a negative effect on the adoption potential of improved fallows (IF). On the other hand, studies on farmers' perceptions confirm that delayed response to adoption of conservation practices could be attributed to the demanding and complex nature of such innovations, with some requiring more labour for planting, transporting, and incorporation (Place *et al*., 2000). The demand for labour also has direct implications for the adoption of biomass by family size (Place *et al*., 2000), with larger families more likely to adopt.

The perception of the soil fertility problem is a key determinant of the acceptance of improved fallows (Franzel 1999). If farmers' perceptions are that soil fertility is not a problem, labour and capital resources will not be channeled towards this cause. Shepard *et al*., (1997), confirmed this in early-stage-analysis of adoption of potential hedgerow intercropping in on-station trials. They report that limitations for the adoption potential included inappropriate targeting, where the farmers' priority problem is not low soil fertility. Studies in Zambia and Kenya show that low soil fertility has been recognized as a problem and consequently, farmers have invested cash in soil fertility improvement technologies.

Specific benefits of the technology also affect acceptance. Fischler and Wortmann (1999), compared mucuna and lablab shrubs as biomass, with crotalaria fallows and weedy fallows in eastern Uganda. They reported that soils following weedy fallows were less manageable, yields were low and weed infestation was high compared to lablab and mucuna biomass and the crotalaria fallow, where weed infestation was low, and yields were higher. Labour demands for the mucuna biomass however, were high due to its extensive rooting system.

Buckles and Triomphe (1999) reported that farmers in northern Honduras adopted mucuna due to its land productivity attributes such as fertilizer effects, moisture conservation, and ease of land preparation. 52% of the respondents also reported that labour productivity of mucuna was the second rank. Mucuna was also used as livestock feed, income generation from seed, and was easily established; however toxicity is a major hindrance to increased use (Tarawali *et al*., 1999).

The financial gains associated with technology use should outweigh the costs of its use. Graene and Casey (1998) reported that promising new technologies are not adopted by farmers because they are not profitable. Negatu and Parikh, (1999) add that farmers decisions are rational and therefore are made based on utility maximization.

2.3 Framework of analysis

Partial budgeting (PB)

Partial budget analysis is an excellent evaluation technique for assessing an incremental technological change at the field level (Roth & Hyde, 2002; Holland, 2007). It is called partial because it includes in its budget analysis only the resources that will be changed, leaving out those that are unchanged (e.g. fixed assets), and supports the assessment of alternatives. It is useful in analyzing the effects of a change from an existing practice. Kay *et al*. (2008) noted that a partial budget is a balance which measures the positive and negative effects of a change in the business. It examines how adopting a new technology affects profitability by comparing the existing situation with the new or alternative method.

The partial budget is based on the concept that technological change will have one or more of the following effects: Positive and negative economic effects. On the positive side, it is hypothesized that the adoption of technological innovation will eliminate or reduce some costs and/or will increase returns. On the negative side, it is hypothesized that technological change will cause some additional costs and/or reduce some returns.

The net change between positive and negative economic effects is an estimate of the net effect of the technological innovation. A positive net change indicates a potential increase in income and a negative net change indicates a potential reduction in income due to the technology.

2.0 Methodology

2.1 Survey area

This study was conducted in Mkinga District, Tanga Region in Tanzania. This area is situated between latitude 05°08'N and longitude 381°35'E. Mkinga district is one of four districts in Tanga region, the other being Tanga district to the East, Lushoto and Korogwe to the West, Muheza to the North and Pangani district to the South. The 2002 National Tanzania Census indicates the population of Mkinga as 107 232 people residing in an area of 2947 Km^2, with population density of 36 people per Km^2.The economy is essentially subsistence agriculture, which occupies more than 70% of the population.

2.2 Data collection and sampling

To analyze the potential impacts of adoption of green manure technology on yield, cost, and profitability of maize production in the Eastern Zone of Tanzania, six villages were covered. The villages were chosen randomly among a list of localities using green manure. In each, 20 maize producers were drawn at random from lists obtained from the regional rural extension services. Thus, a sample of 120 producers was considered (60 with green manure and 60 without green manures i.e. maize after maize), to represent the whole area. A survey was conducted in 2009 based on a semi-structured questionnaire designed for maize producers. Information obtained in the interview was yields, costs of operations, prices. Participating farmers in each group were then asked to record information throughout the growing season.

2.3 Data analysis

To assess the potential impacts of gren manure adoption on farm income, costs and chemical and labour usage, a partial budget was constructed to reflect changes in labour application, yield changes as well as income to farmers.

Construction of the partial budget

Calculation of average yield for each alternative, the economic analysis is based on the average yield of each alternative. The gross field benefit were computed as the product of quantity for maize yields and producer prices as presented in Equation 1

$$B_t = Q_t P_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where: $B_t =$ gross field benefit, $Q_t =$ Quantity of the output, $P_t =$ Producer price.

Calculation of total costs that vary, which requires (i) listing the categories of variable costs, (ii) determining the quantities of inputs utilized in each category, and (iii) setting the price (or opportunity cost) associated with each input. Total variable costs for all inputs in each treatment were calculated using Equation 2.

$$TVC = X_i P_{xi} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where: $TVC =$ Total variable cost, $X_i =$ Quantity of the i^{th} variable input, $P_{xi} =$ Price of the i^{th} variable input.

Calculation of net benefit, which is the gross field benefit less the total costs that vary as presented in Equation 3.

$$NB_t = B_t - TVC_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where: $NB_t =$ Net benefit, $B_t =$ gross field benefit, $TVC =$ Total variable cost.

Using partial budget, the advantages (additional revenue and reduced costs) were compared to the disadvantages (reduced revenue and additional costs). The decision for the producer was made based on the resulting in a net advantage. If the net change is positive, then the alternative situation (green manure technology) has economic advantages. That is, If (c) + (d) > (a) + (b) the change is profitable, given that it is a feasible change (Table 1).

