CHOICE OF GREEN MANURE TECHNOLOGY ON SMALLHOLDER MAIZE PRODUCTION SYSTEMS IN TANZANIA: A CASE OF MKINGA DISTRICT, TANGA REGION

BY

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A DISSERTATION SUBMITTED IN A PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL ECONOMICS OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

ABSTRACT

In Mkinga 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 was conducted to evaluate economic viability of green manure utilization on farmers' livelihoods. The specific objectives of the study were: (i) to measure the accrued costs and benefits of green manure in maize production systems on farmers' livelihood; (ii) to undertake investment analysis in maize cropping with green manures systems; (iii) to establish farmers' own perceptions on the use of green manures in soil fertility improvement for maize production; and (iv) to propose the best alternative options for green manure utilization for sustainable maize production. Data for the study were collected using household survey from a total of 120 households randomly selected from two villages found in similar agro-ecological zone. Descriptive analysis, gross margin analysis, partial budgeting and benefit-cost analysis were used as analytical tools. Results show that farmers adopted two planting options of green manures that is (*Mucuna*/maize intercrop or *Mucuna*/maize staggered). The average maize grain yield over the five years was 906Kg/acre, 374Kg/acre and 304.2Kg/acre in *Mucuna*/maize intercrop and *Mucuna*/maize staggered and with no green manure respectively. The gross margin in maize/*Mucuna* intercrop, *Mucuna*/maize staggered and without green manures was Tsh 215 920 per acre, Tsh 58 620 per acre and -3 945.6 per acre respectively. *Mucuna*/maize intercrop yields a high NPV of Tsh 612 807 and BCR of 2.43 at 20% interest rate. The shift from sole crop to maize cropping with green manure is profitable by Tsh 231 833. Future research in pursuit of improving availability of green manure seeds, produce outlets and integrated nutrient management strategies tapping on farmer innovations is required to ensure sustainability of the production system.

DECLARATION

I, William Juma, George do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has not been submitted for a higher degree in any other university.

17/11/2009

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Date

The above declaration is confirmed

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Date

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DEDICATION

To the Lord, Jesus Christ, my wife, children, parents and innumerable friends.

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LIST OF ACRONYMS AND ABBREVIATIONS

BCR	-	Benefit Cost Ratio
BNF	-	Biological Nitrogen Fixation
BT	-	Biomass Transfer
CBA	-	Cost Benefit Analysis
CIMMYT	-	International Maize and Wheat Improvement Centre
FAO	-	Food and Agriculture Organization
GMs	-	Green Manures
GMCCs	-	Green Manure Cover Crops
INM	-	Integrated Nutrient Management
IRR	-	Internal Rate of Return
LP	-	Linear Programming
MAAIF	-	Ministry of Agriculture, Animal Industries and Fisheries
MAFSC	-	Ministry of Agriculture, Food Security and Co-operatives
MOTAD	-	Minimization of Total Absolute Deviations
N	-	Nitrogen
NGO's	-	Non-Governmental Organisations
P	-	Phosphorus
PBA	-	Partial Budgeting Analysis
SFMT	-	Soil Fertility Management Technologies
SPSS	-	Statistical Package for Social Sciences
SSA	-	Sub-Saharan Africa
SUA	-	Sokoine University of Agriculture
URT	-	United Republic of Tanzania

CHAPTER ONE

INTRODUCTION

1.1 Background

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 (N) is among the major nutrients limiting crop production (URT, 2000). Some parts of Tanzania there is a negative nitrogen balance valued at about 27Kg/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 (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. They have thus become the object of interest among smallholder farmers, researcher and extensions in America, Africa and Asia (Kaizzi *et al.*, 2002). In eastern Tanzania, green manure technology was introduced in Mkinga district (formerly Muheza District) by the Muheza Maize Project into farming systems (Mbwaga *et al.*, 2003). Green manure species of interest in this study are Mucuna (*Mucuna puriens*), Canavalia (*Canavalia ensiformis*) and Marejea (*Crotalaria ochroleuca*).

1.2 Problem Statement and Justification

While chemical fertilizer use by smallholders in Tanzania is limited due to high costs, and the lack of knowledge, organic input use has been emphasized. The Muheza Maize Project (MMP) called for improved land management and soil fertility to increase maize productivity through the adoption of green manures. Gachengo *et al.* (1999) confirms the increasing pressure to use external inputs to reverse the negative nutrient balance and increase crop productivity in Western Kenya. However, relevant practical questions that arise include amongst others, the economic viability of green manure in maize production systems in relation to farm socio-economic circumstances. In addition to the above concerns, FAO (2001a) observed that though a substantial amount of research had been undertaken addressing various resource management strategies and interventions for soil fertility management, investment in research dealing with profitability and sustainability of the interventions, by comparison, had been only modest.

Exposure of soil management strategies through on-farm trials began in Mkinga District in 2002 whose purpose was to develop, test and promote strategies that reduce the impact of pests in particular *Striga* (whose effects was compounded by conditions of low soil fertility) on smallholder farmers. In addition, the project aimed at improving understanding of local coping strategies, identifying constraints to adoption. on-farm evaluation of selected technology options. improving access to inputs and linking stakeholders as partners during the project. Its planned activities, amongst others, were to train extension staff about Integrated Soil Fertility Management (ISFM) and the initiation of demonstration trials on improved soil fertility management options (green manures) in particular. The major participants in MMP were drawn from government; Sokoine University of agriculture (SUA), local and international NGO's and research institutions. For almost six years now farmers in Mkinga District are utilizing some soil improvement technologies introduced by MPP. However, there is a lack of information on (a) the financial and economic returns over time, (b) the labour requirements, and (c) the opportunity costs of land and crop yield for green manure systems. Therefore, the economic viability of green manure systems towards poverty alleviation, are unknown. Early adoption of technologies is mainly by well-off farmers, so the technology may have had little impact on the poorer farmers in the community. This study tried to fill this information gap by applying economic analysis. This study focuses on evaluating economic viability of the interventions to improve soil productivity using green manures.

1.3 Study Objectives

The overall objective was to evaluate economic viability of green manure utilization on farmers' livelihoods in Mkinga District.

The specific objectives of the study were:

(i) To measure the accrued costs and benefits of green manure utilization in maize production systems on farmers' livelihoods.

(ii) To undertake investment analysis in maize cropping with and without green manure systems.

(iii) To establish farmers' own perceptions on the use of green manures species in soil fertility improvement for maize production,

(iv) To propose the best alternative options for green manure utilization for sustainable maize production.

1.4 Hypothesis

This study was directed by one hypothesis that is the economic benefits derived from establishment, management and use of green manure technology for soil fertility replenishment; outweigh the associated costs.

1.5 Structure of the Dissertation

This dissertation is presented in into five chapters. After the first chapter which presented background information, an overview of the research problem, justification and objectives for the study, chapter two present review of relevant literature. Chapter three describes the theory and methodological framework. The results and discussion is presented in chapter four. Chapter five presents conclusion and recommendations based on the study findings.

CHAPTER TWO

LITERATURE REVIEW

2.1 Green Manures

GMs are used primarily as a soil amendment and a nutrient source for subsequent crops. Unlike synthetic N fertilizers, legumes utilized as GMs represent a potentially renewable source of on-farm, biologically fixed N and may also fix and add large amounts of Carbon to cropping systems (Sharma and Mittra. 1988; Hao *et al.*, 2004). Providing adequate soil N fertility with application of animal manure products may result in soil P loading (because manure N/P ratios are often much lower than those maintained by plants (Hao *et al.*, 2004) or soil salinization (due to high ion concentrations in animal manure (Hao and Chang, 2003). Such excess P application and soil salinization may be avoided by use of leguminous GMs (Eigenberg *et al.*, 2002). Green manures grown on site do not incur the often inhibitive handling and transportation costs of other organic inputs. The slow release of N from decomposing GMs residues may be better synchronized with plant uptake than sources of inorganic N, possibly increasing N-uptake efficiency and crop yield while reducing N leaching losses (Aulakh *et al.*, 2000; Cline and Silvemail. 2002).

Green manures generally fall into two categories: tropical ("warm weather") and temperate ("cool weather"). Few, if any, tropical legumes can survive hard freezes (when temperature drops below –2°C for several hours), although they can usually tolerate temperatures >35 to 40°C. Temperate legumes, on the other hand, often decline at temperatures >25 to 30°C but may persist without injury at –10°C or lower. The most widely used tropical GM legumes probably include *Mucuna* *puriens*, *Canavalia ensiformis* and *Crotalaria ochroleuca*, while the temperate GM legumes often include *Trifolium*, *Vicia*, *Medicago* and *Lupinus* (Hossain, 2001).

