Adoption of Soil Fertility Improvement Techologies Among Smallholder Farmers in Southern Malawi

Linda Lindizgani Robert Chinangwa

NORWEGIAN UNIVERSITY OF LIFE SCIENCES
DEPARTMENT OF INTERNATIONAL ENVIRONMENT and DEVELOPMENT STUDIES (NORAGRIC)

MASTER THESIS 30 CREDITS 2006

The Department of International Environment and Development Studies, Noragric, is the international gateway for the Norwegian University of Life Sciences (UMB), eight departments, associated research institutions and the Norwegian College of Veterinary Medicine in Oslo. Established in 1986, Noragric's contribution to international development lies in the interface between research, education (Bachelor, Master and PhD programmes) and assignments.

The Noragric Master theses are the final theses submitted by students in order to fulfil the requirements under the Noragric Master programme "Management of Natural Resources and Sustainable Agriculture" (MNRSA), "Development Studies" and other Master programmes.

The findings in this thesis do not necessarily reflect the views of Noragric. Extracts from this publication may only be reproduced after prior consultation with the author and on condition that the source is indicated. For rights of reproduction or translation contact Noragric.

© Linda Lindizgani Robert Chinangwa, May 2006.
e-mail: zgani1980@yahoo.com

Noragric
Department of International Environment and Development Studies
P.O. Box 5003
N-1432 Ås
Norway
Tel.: +47 64 96 52 00
Fax: +47 64 96 52 01
Internet: http://www.umb.no/noragric

DECLARATION

This thesis has not previously been accepted for any degree and is not being concurrently submitted in candidature of any other degree. This work is the result of my own investigation. All other sources of information are acknowledged and a reference list appended.

Linda Lindizgani Robert Chinangwa

Signature…………………………….

Date………………………………......

DEDICATION

To my mother, for giving me the wings to fly; to my father for giving me the reason to fight. You hold a special place in my heart.

Parents, because of you I can!!

ACKNOWLEDGEMENT

I would like to thank Dr Jens Aune, my supervisor for the encouragement, technical assistance, advice and guidance from the early stages of proposal formulation to write up of the thesis. I'm grateful to Dr Wilkson Makumba, for his input in the formulation of the questionaire and his technical assistance during my research in Malawi.

Special thanks go to Noragric staff for your contribution to my studies in one way or the other and to NORAD-Nowergian Agency for Development for granting me the scholarship to carry out my Msc studies. I am grateful for the support given to me by my Director, Mr Mlenga and all the staff of the Department of Land Resources Conservation, Minisrty of Agriculture Malawi.

To my bothers; Kondani, Tonda, Robert and Walter, my sister Ruth and my nephew Tikondayani, the times I share with you, I cherish, now and always (*Mukanozga kuwako*). To my friends, thank you for the friendship, I am grateful for the times we have come to know each other and the times we have shared during the course of my study.

To ***God***, I can never thank you enough you for all you have done in my life. *Am forever grateful.*

Finally to ***You***, I say thank you for the love, friendship and support. *I love you.*

ABSTRACT

Land degradation and soil erosion are significant environmental problems affecting agricultural productivity and livelihood in Malawi. A number of soil fertility improvement technologies are being promoted by the Ministry of Agriculture and non governmental organization, in order to improve agricultural productivity and food security. The thesis examines farmer's perception of the current level of soil fertility and factors effecting farmers use of different soil fertility improvement technologies. The study was carried in Machinga Agriculture Development Division, Machinga and Zomba districts. Household questionnaire, key informants interview and literature review were used as tools for data collection. A total of 97 households were interviewed. About 73% of farmers perceive that the current level of soil fertility as low and 62%, perceived that soil fertility will continue to decline. The overall reason for using different soil fertility improvement technology is to improve crop yield for household consumption and cash income. Farmers use inorganic and organic fertilizers for soil fertility improvement. The majority of farmers (83%) prefer to use inorganic fertilizers. High price was mentioned as the main factor limiting use of inorganic fertilizer. Therefore, percentage farmer's use of inorganic fertilizer increased with increase in income level. Labor demand limits farmer's use of agroforestry practices. Increase in the number of farmers inheriting land will reduce the use of agro forestry technologies ($p\leq 0.01$). Most female headed families (55%) use compost manure. Use of compost manure decreased with increase in off farm income ($p\leq 0.01$). Livestock manure use is affected by livestock holding sizes. Use of livestock manure increased with increase in livestock holding size ($p\leq 0.01$). Farmer participation in farmer groups also increased use of compost and livestock manure, $p\leq 0.01$ and $p\leq 0.05$, respectively. About 39% of farmers combine organic and inorganic fertilizer for soil fertility improvement. Farmer use of different soil fertility improvement technologies is affected by technology characteristics and different socio- economic factors.