Table 1: Partial budget: comparison of green manure technology versus maize after maize practices

Costs	**Benefits**
a) Additional costs: costs from the use of green manure (alternative situation) that are not required when using maize after maize practices (current situation).	c) Additional revenues: revenues from the use of green manures (alternative situation) that are not received when using maize after maize (current situation).
b) Reduced revenues: revenues from maize after maize practices that will not be received when using green manure.	d) Reduced costs: costs from maize after maize practices that will be avoided when using green manures.
Total Costs: $\boldsymbol{a + b}$	**Total Benefits:** $\boldsymbol{c + d}$
Net change in profit: $\perp[\boldsymbol{c + d - (a + b)}]$	

3.0 Results and Discussion

3.1 Technology effects on the cost and income

Farmers with green manure in the study area adopted two planting options of green manure. In the first option, green manures were intercropped with maize toward the middle of the growing season, with the idea that their major growth would occur during the dry season. The reason for green manure/maize intercrop is that subsistence farmers need to cultivate and harvest something each year. This option was compared from maize cropping without green manures (maize after maize).

Potential technology effects on the cost and income of maize production at the individual farm level are analyzed by comparing currently situation (maize after maize) and the alternative situation (green manure intercropped with maize) to manage noxious weed (Striga). The new technology assumed changes in other inputs and production factors elicited during the interviews. Only variable costs are included because it is assumed that fixed costs (e.g. land/land rental, machinery, tools, irrigation) would be the same in both with and without green manure technology (Table 1). The information provided was used to construct the budget for maize production under *with* and *without* framework of technology assessments.

Table 1: Crop budget of green manure/maize intercropped vs maize after maize based on 2009 data

Particulars	**with green manure**	**maize after maize**	**quantity change**	**% change**
Maize seeds	2 240	2 240	0	0
Green manure seeds	0	0	0	0
Land preparation	27 400	31 980	(4 580)	-17
Sowing of maize seeds	22 800	22 800	0	0
Sowing of green manure seeds	8 000	0	8 000	100
Weeding	8 000	28 090	(20 090)	-251
Harvesting	20 000	17 800	2 200	11
Total production costs	88 440	102 910	(14 470)	-16
Yields (Kg)	1 489	340	1 149	77
Prices per Kg	396	396	0	0
Gross revenue	589 644	134 640	455 004	77
Net revenue	501 204	31 730	469 464	94

The resulting effect of adoption of green manure technology will decrease in production cost brought about by potential reduction in labour use for weeding and land preparation. The use of conventional practices such as growing maize continuous season after season (maize after maize) will potentially decrease production cost by 16%. As a result of prevented yield loss, marketable output will increase by 77%. Subsequently, the use of green manure technology will increase net income four folds compared to chemical fertilizers to manage Striga weeds in maize production systems in Tanzania.

3.2 Income and cost effects of technology

The attractiveness of nay technical innovation can be gauged by its private benefits and costs a technological innovation is said to be economically attractive if the benefits from the technology outweigh the costs in applying the technology.

In order to assess the relative attractive of green manure technology over the performance the current practices, a partial budget was constructed using the information derived from the interview with farmers during surveys. The results of the analysis are shown in Table 2. Using the 2009 crop budget, the adoption of green manure will reduce costs of hired labour for weeding by 251% and thus reduction of production costs by 16%.

There will be resulting savings on the cashflows from farmers. Additionally, the adoption of green manure will prevent striga infestation and increase marketable yield. This additional marketable yield will be additional return to the adopting farmers. The resultant increase in profits for green manure technology was Tsh 478 654/acre, resulting

in a B:C ratio of 7:1. The result simply indicates that holding other factros constant, the adoption of green manure will increase income by Tsh 478 654/acre, and for every addirional Tsh invested will increase profit seven times.
The results indicates that at the farm level, the green manure technology (green manure/maize intercopped) appears favourable in terms of reducing costs and increasing net profits, hence farmer will accept it if green manure seeds become availanle in the market each season.

Table 2: Partial budget of green manure adoption

Particulars	Based on 2009 crop budget
Incremental benefits	
Reduced costs:	
▪ labour cost for weeding	20 090
▪ land preparation	4 580
Additional revenues:	
▪ Increased revenues	455 004
Total incremental benefits	**479 674**
Incremental costs	
Additional costs:	
▪ Sowing of green manure	8 000
▪ Harvesting	2 200
Reduced revenues:	-
Total incremental costs	**10 200**
Net incremental benefits	**478 654**
Inc. B:C ratio	7:1

4.0 Conclusion and recommendations

The conclusions drawn from this study may be of benefit to a range of stakeholders. It has exposed farmer preferences as an input into future research. It is also beneficial to NGO's, and their beneficiaries in knowing the best alternative of soil management interventions for further dissemination and promotion. Policy makers have been informed of viable environmentally and financially sustainable soil management practices that may be utilized in policy formulation because the use of green manure reduces chemical fertilizer applications. Finally, smallholder farmers have received information on feasible and sustainable soil fertility management practices compatible with farming practices. Consequently, farmers will realize improved crop performance, yields and crop productivity.

This research has shown that better yields are attainable with use of green manure. Furthermore, these technological interventions are profitable and can easily be incorporated into farming systems. In light of this conclusion, the following recommendations have been made. Increase the scaling up of use and impact of green manure technology, not only in the study area but also in other parts of the country. Future research should strive to further develop and strategize dissemination channels to reach more of the smallholder population to increase their knowledge base on the alternative values of green manures. By virtual of their living in the remote world, smallholder farmers marginally access information about upcoming technologies that may influence their production and investment choices.

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