2.2 Types of Green Manure

Genetic differences (species and variety) may dictate that some legumes grow larger and accumulate more N than others. Environment (temperature, soil type, and nutrient and water availability) and management (e.g. planting density and timing, mowing, and pest control) may further alter performance of individual GMs species (Kouyate *et al.*, 2000; Ross *et al.*, 2001; Steinmaier and Ngoliya, 2001). Green manures do not derive direct sales profit, they are often chosen that require acceptably low levels of nutrient, irrigation, and pest control inputs and often fit into otherwise unplanted fallow periods. Legume GMs species are often preferable to non legumes because they supply their own N, but in production scenarios where N is less limiting, where a specific GM service other than high N supply (such as allelopathy) is sought, or where legumes do not perform well, non le gumes or mixtures of legumes and non legumes may be more advantageous. Desirability of GMs may also include or exclude ability to reseed, growth habit (e.g., upright, prostrate, or viney), aggressiveness, and presence of toxic or allelopathic chemicals affecting livestock, crops, or plant pests. These characteristics are often controlled at the species or variety level.

2.2.1 Canavalia (*Canavalia ensiformis*)

It is a drought-resistant, shade-tolerant, hardy legume that grows well in extremely poor and droughty soil. There are two kinds of jack bean, one that climbs and thoroughly covers the soil and another that has a bushy growth habit and does not climb at all. It begins flowering after 4-5 months, then produces seed pods continuously for one year. It will grow through some 5-6 months of dry season if above about 600 meters and can serve to shade the soil during this time to prevent loss of organic matter. Less than 500 meters it will often stop growing after about 3 months without rain and may even drop its leaves if soils are thin and temperatures exceptionally high. The stem will become somewhat woody, but only if left for seed and under fairly warm conditions.

Marshall (2002) reported that jack beans grow vigorously at sea level. and can be used as a green manure crop up to about 1600-1800 meters. It does not thrive in soils with excess water. They do very well in maize fields, but are preferred over velvet beans only when it is too dry for velvet beans to thrive. This tends to be the case where maize has been replaced with sorghum or millet due to insufficient rainfall. It grows vigorously on soil so badly eroded and depleted that no weeds would grow there at all. The jack bean will be eaten by grazing animals, but is liked less than other green manures. Hence jack beans are preferable where animal damage is feared. Non-climbing varieties are proving to be very good for weed control and nitrogen fixation under fruit trees. It has virtually no natural pests or diseases. Its leaves are sprinkled on leaf-cutter ant hills to eliminate them.

Jack bean should be planted in soil that has been cultivated within 3 years and weeded very recently (although at elevations below 500 meters or in sandier soils, cultivation may not be needed). Jack bean has even been planted in fields already intercropped with both maize and beans without much adverse effect on even the beans. If planted in a maize or sorghum field. it should be seeded within 15-30 days of the primary crop. depending on climate. speed of growth of the other crop. etc. It can be planted with a dibble-stick (at 2 seeds/m^2) or broadcast (at 4 seeds/ m^2). though if broadcast it will take another 2 weeks or so to germinate unless soaked in water overnight before planting.

2.2.2 Mucuna (*Mucuna puriens*)

Is by far the most promising green manure which covers the soil completely and then climbs as high as its support allows (up to well over 6 meters). It is highly palatable to animals and has found wide acceptance in Honduras areas as a coffee substitute (Triomphe, 1999; Marshall, 2002). The plant dies after it has set seed. Sometimes velvet bean roots produce solid clusters of dark red nodules that are four centimeter in diameter. Like jack bean, the velvet bean will volunteer heavily the second year if seed is allowed to mature and fall on the ground. In fact, farmers in Honduras get good growth each year in their maize fields without bothering to reseed it. They harvest 4 t/ha of mono cropped maize planted year after year on the same land under typical jungle conditions. using chemical fertilizer plus velvet bean (Triomphe. 1999; Marshall, 2002).

The velvet bean has not done well in waterlogged soils nor have a pH of 4.5. Like the jack bean, it needs to be planted in a field that is either sandy or has been cultivated within the last 3 years. Velvet bean will take a bit cooler climate than jack bean, but still does best at sea level and does poorly over 2,000 meters. In cool climates it will grow 3-4 months into the dry season, but is not as drought-resistant as jack bean. Velvet bean grows even more vigorously than jack bean under less harsh conditions, but in areas of severe drought, jack bean will out-perform velvet bean. The velvet bean is presently our species of choice, in most cases, for growing in maize fields, rehabilitating depleted land, and weed control. It has been used in Guatemala and parts of Honduras to eliminate serious weeds such as nutgrass (*Cyperus rotundus*), Bermuda grass (*Cynodon dactylon*) and imperata grass (*Imperata cylindrica*).

It is an extremely good, fairly palatable high-protein fodder for most animals, especially cattle, and is eaten by virtually all animals except, sometimes, chickens (Kaizzi *et al*., 2002). Thus, like the lablab bean, it can be an important source of high protein fodder well into the dry season, when many domestic animals are losing weight for lack of food. There are two kinds velvet bean. The more common one has an extremely irritating itchy powder on the mature pod. Farmers who know this plant will not want to plant the non-itchy-powder varieties until they have been shown that the pods are harmless. The green manure (velvet bean or jack bean) may be intercropped with maize in the first season. After harvesting the grain they cut the residue and green manure down, leaving this on the surface as mulch. The second crop is planted 20 days later with a dibble stick right through holes cut in the mass of dead velvet bean. There is usually a net saving of labor because planting and cutting of the green manure requires less work than the two weeding operations that are thus saved with the second crop. This is the sort of technology one dreams of, but rarely finds: net savings of labor, zero cash cost, decreased risk (the mulch gives some protection from erosion and drought), increased productivity, increased soil fertility and increased protein intake for animals or people.

2.2.3 Marejea (*Crotalaria ochroleuca*)

Sun hemp is receiving widespread acceptance as a versatile green manure in East Africa. Its seed bank distributes about 150 tons of seed per year. Though sun hemp has a totally different growth habit than the green manures we have featured in the past, it has many of the same uses. It is a vigorous upright legume growing two meters tall. Among other things, they use it to improve the soil, kill weeds, feed livestock, and control erosion.

Crotalaria ochroleuca is free of toxin (except perhaps the seed) and is fed to livestock. Cattle can be allowed to graze in the sun hemp field, but they must not be allowed to spend more than about one hour in the area. The seeds are used to keep weevils from stored rice and maize. Sun hemp seeds are spread over the ground and bags put on top of the seeds. This procedure is continued, layering sun hemp seed and bags of stored grain. After about nine months, the process must be repeated (Ramos *et al.*, 2001). As with velvet bean, farmers are especially appreciative of its usefulness in controlling weeds and improving the texture of the soil.

2.3 Planting Options of Green Manure

The major problem with green manure use around the third world is that village farmers cannot afford to give up land in order to grow "just" a soil amendment (Ramos *et al.*, 2001). When they have the land, they cannot spare the labor.

However, there are two ways in which these objections can be overcome (i.e. *Mucuna* staggered and *Mucuna*/maize intercrop). In many situations only one of these will be appropriate (Table 1).

Table 1: Green manure planting options adopted by farmers

Year 1	*Mucuna*	Maize/ *Mucuna*
Year 2	Maize	Maize/ *Mucuna*
Year 3	*Mucuna*	Maize/ *Mucuna*
Year 4	Maize	Maize/ *Mucuna*
Year 5	*Mucuna*	Maize/ *Mucuna*

In the first option where there are severely degraded and striga-infested fields, green manures such as *Mucuna* should be planted in a pure stand at the start of the rainy season (*Mucuna* staggered). The plot is slashed with cutlass or sickle before seeding *Mucuna* at spacing of 0.8 x 0.4 m. If two seeds are planted per hole, approximately 30 kg of seed/acre are required. In addition if *Mucuna* spacing is 0.8 x 0.8 m, with two seeds per hole; about 15kg/acre are required. Three or four weeks after planting *Mucuna*, a second slashing may be necessary to allow *Mucuna* seedlings to overcome striga, which is a fast-growing weed. In the bi-modal zone, *Mucuna* is planted in March and April to maximize biomass accumulation, groundcover and seed production. Sowing can be extended to May if the rains are insufficient (Kaizzi *et al.*, 2002; Marshall, 2002).

In the second option is when striga infestation is not severe, *Mucuna* can be intercropped with maize toward the middle or end of the growing season, with the idea that their major growth would occur during the dry season, thereby using land that would not ordinarily be under cultivation. Maize is planted at a normal spacing of 0.8 x 0.4 m with two seeds per hole. *Mucuna* seeds are sown, either between or within the rows, 30 days after planting maize just after the second weeding in the first cropping season. *Mucuna* remains in the field after maize is harvested until the end of the second cropping season, thereby precluding the planting of a second crop. Seeding of *Mucuna* earlier than 30 days after planting maize can result in reduced maize yields. After maize harvest, the land is left to *Mucuna* fallow, which prevents farmers from cropping the land during the second minor rainy season (Marshall, 2002). This allows groundcover to fully develop for biomass accumulation and nitrogen fixation while weeds such as Striga are smothered. During the following dry season that lasts from November to March. *Mucuna* dies off and the farmer can farm the field again at the next main cropping season with minimum investment in labor to open the rows through the *Mucuna* mulch.