LIST OF ACRONYMS AND ABBREVIATIONS

ADD	Agricultural Development Division
ADMARC	Agricultural Development Marketing Cooperation
CTA	Technical Centre for Agroforestry and Rural Development
DLRC	Department of Land Resources Conservation
DREA	Department of Research and Environmental Affairs
EIU	Economic Intelligence Unit (USA)
EPA	Extension Planning Area
FAO	Food Agricultural Organisation
ICRAF	International Centre for Agroforestry Research
MADD	Machinga Agricultural Development Division
MAFE	Malawi Agroforestry Extension
MK	Malawi Kwacha
MoFFEA	Ministry of Forestry Fisheries and Environmental Affairs
NGO	Non Governmental Organisation
SER	State of Environmental Report
SFFRF	Smallholder Farmer Fertilizer Revolving Fund
SPSS	Statistical Package for Social Scientists
US$	United States Dollar

TABLE OF CONTENTS

DECLARATION..i

DEDICATION...ii

ACKNOWLEDGEMENT……………………………………………………………..…..iii

ABSTRACT...iv

LIST OF ACRONYMS AND ABBREVIATIONS……………………………………...v

TABLE OF CONTENTS.. vi

LIST OF TABLES ……………………………………………………………………viii

LIST OF FIGURES…………………………………………………………………..ix

1 INTRODUCTION.. 1

1.1 BACKGROUND 1

1.2 PROBLEM STATEMENT 2

1.3 RATIONALE OF THE STUDY 3

1.4 RESEARCH QUESTIONS.. 4

2 LITERATURE REVIEW.. 5

2.1 SOIL FERTILITY IN MALAWI... 5

2.2 POLICY BACKGROUND ON SOIL FERTILTY IMPROVEMENT INITIATIVES 6

2.3 SOIL FERTILITY IMPROVEMENT METHODS.. 8

2.3.1Inorganic fertilizers 9

2.3.2Agroforestry practices 9

2.3.2.1Intercropping of Glicidia sepium and maize 10

2.3.2.2. Improved fallow 11

2.3.2.3Annual relay fallow cropping.. 13

2.3.3Livestock manure 14

2.3.4Compost manure.. 15

2.3.5Early ploughing and crop residue management 15

2.4 FARMER TECHNOLOGY ADOPTION 16

3 METHODOLOGY 19

3.1 DESCRIPTION OF STUDY AREA 19

3.1.1Location and demography 19

3.1.2 Livilihoods in the research area 21

3.1.3Soils and climate 21

3.1.4Farming practices 22

3.2 SURVEY METHODS 22

3.3 DATA COLLECTION METHODS 23

3.3.1Household Questionnaire 23

3.3.2Key Informants interviews 23

3.4 DATA WEAKNESS 24

3.5 METHODS OF ANALYSIS 24

4 RESULTS AND DISCUSSION 25

4.1 FARMER'S PERCEPTION OF SOIL FERTILITY PROBLEMS 25

4.2 ADAPTATION TO DECLINING SOIL FERTILITY 27

4.3 FACTORS INFLUENCING USE OF SOIL FERTILTY IMRPOVEMENT TECHNOLOGY 35

4.3.1Inorganic fertilizer 36

4.3.2Agroforestry 38

4.3.3Compost manure 41

4.3.4Livestock Manure 44

4.3.5Integration soil fertility Improvement method 46

4.4 ACCESS TO TECHNICAL SUPPORT……………………………..……….48

5 CONCLUSION 49

6 REFERENCE 51

7 APPENDIX 1: HOUSEHOLD SURVEY QUESTIONNAIRE 57

List of Tables

Table 1: Financial Analysis of *Gliricidia* system in Net benefits 11

Table 2: Financial profitability of maize production systems under improved fallow per ..... hectare over a five-year cycle 13

Table 3: Maize yields at Songani Watershed, Machinga, 1998 14

Table 4: Logistic regression showing factors affecting farmer use of Inorganic fertilizer 36

Table 5: Inorganic fertilizer use by access to credit 37

Table 6: Logistic regression showing factor affecting farmer use of agroforestry technologies 38

Table 7: Compost manure use by gender 42

Table 8: Logistic regression showing factors affecting farmer use of compost manure 42

Table 9: Logistic regression showing factors affecting farmer use of livestock manure..…44

Table 10: Logistic regression showing factors affecting use of integrated methods 46

List of Figures

Figure 1: Inorganic fertilizer prices, Kwacha/ metric ton, in Malawi 7

Figure 2: Farmers perception of the current soil fertility level 26

Figure 3: Farmer's perceived future changes in soil fertility levels.................................... 26