2.4 Suitability of Green Manure

The choice of economic crop also affects the suitability of GMs approaches based on crop cultural requirements and vulnerability to pests and disease. For example, increasing GM residue in the soil seedbed through use of reduced tillage may appear desirable in many environments. but crop species and varieties differ in their sensitivity to fungal attack that may occur without tillage. Some cruciferous (e.g.. radish) or solanaceous (e.g., potato [*Solanum tuberosum* L.]) crops may demonstrate less adaptation to such systems than larger seeded grains and legumes (Cherr, 2004). With proper selection and management, however, GMs may suppress pests otherwise requiring chemical or cultural intervention.

A number of researchers have investigated GMs-based control of weeds and nematodes through physical, biotic, and allelopathic interactions. Physically, GMs may outcompete weed species for light, nutrients, and water at crucial stages and may otherwise disrupt the life cycle of nematodes by acting as nonhosts. Blackshaw *et al.* (2001) found yellow sweet clover [*Melilotus officinalis* (L.) Lam.] suppressed fallow weed biomass by 77 to 99% over 3 years. However, the effectiveness of physical weed suppression by GM often depends on interaction between their environmentally mediated performance, growth habit, and management. For instance, Ross *et al.* (2001) found clovers to have the greatest weed suppression ability on a low-fertility site when unmowed, with the greatest suppression by tall-growing annuals such as berseem clover (*Trifolium alexandrinum* L.). In the same study, weed suppression by clovers on high-fertility sites was enhanced by mowing and did not differ among species. Green manure live mulch, when maintaining an early season advantage over competition, may provide weed suppression comparable to plastic mulch (Ellis-Jones *et al.*, 2000). Biomass, growth habit, and developmental stage of GMs intercrops and live mulches must be managed to prevent competition with economic crops. For example, low-growing GMs such as Canavalia (jack bean) and red clover (*Trifolium pratense* L.) may be required to avoid shading of economic crops (Bukovinsky *et al.*, 2004). Delay of inter planting until after the establishment of an economic crop may also mitigate competitive reduction of economic crop growth (Thiessen *et al.*, 2001).

Suppression of parasitic nematodes by GMs also exemplifies the importance of highly specific GMs–environment–management interactions. Different crop species, and even different varieties of the same crop species, vary in their resistance to different nematode species. Plants may also show different levels of susceptibility to regional races and local isolates of nematode species. Overuse of resistant crop varieties can select for "resistance-breaking" nematodes (McSorley, 2001). Crop rotation with a non host or nematode-suppressant GMs may help reduce such selection pressures by providing an opportunity to disrupt nematode life cycles. For example, a number of GMs species act as non hosts or suppressors of one or more *Meloidogyne* species (root-knot nematodes) e.g. *Marejea*, *Canavalia*, and *Mucuna* (McSorley, 1999).

On the other hand, some GMs species may exacerbate infestations of plant-parasitic nematodes by acting as hosts. Fore example, sun hemp has been found to be a poor host of reniform nematodes (*Rotylenchulus reniformis*), yet may support a slow population increase with time (Wang *et al.*, 2003b). Green manures may control pests indirectly by providing habitat for organisms that feed on or parasitize weeds, insects, and nematodes. Greenhouse studies in Florida using sandy soil have shown that sun hemp can increase omnivorous and predatory nematodes on soils with low organic matter (<2%), though perhaps not enough to control parasitic nematodes such as *Meloidogyne* sp. Wang *et al.*, 2003a). Wang *et al.* 2003a found application of sun hemp residues to a silty clay at a rate of 10 g dry residue kg^{-1} dry soil enhanced nematode-trapping fungi. Studying cucurbit crops (*Cucurbita* sp.) with buckwheat refuges, Platt *et al.* (1999) found numbers of insect predators and parasitoids caught on sticky traps increased by 2 to 19 times as one moved toward buckwheat refuges from 20 to 35m away. However, the method of biological control differs among pests, with some controlled by general increases of biological activity while others require development of proper habitat for specific antagonists (Davis *et al.*, 1996; Wang *et al.*. 2003a, 2003b). Allelopathic chemicals released by specific GMs species may directly inhibit weed growth, although allelopathy is highly specific to GMs species, environment, residue management, and target organism (Blackshaw *et al.*, 2001; Inderjit, 2001). Allelopathic chemicals and delayed release of N from decomposing GMs may thus reduce small-seeded weed growth more than that of large-seeded crops, providing such crops with a critical early season advantage (Petersen *et al.*, 2001).

2.5 Perceptions of Green Manure

The perception of the soil fertility problem is a key determinant of the acceptance of improved technology (Franzel, 1999; Blackshaw *et al.*, 2001). 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; Dobbs, 2004). 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 Wortman (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.

Tarawali *et al.* (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. Fifty two percent of the respondents also reported that labour productivity of *Mucuna* was the second rank. Mucun*a* was also used as livestock feed, income generation from seed, and was easily established; however toxicity is a major hindrance for its increased use (Tarawali *et al.*, 1999; Dobbs, 2004).

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 farmer's decisions are rational and therefore are made based on utility maximization.

2.6 Economics of Green Manure

Economic viability of GMs-based systems depends on externalities and internalities (Dobbs, 2004). Farmers (and researchers) have no direct control over factors external to their operations. Currently, low costs that farmers associate with chemical-based approaches to production may not accurately reflect the expenses passed externally to society. Existing government policies generally do not bill farmers for potential impacts of agriculturally related pollution, global warming, and ecological disruption on human health and economic activity. If government subsidies or market prices directly experienced by the farmer do not accurately reflect costs or savings passed on to society, then GMs approaches may become less profitable or involve more risk to the farmer regardless of net value (Ali and Narciso. 1996; Dobbs, 2004). Moreover, government policies or market prices may have different impacts regionally (Young and Painter. 1994) or on different GMs approaches (Painter *et al.*, 1994). Because farmers typically have little ability to accept economic risk, they often cannot afford short-term experimentation with GMs approaches even if it leads to long-term economic profit (Painter *et al.*, 1994). In scenarios where mechanization is not possible, GMs approaches with high labor requirements for planting and residue management may become too costly, especially where synthetic fertilizers are inexpensive (Rao and Mathuva, 2000).

Internally, a particular approach to crop production will affect economic profit and risk. Farmers may also have to consider input, transition and opportunity costs associated with GMs (Ali and Narciso, 1996; Dobbs, 2004). External factors aside, GM approaches are more often found to be economically superior to conventional approaches when capable of providing multiple services (Young and Painter, 1994; Dobbs, 2004), when GMs replaces costly conventional inputs such as fallow management (Ellis-Jones *et al.*, 2000), when one or more species from multispecies GMs mixtures serves as an economic crop (Painter *et al.*, 1994), and when strict GMs crops are replaced with crops that provide food or feed while residue is left in the field (Dobbs, 2004). Variable weather or other environmental patterns may also alter year-to-year profitability of green manures approaches (Vigil and Nielson, 1998; Hossain, 2000). Use of GMs or GMs plus reduced tillage approaches may also economically justify and ecologically mitigate the use of other inputs (Young and Painter, 1994; Painter *et al.*, 1994).

2.7 Analytical Techniques in Related Studies

2.7.1 Gross margin analysis

Gross margin analysis involves determining all variable costs and revenue associated with an enterprise. To define the concept of gross margin we first have to distinguish between variable and fixed costs. Variable costs are those costs that increase or decrease as outputs changes while fixed costs do not change as output is changing (Hao *et al.*, 2004). Common examples of variable costs in crop production include seeds, fertilizers and pesticides. The most important fixed costs in agricultural production are owned land, family labour, farm building, farm machinery and implements. The gross margin of a farm activity is the difference between the gross income earned and the variable costs incurred (Ross *et al.*, 2001).

The enterprise output is the total value of the production of the enterprise. It is not only limited to the amount of production being sold. It also includes the value of any produce consumed on the farm or produce given away to relatives/friends or transferred to another enterprise e.g. maize fed to cattle. Enterprise output is affected by yields of the enterprise, price per unit received for the product, scale of the enterprise and valuation changes. The total farm gross margin is the sum of gross margins from all enterprises. The gross margin is in essence is the return to capital, labour, management and risk. Variable costs considered are those costs attributed to the enterprise. To be regarded as variable cost in the gross margin sense, costs have to satisfy two criteria, which are also satisfied by enterprise outputs. They must be specific to a single enterprise and vary approximately in proportion to the size of the enterprise.

Gross margin analysis is thereby a simple, but in many cases a sufficient powerful tool for economic analysis of introduced technologies. It widely used in farm planning and can be used to prepare partial budgets for minor changes in farm programmes. According to Ferris and Malcolm (2000), gross margin analysis has the following limitations:

- Gross margin is not a profit figure. Fixed costs have to be covered by the gross margin before arriving at a profit figure.
- Gross margins can vary widely from one year to the next. This is due to differences in market prices, weather conditions and efficiency. This can result from differences in performances in performance levels or differences in the overall system of production or method of recording. Comparison to average gross margins can be useful but it should be done over a number of years. However, it gives the starting point in the assessment of the enterprise.

2.7.2 Partial budgeting

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. The benefits of the technology under investigation are defined in monetary value terms and an attempt is made to identify costs incurred or affected directly from its implementation on the farm. This includes extra income and costs obtained by the farm and income and costs forgone from implementing the new technology (Prasad *et al.*, 2002). The costs include related variable costs, and fixed costs such as the additional capital investment and depreciation necessary to utilize the technology. It is an enterprise budgeting tool, which enables comparisons between enterprises by generating gross margins of each enterprise (Harsh *et al.*, 1981; Gittinger, 1984; CIMMYT, 1988).

Partial budgeting method are relatively straightforward to develop and the technical and price assumptions applied can be transparent. A further advantage of budgeting methods is that they are able to incorporate various degrees of sensitivity analysis to investigate the impact of uncertainty on the evaluation results. The partial budget can also be subjected to a sensitivity analysis to determine which key parameters affect enterprise performance.

According to Prasad *et al.* (2002), researchers make recommendations to farmers about what to adopt. To make these recommendations, the following economic criteria should be observed (provided the technology is in line with the farmer's

- If net income remains the same or decreases, the new technology should not be recommended as it is not more profitable than the farmers' current technology.
- If net income increases and variable costs remain the same or decrease, the new technology should be recommended as it is more profitable than the farmers' current technology.
- If both net income and variable cost increase (the most common case), the MRR should be considered. The greater the increase in NI and the higher the MRR, the more economically attractive the new technology is.

2.7.2.1 Data required for partial budget analysis

The most important step in performing partial budget analysis is the proper identification of data on the costs and benefits associated with the alternative technologies. Generally the following are essential data that must be collected:

- Quantities of inputs which vary between alternative technologies
- Prices of these variable inputs
- Yields or productivity levels resulting from the alternative technologies
- Prices of the outputs valuing non-market inputs or products opportunity cost (the value of the resource or product in its next best alternative use, e.g. family labour vs. market labour wages).

2.7.2.2 Weakness and shortcoming of partial budgeting

A major limitation of these budgeting methods is that they cannot provide optimal farm plans so the issue of how and to what extent a farm manager is likely to adopt a new technology amongst existing farm activities remains undetermined. Tronsco (1985) identifies two significant limitations of the partial budgeting approach to evaluate technologies at the farm level. Firstly, partial budgeting takes little account of the pervasive impacts of a new technology upon the whole-farm system and secondly, it cannot easily accommodate the impact of risk (although this is now less of a limitation with modern software packages). Further, where the benefits of the new technology accrue over time, discounting would be necessary to properly compare them with current costs.

2.7.3 Benefit Cost Analysis (CBA)

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 Hao *et al.* (2004), 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 (Francisco, 1998).

Using the CBA method, Bowen *et al.* (1993) analysed the financial and economic benefit of 56 agro-forestry systems in Central America and the Caribbean. They found that 75% of the agro-forestry systems analysed had positive NPV at a 20% real discount rate. Francisco (1998) used the CBA framework to analyse the profitability of soil conservation technology in Malaysia, Thailand and the Philippines. The soil conservation treatment in the Philippines involving banana and sapodilla as hedgerows with maize and peanut receiving high level of fertilisers, proved to be most profitable with a BCR of 1.93. In Thailand, a comparison of the NPV realisable from the 'with' and 'without' fertiliser treatment systems revealed that in general, fertiliser played a key role in enhancing profitability of the farm enterprise. The analysis of return to labour from all treatments in Chiang Mai revealed that annual returns to labour were highest in the agro-forestry system in both the 'with' (Baht 55 395 per hectare) and 'without' (Baht 22 328 per hectare) fertiliser treatments. Prasad *et al.* (2002) also estimated the economic returns of 72 alternative land use systems under agriculture in the Eastern Corn Belt. It was found in this study that groups of farmers who appeared to have different ranking of preferences could find alternatives that simultaneously satisfied their goals.

Charan (2000) made a detailed study of the benefits and costs of West Bans Soil Management options Projects in Rajastathan India. The study was based on considerable field investigations designed to obtain a detailed farm cost and return from the project area. The analysis of data suggests that gross farm output was significantly higher in cereals rotated with herbaceous legumes as compared to conventionally produced field maize crop systems grown without leguminous crops. After meeting the costs of cultivation which was also comparatively higher, the project farms had greater net surplus with them. On the basis of the above results, direct primary benefit-cost ratio of the technology was calculated. In the course of time the estimates of the costs had to be revised. However, as the revised estimates of the costs were high, the technology proved to be financially unsound. Hence it was likely that, had the original estimates been made on the basis of the revised figure, the project technology would not have been sanctioned on the financial grounds.

Benefit-cost calculations also were applied for integrated soil fertility management in Kenya by Rao and Mathuva (2000). By tracing operation of the technologies for five years they found the present value of Ksh 386 000 and therefore the technology was justifiable in terms of benefit-cost criteria. But further studies have indicated that the results could nevertheless be sensitive to given assumptions if for instances one used the market price of labour (Ksh 3.31 per man day at that time) in calculations, instead of lower value based on an estimate of real social value, the technologies would not have been justifiable.

Lotter *et al.* (2003) used benefit-cost analysis to performance of organic and conventional cropping systems in an extreme climate year. Net Present Value (NPV) and Internal Rate of Return (IRR) were incorporated in order to supplement the main benefit-cost analysis. Results showed that, at the yield level 3.8tons/ha (which was the average production performance) NPV was -38Million when discounted at 20% interest rate, while the IRR was 3%, which was far below the opportunity cost of capital which was assumed to be 12%. Finally the Benefit Cost Ration (BCR) was computed and found to be less than one in both two cases i.e. 0.83 and 0.75 for financial and economic analysis respectively. She finally concluded that, given bank lending rate of 20% and yield level of 3.8t ha^{-1} the farm was operating inefficiently and thus financially unjustifiable. Similarly at the same level of output the farm was economically unjustifiable given opportunity cost of capital at 12%. Poor performance was said to be caused by unreliable rainfall. Other constraints were said to be inadequate machinery and equipments. However, he noted in his conclusion that the farm was would be financially and economically justifiable if the output was to be raised up to a level of 4.7 t/ha. At this level of output, the NPV, IRR and the BCR ratio would be Shs [illegible]8.17 billion, 17% and 1.3 respectively. Raising output from 2.[illegible] t/ha to 4.7 t/ha was considered to be possible as [illegible] mobilization of the available resources at the farm.

CHAPTER THREE

METHODOLOGY

3.1 Conceptual Framework

The assumption that farmer's choice of a soil fertility management option is based on the desire to increase the profit derived from increased crop yield. As such the underlying problem is that of optimizing profit, given the technology and soil fertility management options available. Thus given the production function: $h(q,x,z) = 0$. Where q the vector is output, x is the vector of variable inputs and z is a vector of fixed factors. According to Sadoulet and Janvry (2003) the farmer's restricted profit is $\Pi = pq - cx$. The farmer's are assumed to choose a combination of variable inputs and outputs that will maximize restricted profit subject to the production technology constraint: $Max: p'q - c'x$ Subject to $h(q,x,z) = 0$. Where p and c are the output and input prices respectively.

The solution to this profit maximization problem becomes a set of input demand and output supply functions of the form: $x = x(p,c,z)$ and $q = q(p,c,z)$. According McFadden (2002) the maximum profit the farmer could obtain given the output and input prices, the availability of fixed factors and the production technology $\Pi = p[q(p,c,z)] - c[x(p,c,z)]$.

This is linked to the current study due to the fact that farmers choose planting option of green manure that realizes attracting maize yield and hence maximum profit. With increase of profit, farmers might be willing to adopt the technology of green manure consequently, enhancing poverty alleviation.

3.2 Location of the Study

This study was conducted in Mkinga district located between latitudes 05°08'South and longitudes 38°35'East. 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 (Table 2).

Table 2: Basic data about the study location (Mkinga District)

Features	Environmental and farming systems
Location	Latitudes 05°08'S and Longitude 38°35'E
Area	2947 square kilometers
Relief and Climate	Altitude 183m above sea level, bimodal rainfall with long and short rain seasons. The mean annual rainfall was 1034mm
Soils	Rhodic Ferralsol comprising 20% of soils
Topography	Pen plains, mountains and small area of coastal plans
General Description	Mainly annual mixed crop farming
Main Crops	Cassava, Maize, Beans, Paddy, Bananas, Sweet potatoes, Legumes, Cashew nut, Coconut and Oranges.
Livestock	Indigenous Cattle, Dairy Cattle, Goats, Sheep and Local chicken
Population	107 232 people
Population Density	36 people per square kilometer
Average farm size	Less than 5 acres
Household size	4.8 people per household
The people and the economy	Food crops, cash crops, fruits and vegetables and diary farming

Sources: Mkinga District Agriculture and livestock development office (2007)

3.3 Research Design

A cross-sectional research design was applied in this study. This design allows data on different groups of respondents to be collected at a single point of time. The design is useful for the description purposes as well as determination of relationship between and among variables.

3.4 Sampling Technique

The target population this study was smallholder maize farmers from selected villages. Two villages namely Mapatano and Mtakuja were purposely picked from Maramba Division. These villages were considered in this study as a case representing DFID funded project. A sample of 30 farmers with and 30 farmers without green manures from the two villages was selected randomly from list at the village office and green manures farmer groups. A total sample of 120 farmers was used in generating the information used this study.

3.5 Data Collection

Primary data were collected using structured questionnaire (Appendix 1). The questionnaires were administered to selected smallholder maize farmers in the study area. Secondary data were collected from institutions such as Sokoine University of Agriculture (SUA), Ilonga Agricultural Research Institute and Mkinga District Agriculture and Livestock Office (DALDO). Internet search was also used in this regard.

3.6 Analytical Techniques

3.6.1 Descriptive statistics

Descriptive statistics of the socio-economic setting of the farmer were analyzed from a survey instrument. These statistics such as frequency distribution, means, and percentage and cross tabulation were used to outline the socio-economic characteristics of the respondents.

3.6.2 Measurement of farmers' profits

Relative profitability of different technology is essential for decision making of farmers about a particular technology. For financial analysis of different technology, it is necessary to compute costs of inputs, which need to be deducted from the value of output. Farmers in the study areas used purchased as well as home supplied inputs. Though the cost of home supplied inputs are difficult to calculate in monetary terms those are calculated on the basis of opportunity cost principle. Opportunity cost of an input is defined as an income that it is capable of earning from alternative employment in or outside the farm. For calculating economic returns, per acre returns from the option used by farmers were broadly classified into gross return, gross margin and net return. The value of the maize grain was used to estimate the gross returns. Existing market prices were considered. In calculating the production cost, maize seeds and human labor were considered.

3.6.2.1 Computation of gross return

Gross return was calculated by multiplying the total volume of maize production by the average prices (the average of the farm gate price) of maize in the harvesting period. The following equation was used to calculate gross return.

$$GR_m = Q_m P_m \quad \text{...} (6)$$

Where:

GR_m = Gross return (Shs/acre) from maize crops of individual cropping system

Q_m = Quantity of maize grain (kg/acre) of maize in individual cropping system

P_m = Unit price (Shs/kg) of maize grain

3.6.2.2 Computation of total cost

Total cost (TC) includes all types of variable costs involved in the production process. The variable cost was estimated as follows:

$$VC = X_i P_{xi} \quad \text{...} (7)$$

Where:

VC = Total variable cost (Shs/acre),

X_i = Quantity (kg/ha) of the ith variable input,

P_{xi} = Per unit price (Shs/kg) of the ith variable input

3.6.2.3 Computation of farmers' profit (gross margin and net return)

Farmers' profits were computed by gross margin (GM) analysis with the following equation:

$$GM = TR - TVC \qquad \text{...(8)}$$

Where:

GM = Average gross margin in Shs/acre,

TR = Average total revenue (gross return) in Shs/acre.

TVC = Total variable cost (Shs/acre),

The information for gross margin (GM) and gross margin ratio (GMR) was organized as in the template below (Table 3).

Table 3: The gross margin outline

Item	Amount	Total
Sales/Revenue		
Total Revenue		....
Variable costs	....	
Land preparation	....	
Input costs	....	
Labour costs		
Total Variable Costs		....
Gross margin (GM)	....	

3.6.3 Partial budgeting analysis

Partial budgeting was to get a more systematic picture of the comparative advantage of the technology options (with and without green manures) in maize production system. The method tabulates the expected gains due to a relatively minor change (marginal) as a result of proposed change. The farmers' objective was to increase maize production due to incorporation of green manure in their farms. The partial budgeting analysis was done by:

(i) Identifying all operations that were/will be performed (the elements in the production process that are different, such as labour requirements). For green manures, these included seedling production. incorporation in the field, including land preparation and maintenance (weeding).

(ii) Estimating the quantities (quantify inputs that are different for the technologies) of inputs for each operation (i.e., labour) and determining the 'field price' of labour whether it is cash cost or an opportunity cost (i.e., quantity used times field price) for each input. The price was multiplied by the number of units to get a total cost for that input.

(iii) Quantifying outputs, valuing them and determining a 'field price' for outputs, whether sold or used by the household. The price was multiplied by the number of units to get a total value for the benefit. The information of partial budgeting analysis was organizing as in the template below (Table 4).

Table 4: The Partial budget outline

Budget item	Value (Tsh)	
Added revenue- List the items of income from the new technology that will not be received from the existing technology.	——	
Reduced expenses- List the items of expense for the existing technology that will be avoided with the new technology.	——	
Added revenue plus reduced expenses (total credits).		——
Added expenses- List the items of income from the existing technology that will not be received from the new technology.	——	
*Reduced revenue-*List the items of expense from the new technology that are not required with the existing technology.	——	
Added expenses plus reduced revenue (total debits).		——
*Difference-*A positive (negative) difference indicates that the net benefits the existing technology by the amount shown of the new technology exceed (are less than) the net benefits of. (change in net farm income).		——

3.6.4 Investment analysis

Analysing the differences in net income in maize cropping with and without green manure systems is very important in finding the best alternative option to be adopted by farmers. In this study, a financial analysis was used for comparing the costs and benefits between maize cropping with and without green manures. The main steps in this analysis are:

- Identifying the costs and benefits of each treatment
- Evaluating the costs and benefits of each treatment
- Comparing the costs and benefits between soil erosion control treatments.

The cash flow running for five years for both options were prepared to show the movement of cash into and out from the options. The time of cash flows into and out from maize cropping with and without green manures options were used as inputs in financial models such as Benefit-Cost Ratio (BCR) and Net Present Value (NPV). The NPV and BCR were used to compare the benefit of maize cropping with and without green manures.

In financial appraisal this principle was accommodated by discounting to produce a net present value (NPV). Its application allows future income receipts from the investment to be expressed in terms of (lower) 'present values'. The basic technique for calculating the NPV is to discount costs and benefits occurring in different periods and express them all at a common value at any one point of time. According to this criterion, the investment is said to economically efficient if the NPV is greater than zero. The formula of the NPV is as follows:

$$NPV = \frac{TR_1 - TVC_1}{(1+i)^1} + \frac{TR_2 - TVC_2}{(1+i)^2} + \frac{TR_t - TVC_t}{(1+i)^t} \text{..........................} (9)$$

Where:

NPV = Discounted net benefits in Tshs,

TR= Total revenue or benefits from year t,

TVC= Total variable costs in year t,

i = Discount rate in percentage

t= time in year

Discount rate: The choice of discount rate is important because the main costs generally occur early on with the main benefits flowing several years later. The higher the discount rate the lower the present value of benefits compared to the discounted costs and the more likely that the benefit-cost comparison will be unfavourable (Godsey, 2003). The discount rate (opportunity cost of capital) used in this study was taken as 20% (Tanzania Government Treasury Bond rate). It is also the rate charged by a local finance company (personal observation).

The estimation equation for the BCR is given below:

$$\text{BCR} = \left[\frac{TR_1}{(1+i)^1} + \ldots + \frac{TR_t}{(1+i)^t}\right] \div \left[\frac{TVC_1}{(1+i)^1} + \ldots + \frac{TVC_t}{(1+i)^t}\right] \text{...................} (10)$$

In this case, if the ratio is greater than 1, it means that an investment could be economically worthwhile and vice versa is true. If it is exactly 1, the investment produces zero net benefits over lifetime.

3.7 Limitations of the study methodology

The limitations of the study methodology emanated from the areas of data availability and reliability. Most data were collected from farmers who do not keep farm records regularly, thus their responses depend on their memories of respective issues. Such data can hardly be fully reliable. Farmers had problems of memory recall and some could not estimate some of the research parameters like farm size, output harvested per area, amount sold, consumed and convention of local measurements like Kiroba to metric measures (e.g. Kilogram). In some cases the researcher had to rely on their rough estimates. Farmers under this study had the same shortcomings thus reliability of collected data could somehow be carrying the same weakness. However, much computational task was done in order to convert answers in to proper units of measures because many units were not standardized. Farmers' income and cost of production (variable costs) were obtained through calculating on average bases.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Socio-economic Characteristics of Respondents

Results in Table 5 shows that most (67.2 %) of respondents are married, 20.2% are single, 8.4% are widowed while 4.2% were divorced. This finding has an implication that many married couples concentrate more on production and thus may influence efficiency in production. Chiduo, (2001) found that married people have better chances of venturing in on-farm activities than people who are not married.

The age of respondents range considerably from 18 years to a maximum of 65 years with mean age of 42 years. About 65.5% of the respondents are within the age range of 18–45 years of age, 18.5% are within the age range of 46–55 years of age while 16.0% of them are above 55 years of age. The mean age indicate that most of the respondents belong to the productive group with long-term term- experience in farming and financially stronger with capital to invest in green manure technology.

Majority (62.4%) of the respondents had attained primary education, 11.6% had attained adult education, 13.4% had secondary education and 12.6 % of the respondents had no formal education. This shows that the population is relative literate. This particularly has implication of the types of extension method that can be used for them. Farmers can support better and adopt the green manure technology.

Table 5: Distribution of the respondents' socio-economic characteristics

Socio-economic characteristics	Villages (%)		Total Percent
	Mapatano	Mtakuja	
Marital status			
Single	12(20 0)	13(20.3)	25(20.2)
Married	39 (65.0)	41(69.5)	80(67.2)
Divorced	3(5.0)	2(3.4)	5(4.2)
Widow	6(10.0)	4(6.8)	10 (8.4)
Total			120(100.0)
Age			
18-45 years	36(60.0)	43(71.2)	79(65.5)
46-55 years	11(18.3)	11(18.6)	22(18.5)
Above 55 years	13(20.1)	6(10.2)	19(16.0)
Total			120(100.0)
Education			
No formal	5(8.3)	10(16.9)	15(12.6)
Adult education	9(15.0)	5(8.5)	14(11.6)
Primary education	36(60.0)	39(64.4)	75(62.4)
Secondary education	10(16.7)	6(10.2)	16(13.4)
Total			120(100.0)
Occupation			
Farming	41(68.3)	37(62.7)	78(65.5)
Off farm (e.g. small business)	11(18.3)	15(23.7)	26(21.0)
Faming and Casual labour	8(13.3)	8(13.6)	16(13.5)
Total			120(100.0)
Household size			
1-3 people	3(5.0)	8(13.6)	11(9.2)
4-6 people	48(80.0)	42(69.5)	90(74.8)
≥ 7 people	9(15.0)	10(16.9)	19(16.0)
Total			120(100.0)
Farm size			
0.5-2 ha	30(50.0)	29(47.5)	59(48.7)
3-5 ha	22(36.7)	20(33.9)	42(35.3)
≥ 6 ha	8(13.3)	11(18.6)	19(16.0)
Total			120(100.0)

Numbers in brackets are parentage of respondents

Most (65.5%) of the respondents are involved in farming activities as a major livelihood source. 21% are involved off-farm activities, 13.5% depended on farming and casual labour. Since the green manure technology is associated with a higher cash disposal to invest in additional cost (such as human labour), farmers have financial capacity to invest in soil resource to overcome the problem of soil nutrition depletion.

The household size of the respondents ranged between 3 and 13 members with the average household size of 4.78 members. About 74.8% of the respondents have between 4–6 members family size, 9.2% of them have between 1-3 members family sizes while 16.0% of them have seven and above members. The average family size in this study is the same as that obtained at Mkinga District Agriculture and Livestock Development Office in 2007 (Table 2). Family size per household is important in determining the levels of production and consumption in a family. The implication of household size is the availability of productive human labour within the family to adopt green manure technology. Senkondo (1992) also reported that family size is used to determine the available labour for farm work basing on the extent of contribution of each in farm work. However, the implication of large family sizes to risk farmer's especially rural women is additional burden because they would have to spend more time attending them.

Farm size ranged from 0.5 acre to 13 acres with an average of 2.3 acres per household. Most 48.7% of the respondents had farm sizes between 0.5-2 acres, 35.3% had farm sizes between 3-5 acres while 16.0% of them had farm sizes above six acres. Their farm sizes are generally small, which is due to their restricted access to production resources.

4.2 Farmers' Perceptions of Green Manure Technology

Farmers in the study area used three types of green manures (*Mucuna puriens*, *Canavalia ensiformis* and *Crotalaria ochroleuca*) as an alternative to improve soil fertility. Some of the green manure species were used by farmers in combination and others alone. Farmers with limited land intercropped the green manures crops (*Mucuna*, *Canavalia* or *Crotalaria*) with maize toward the middle of the growing season, with the idea that their major growth would occur during the dry season, thereby using land that would not ordinarily be under cultivation. The method was used to avoid the decrease of production of maize crop at the first season and hence increases in the crop in succeeding years.

Farmer assessment and ranking of intensified green manures legume technologies during group discussion roughly revealed interesting aspects about smallholder farm-level investment decision making in soil fertility management. Farmers consistently ranked maize after *Mucuna puriens* as best technology over *Canavalia ensiformis* and *Crotalaria ochroleuca*. Farmers reported that *Mucuna puriens* is a heavy biomass producer (the amount of biomass from *Mucuna* is higher than that of *Crotalaria*), provides ground cover for moisture retention suppresses persistently troublesome weeds especially witchweed (*Striga* sp.). The proportion of leafy plant parts of *Mucuna* is higher than those of *Crotalaria* as reported by farmers during the discussion. Weed control could thus be achieved with little cash expenditures.

Farmers also observed that degraded land patches in the maize fields, where further cultivation does not yield anything as a result of soil fertility depletion, may be reclaimed by replacing establishing continuous *Mucuna puriens* intercrop/rotation system with maize in a way that involve little opportunity cost of labour and cash resources. Farmers in the study area adopted *Mucuna puriens* due to its land productivity attributes such as fertilizer effects, moisture conservation and easily established. However, labour demands for the *Mucuna* biomass is high due to its extensive rooting system, often reduces farmer's preference of this technology.

4.3 Economic Viability of Maize Cropping Systems

The study assessed the performance of maize cropping with and without green manure technology using gross margin. This analysis was specifically used to assess the profitability of maize with and without green manure systems based on the accrued costs and benefits of green manure utilization in maize production systems. Detailed calculation is found in Appendix 2, 3 and 4.

4.3.1 Yields

Farmers with green manure in the study area adopted two planting options of green manure. In the first option, green manures such as *Mucuna* was planted in a pure stand at the start of the rainy season and maize crop followed in the next season/year (*Mucuna* staggering). In the second option, green manures were intercropped with maize toward the middle or end of the growing season, with the idea that their major growth would occur during the dry season. The reason for *Mucuna*/maize intercrop is that subsistence farmers need to cultivate and harvest something each year. The two options were compared from maize cropping without green manure. The two options were compared with maize cropping without green manures (maize after maize).

Results show that the average yield were 374kg/acre and 906kg/acre in maize staggered with *Mucuna* and maize intercropped with *Mucuna* respectively (Table 6). The average yield in maize cropping without green manure is low (340.2kg/acre) when compared with two options of planting green manures.

Table 6: Comparison of maize yields in planting options of green manure

Year	Average maize production (Kg/acre)		
	Maize/green manure intercroped	Maize staggering with green manure	Maize without green manure (Maize after maize)
1	785	0	375
2	890	905	368
3	930	0	333
4	950	965	325
5	975	0	300
Total	4 530	1 870	1 701
Average	906.0	374.0	304.2

4.3.2 Costs

The labour used in farm works in Mkinga was mainly family labour. However, a cultivation practice that requires hired labour was considered in this study. Therefore, all calculations were carried out with inclusion of family labour in the production costs associated to the options adopted by farmers. The scenarios with the exclusion of family labour cost seem more meaningful for poor farmers. The opportunity cost of labour used in the case of family labour was Tsh 1 500 per workday, which is the common price of hired labour in the District.

Results show that the average variable cost associated in *Mucuna*/maize staggered was Tsh 89 700 per acre, which was lowest than that of maize without *Mucuna* (Tsh 137 970) and (Tsh 144 440) of *Mucuna*/maize inter crop (Table 7). Higher portion of variable cost in *Mucuna*/maize intercrop was incurred for using human labor in maize cropping with green manure performed by human labor for planting and incorporating of green manures in maize farms in each year.

Table 7: Comparison of costs in planting options of green manure

Year	Maize/green manure intercroped	Maize/green manure staggered	Maize without green manure (Maize after maize)
1	135 500	74 000	125 000
2	147 100	102 600	131 950
3	147 700	58 750	133 600
4	130 900	97 150	148 850
5	161 000	116 000	150 450
Total	722 200	448 500	689 850
Average	144 440	89 700	137 970

4.3.3 Gross margins

The gross margin (Table 8) was higher in maize when inter cropped *Mucuna* (Tsh 215 920 per acre). Farmers benefits yearly as gross margin increases yearly. With increase of gross margin, farmers might be willing to adopt the technology of green manure consequently, enhancing poverty alleviation.

The gross margin in maize staggered with *Mucuna* was Tsh 58 629 per acre. After one year farmers gets higher gross margin. The following years, farmers does not realize attracting yield. This planting option delays the strategy of reducing rural poverty. Consequently, not desirable for poor farmers.

The negative value of the gross margin in maize without green manure option was attributed due to high costs associated with weeding and land preparation with low returns. The low returns is due inability of the soil to support development of maize and competitions to the nutrients as a results of high infestations of *striga* in the fields. This implies that the planting option is ineffective. Consequently, poverty reduction will not be achieved.

Table 8: Average gross margin for maize production over five years cycle

Planting options	Maize/green manure	green manure staggered	Maize without green manure
Revenue	360 360	148 320	134 024.4
Variable costs	144 440	89 700	137 970
Gross Margin	215 920	58 629	-3 945.6

The difference in gross margin was achieved through increased maize yields due to shift from maize cropping without green manure to maize cropping with green manure. The increase in maize yields was likely due to the nitrogen replenishing ability of the green manures through biological nitrogen fixation and nitrogen release from incorporation of the residues from green manure which resulted in residual soil fertility for the subsequent rotation of maize crop with green manures.

The price of land (fixed cost) was difficult to identify by farmers. However, as mentioned by Chiduo (2001), there is no need to value the land if farmers want to change existing land use to a new technology because it would be canceled out in a "with" and "without" comparison. Thus, for simplicity and with the assumption that the value of land is the same and does not change over time for both cultivation practices, it was neglected from the calculations. This implies that the fixed cost was zero and the net return was equal as gross margin.

4.3.5 Partial budgeting

A partial budget (Table 9) was done to compare the net farm income for maize cropping with green manure technology and maize cropping without green manures. This is in relation to the following question: Should a farmer use green manures or should not use green manures? How could farmers choose green manures while having the option to of not using green manures?

Table 9: Partial budget of *Mucuna*/maize intercrops vs. maize without *Mucuna*

Budget items	Value (Tshs)	
Added revenue- income from maize cropping with green manure technology that was not received from maize cropping without green manures technology.		
▪ Maize yields from green manure technology utilization (906kg × Tsh 396 /kg)	58 776.0	
Reduced expenses- expense for the maize cropping without green manure technology that was avoided with maize cropping with green manure technology.		
▪ Total labour hours without green manure technology (91.98 h × Tsh1500 /h)	137 970.0	
Added revenue plus reduced expenses (total credits)		496 746.0
Reduced revenue- income from maize cropping without green manure technology that was not received from maize cropping with green manure technology.		
▪ Maize yields from without green manure technology (304.2kg × Tsh 396 /kg)	120 463.2	
Added expenses- expense from maize cropping with green manure technology that was not required with maize cropping without green manure technology.		
▪ Total labour hours with green manure technology (96.30 h × Tsh 1500/h)	144 450.0	
Added expenses plus reduced revenue (total debits)		264 913.2
Difference (positive net farm income/gain)		231 832.8

The difference between the credits and debits is Tsh 231 832.8. This is the change in the return to farmers using green manure technology. A positive difference indicates that the net benefits (net farm income) in maize cropping with green manure technology exceed the net benefits of maize cropping without green manure. The partial budget showed that *Mucuna*/maize intercrop option was economically feasible than maize grown without *Mucuna*. The change from sole crop to *Mucuna*/maize intercrop is beneficial to farmers.

4.4 Investment Analysis for Maize Production

To determine the best planting options of green manure technology for soil fertility improvement, a financial cost-benefit analysis was carried out on technological treatments of soil conservation. This is based on the hypothesis that in the long run, farmers growing maize with green manures systems would receive higher net farm incomes compared with farmers without green manures systems.

The financial analysis was based on current prices of outputs and inputs. The results were expressed in the net present value (NPV) and (BCR) using a 20% rate of discount. The life-span for calculating NPV and BCR was five years for the two planting options of green manure (maize intercropped with *Mucuna* and maize staggered with *Mucuna*). The investment analysis of maize without *Mucuna* was performed for comparison.

Under maize intercropped with *Mucuna*, the yield of maize was highest (906Kg/acre), and the material and labour cost lowest compared with other planting options. The soil became fertile because of high nitrogen replenishment ability through biological nitrogen fixation and nitrogen release from incorporation of the residues (green manures) for maize production. The present value of net benefit (NPV) and Benefit Cost Ratio (BCR) was Tsh 612 806.8 and 2.4 respectively at 20% discount rate with a life span of five years (Table 10). These results suggest that growing maize intercropped with *Mucuna* is a suitable form of soil conservation technology for farmers.

Table 10 : NPV and BCR for maize production systems maize intercropped with green manure

Year =	1	2	3	4	5
Revenue	282600	336420	368280	393300	421200
Cost	135500	147100	147700	130900	161000
R – C (Net)	147100	189320	220580	262400	260200
Discounting factor	1.2	1.4	1.7	2.1	2.5
Annual Cash Flows	122583.3	131472.2	127650.5	126518.8	104582.0
PVR	235500.0	233625.0	213125.0	189633.6	169292.6
PVC	112916.7	102152.8	85474.5	63114.8	64710.6

- Net Present Value (NPV) = sum of discounted annual cash flows
  = Tsh 612 806.8, an option with positive NPVis a 'go'
- Sum Present Value Revenue (PVR) = 1041176.20
- Sum Present Value Cost (PVC) = 428369.4
- $B/C = \frac{\sum PVR}{\sum PVC} = \frac{1041176.2}{428369.4} = 2.4$, greater than one, hence 'go'

Under maize *Mucuna*/maize staggered, the returns were lower than that under the *Mucuna*/maize intercrop, the NPV and BCR was Tsh 612 806.8 and 1.7

respectively at 20% discount rate with a life span of five years (Table 11). Under this planting option. material and labour costs were higher compared with the *Mucuna*/maize intercrop. Therefore, this planting option is not so good for poor farmers compared to Mucuna/maize intercrop.

Table 11 : NPV and BCR for maize production systems maize/green manure staggered

Year =	1	2	3	4	5
Revenue	0	342090	0	399510	0
Cost	74000	102600	58750	97150	116000
R – C (Net)	-74000	239490	-58750	302360	-116000
Discounting factor	1.2	1.4	1.7	2.1	2.5
Annual Cash Flows	-61666.7	166312.5	-33998.8	145785.9	-46623.8
PVR	0	237562.5	0	192627.8	0
PVC	61666.7	71250.0	33998.8	46841.9	46623.8

- Net Present Value (NPV) = sum of discounted annual cash flows
  = Tsh 169 809.1, an option with positive NPVis a 'go'
- Sum Present Value Revenue (PVR) =430190.3
- Sum Present Value Cost (PVR) = 260381.2
- $B/C = \frac{\sum PV}{PVC} = \frac{430190.3}{260381.2} = 1.7$, greater than one, hence 'go'

Under maize cropping without *Mucuna* the profitability was low. The yield of maize was low due to high soil loss. The labour cost was higher than that for the other planting options because the labour requirement for land preparation and weed control was high for this treatment. Therefore, the net present value of the net benefit was negative (NPV of Tsh -2 976.0) and the Benefit Cost Ratio was less than one ($BCR = 0.9$). These results indicate that farming systems without soil conservation practices will not be financially viable in the long run (Table 12).

Table 12 : NPV and BCR for maize production systems without green manure

Year =	1	2	3	4	5
Revenue (R)	135000	139104	131868	134550	129600
Cost (C)	125000	131950	133600	148850	150450
R – C (Net)	10000	7154	-1732	-14300	-20850
Discounting factor	1.2	1.4	1.7	2.1	2.5
Annual Cash Flows	8333.3	4968.1	-1002.3	-6894.9	-8380.2
PVR	112500	96600	76312.5	64874.64	52090.0
PVC	104166.7	91631.9	77314.8	71769.5	60470.3

- Net Present Value (NPV) = sum of discounted annual cash flows
  = Tsh -2976.0, an option with negative NPV, hence no 'go'
- Sum Present Value Revenue (PVR) = 402377.17
- Sum Present Value Cost (PVR) = 405353.21
- $B/C = \frac{\sum PV}{\sum PVC} = \frac{402377.2}{405353.2} = 0.9$, less than one, hence no 'go'

4.5 Rewarding Option for Maize Production Systems

(i) Based on gross margin results in maize intercropped with *Mucuna* was positive and higher (Tsh 215 920 per acre). This was achieved through increased maize yields for an average 906Kg/acre over five years. Therefore, growing maize intercropped green manure is most rewarding option to farmers for use. Partial budgeting results show that the difference between the credits and debits was Tsh 79 740. This is the change in the return to farmers due to green manure technology utilization. The change from sole crop to either *Mucuna* staggered or *Mucuna*/maize intercrop is beneficial to farmers.

(ii) Based on farmers' perceptions, the increase in maize yields was due to the nitrogen replenishing ability of the green manures through biological nitrogen fixation and nitrogen release from incorporation of the residues from green manure which resulted in residual soil fertility for the subsequent rotation/intercrop of maize crop with green manures. In addition. green manure (*Mucuna puriens*) was preferred by farmers due to its ease establishment, land productivity attributes. moisture retention. ease of land preparation and ability to suppress persistently troublesome weeds.This suggest that maize cropping with green manures is the best alternative option for farmers to use.

(iii) Weeding which is done by the risk-averse farmers, especially women. usually by hand has been described as one of the most demanding jobs in farming. The continued use of hand weeding as means of controlling weeds for the small holder farmers has been demanding more household labour thus resulting to farmers failing to timely weed their farms and in many cases not weeding their fields at all. This adversely resulted into low agricultural production and ultimately predisposed small holder farmers to household food insecurity and poverty. Also. high household labour demand for weeding forced households to use children labour, thus resulting to children not attending classes. This again led to illiteracy and ultimately households becoming vulnerable to poverty. The use maize cropping with green manure is efficient and small holder user friendly. The technology help farmers to weed their field timely and save household labour (women and children) time and effort, thus reducing drudgery and time spent in the field. This suggests that the option is suitable for farmers to use.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The following conclusions can be drawn from this study:

(i) The economic viability in maize cropping with and without green manures on farmers' livelihoods was based on gross margin and partial budgeting analyses. *Mucuna*/maize intercrop and *Mucuna*/maize staggered options had positive and above zero gross margin implying that the total variable costs in five years were recovered. However, the gross margin in maize cropping without green manures was negative. This implies that the total variable cost in this option was not recovered. The higher net benefits obtained in maize cropping with green manure was achieved through increased maize yields due to the nitrogen replenishing ability of the green manures through biological nitrogen fixation and nitrogen release from incorporation of the residues which resulted in residual soil fertility for the subsequent rotation/intercrop of maize crop with green manures. Based on partial budgeting analysis, the shift from growing maize without green manures to maize cropping with green manures gives a positive net farm income, implying that farmers' choice for maize cropping with green manure technology is rational.

(ii) Technology of incorporating green manure is more viable than without green manure. This is confirmed by NPV and BCR. Contribution of green manure on farmer's production is positive.

5.2 Recommendations

The recommendations are intended to 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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APPENDICES

Appendix 1: A questionnaire used during the data collection process

CONTRIBUTION OF GREEN MANURE ON SMALLHOLDER MAIZE PRODUCTION SYSTEMS IN TANZANIA: A CASE OF MKINGA DISTRICT, TANGA REGION

SECTION A- PART I: IDENTIFICATION PARTICULARS

1. Name of the interviewer____________________________________
2. Date of Interview____
3. Name of the village____
4. Name of Head of Household__________________________________
5. Questionnaire ID:____

SECTION A- PART II: SOCIO-ECONOMIC CHARACTERISTICS OF THE HOUSEHOLD

1. Gender of person being interviewed 1) Female2) Male
2 Age of respondent ______________________________
3. Level of education for the household 1) No formal education 2) Adult education 3) Primary education 4) Secondary education 5) Other (specify) .. .. [ ]
4. Marital status 1) single 2) married 3) divorced 4) widowed [ ]
5. How many people are in your household? [ ]
6. How many children of 8 to 14 years are in your household? [ ]
7. How many males, of 15 years and above are in your household? [ ]
8. How many females, of 15 years and above are in your household [ ]

9. What is principal occupation of the household members?
1) Farming 2) Officially employed 3) Casual laborer 4) Business (Specify) 5) other (specify) ( ).............. [ ]

SECTION B - PART I: DECISION-MAKING IN THE HOUSEHOLD

10. In the household, who is mainly involved in the farming? _______

11. Who makes the decisions concerning soil fertility replenishment? _____

12. Who makes the decisions concerning use and adoption of new agricultural technologies or practices?________

Codes for Qsns. 10 to 12

1= Wife 2= Husband 3= Co-wife 4= Son 5= Daughter 6= Mother

7= Father 8= ouse helper/ farm labourer 10= others (specify)

SECTION B- PART II: ACCESS TO SERVICES

13. Have you received extension services on (1) Yes [ ] (2) No [ ]

14 [If yes], how many times a year do you receive visits from extension services? _______

SECTION C: GREEN MANURE ESTABLISHMENT, MANAGEMENT, USE, & EXPERIENCE

15 Who first came to know about green manure in the household? _______

16. From what source, did you come to learn of green manure use? [ ]

1. Muheza Maize Project 2. Extension officer 3. Other farmers

4. NGOs 5. Others (specify) ______

17. How long have you been using green manure systems in maize production? _

18. What was the primary reason for planting it on your farm? [ ]

1. To suppress weeds 2. Animal feeds 3. Medical purposes 4. To increase maize yield 5. Others (specify) ______

19. Who planted the green manure? ________________________________

20 Who manages the green manures? ______________________________

21. How do you compare the overall soil fertility of plots planted with green manure, now and before planting green manure? 1) Increased 2) Decreased 3) Same 4) Don't Know [ ]

22. What limitation have you encountered when establishing green manure in your farm?

1) Associated with insects and pests 2) High labour requirement Unavailability of seeds 3) Inadequate seeds 4) Lack of technical back up 5) lack of equipment for residue incorporation 6) Drought [ ]

SECTION D: LAND & PLOT CHARACTERISTICS

23. Who owns land in this house hold? ______________________________

24. Number or parcels of land owned by this household______________________

25. Approximate size of farm (sum of all parcels) ______________________

26 Why did the farmer decide to plant some plots with green manure and not the others? ____

SECTION E: FARM BUDGETS

28. Indicate costs and returns in maize production with and without green manure?

	Without green manure(farmers' practice)		With green manure (e.g. mucuna)	
	Season 1	Season 2	Season 1	Season 2
A. Returns				
Maize yield in Kg per acre				
Producer price (Tshs/Kg)				
Total Returns per acre				
B. Cost of inputs/labour costs (Tshs/acre)				
Field preparation				
Costs of maize seeds (Kg/acre)				
Maize seed sowing				
Planting of green manure				
Incorporation of green manures				
Weeding 1				
Maize harvesting yield				
Transport of maize from the field				
Total cost per acre				
Net Benefits				

Appendix 2: Gross margin analysis of maize/green manure staggered

Items	Year 1	Year 2	Year 3	Year 4	Year 5	Total	Average
I. COSTS							
Maize seeds	0	2100	0	2400	0	4500	900
Land preparation	23000	22500	20500	18500	16500	10140	20280
Planting maize	0	22000	0	24000	0	46000	9200
Planting green manures	20000	0	25500	0	28000	73500	14700
Cots for incorporating	12000	0	0	0	19000	31000	6200
1st weeding	13000	10500	8500	7450	6500	45950	9190
2nd weeding	6000	4500	4250	3400	3000	21150	4230
Harvesting and shelling	0	35000	0	32500	33500	101000	20200
Storage cost	0	6000	0	8500	9500	24000	4800
Total costs	74000	102600	58750	97150	116000	448500	89700
II. REVENUE							
Sale of maize (Kg)	0	905	0	965	0	1870	374
Price (Shs/Kg)	0	378	0	414	0		
Revenue	0	342090	0	399510	0	741600	148320
Gross margin (Revenue less costs)	-74000	239490	-58750	302360	-116000	293100	58620

Appendix 3: Gross margin analysis of maize intercropped with green manure

Items	Year 1	Year 2	Year 3	Year 4	Year 5	Total	Average
I. COSTS							
Maize seeds	2000	2100	2200	2400	2500	11200	2240
Land preparation	23000	25000	28000	30000	31000	137000	27400
Planting maize	20000	22000	23000	24000	25000	114000	22800
Planting green manures	20000	24000	25500	2000	28000	99500	19900
Cots for incorporating	12000	15000	16500	17500	19000	80000	16000
1st weeding	13000	12500	10000	9500	8500	53500	10700
2nd weeding	6000	5500	5000	4500	4000	25000	5000
Harvesting and shelling	34000	35000	30000	32500	33500	165000	33000
Storage cost	5500	6000	7500	8500	9500	37000	7400
Total variable costs	135500	147100	147700	130900	161000	722200	144440
II. REVENUE							
Sale of maize (Kg)	785	890	930	950	975	4530	906
Price (Shs/Kg)	360	378	396	414	432		
Revenue	282600	336420	368280	393300	421200	1801800	360360
Gross margin (Revenue less costs)	147100	189320	220580	262400	260200	1079600	215920

Appendix 4: Gross margin analysis of maize cropping without green manure

Items	Year 1	Year 2	Year 3	Year 4	Year 5	Total	Average
I. COSTS							
Maize seeds	2000	2100	2200	2400	2500	11200	2240
Land preparation	27000	27850	29550	37500	38000	159900	31980
Planting maize	20000	22000	23000	26000	28000	119000	23800
1st weeding	25000	26500	27000	30950	31000	140450	28090
2nd weeding	24000	25500	26850	29500	30450	136300	27260
Harvesting and shelling	19000	20000	18500	16500	15000	89000	17800
Storage costs	8000	8000	6500	6000	5500	34000	6800
Total variable costs	125000	131950	133600	148850	150450	689850	137970
II. REVENUE							
Sales of maize (Kg)	375	368	333	325	300	1701	340.2
Price (Kg)	360	378	396	414	432		
Total Revenue	135000	139104	131868	134550	129600	670122	134024.4
Gross margin (Revenue less costs)	10000	7154	-1732	-14300	-20850	-19728	-3945.6