Figure 4: Percentage of farmers using different of soil fertility improvement technologies 27

Figure 5: Farmers preference of different agroforestry tree species 30

Figure 6: Percentage of farmers practicing agroforestry technologies according to years of practice 31

Figure 7: Preference of farmers soil fertility improvement technology use depending on crop type 33

Figure 8: Preference of farmers soil fertility improvement technology use according to terrain category 34

Figure 9: Percentage of farmers using inorganic fertilizer at different estimated annual labour income levels 37

Figure 10: Percentage of farmers practicing agroforestry according to levels of education 40

Figure 11: Percentage of farmers practicing agroforestry according to months they experience food shortage *41*

List of Maps

Map 1: Map of Malawi showing the study districts ……………………………………….20

1 INTRODUCTION

1.1 Background

Land degradation and soil nutrient depletion have become serious threats to agricultural productivity in sub- Saharan Africa. Most arable lands have been affected by degradation thereby reducing agricultural productivity, which in turn results in poor economic growth of countries (Bekele, 2003).Ultimately this results in abject poverty and high incidences of food insecurity among the population that depend on agriculture for livelihood. The continued threat to land resources is exacerbated by the need to reduce poverty and poor farming practices, especially among smallholder farmers.

The National Environment Action Plan for Malawi isolates soil degradation as the most serious environmental problem facing modern Malawi (Malawi Government, 1994). Agriculture dominates the economy, with about 80% of Malawians reliant on subsistence farming as an income source (Malawi Government, 2002). Therefore, land degradation and soil erosion may be the most significant environmental issues affecting livelihoods in Malawi, because they undermine the foundation of the economy.

Malawi's population is growing at a rate of 2% (EIU, 2004), leading to land shortages and continuous arable cultivation without fallowing. About 55% of the smallholder farmers have less than one hectare land to cultivate (Bunderson and Hayes, 1995), which is insufficient to meet the basic food needs of the family. The result is intense pressure on available land and natural resources leading to soil erosion and fertility loss. This leads to more insecure households and stagnating economic growth. The present soil fertility loss will affect not only the yield level today, but also the yield of succeeding years (Bekele, 2003). Hence, this will affect agricultural productivity and the economy in the succeeding years. Therefore, ensuring high levels of agriculture productivity, improved economic status and household food security remains a major challenge for smallholder farmers in Malawi.

To improve agriculture production, the government of Malawi, has been promoting soil fertility replenishing technologies through nutrient inputs from organic and inorganic sources. However, the replenishment of soil fertility from inorganic fertilizers is constrained by prohibitive purchase prices (Phiri *et al.,* 1999). In response to this challenge, the government of Malawi aims at maintaining soil's productive capacity, by increasing the area under low cost soil fertility improvement technologies (Malawi Government, 2002). Research has lead to recommendation of a range of low external input technologies, of proven effectiveness, for soil fertility improvement (Whiteside and Carr, 1997) like agroforestry. The adoption of such technologies on the other hand is depended on the technology requirements and farmers resource endowments.

1.2 Problem statement

One of the biophysical constraints to increasing agriculture productivity is the low fertility of the soils (Bekunda *et al.,* 1997). Improving soil fertility levels has become an important issue in development agendas because of its linkage to food insecurity and economic well being of the population (Ajayi *et al.*, 2003).

The use of inorganic fertilizers is an option for replenishing soil fertility for increased agriculture production. However, the replenishment of soil fertility with inorganic fertilizers at the recommended rate and appropriate time is constrained by high price of fertilizer and delivery delays. Transport and other costs like duties and taxes, double the international price of fertilizer by the time it reaches Malawi (Donovan, 1996). In order to address the fertilizer price problem and enhance smallholder agricultural productivity, the government of Malawi used to subsidize agriculture production inputs. Due to the structural adjustment programs required by the World Bank and other donors, Malawi removed inorganic fertilizer subsidies (Sahn *et al.,* 1990). Therefore, inorganic fertilizer option remains unattainable to most of the smallholder farmers. This has led to a reduction in the use of inorganic fertilizers that were commonly used by farmers to replenish soil fertility. This is a challenging situation given the increase in population and low adoption rates of low cost organic fertilizer. Therefore, government policies have a significant influence in farmer's decisions regarding soil fertility improvement technologies.

Most farmers in Malawi have options for modifying their farming practices in response to declining soil fertility. Depending upon site and other local conditions and nature of technology, a given technology maybe profitable and others not. Thus, it is difficult to draw general conclusion about the overall attractiveness of adopting soil fertility improvement technologies.

The use of inorganic fertilizers as an option for improving soil fertility and productivity, has immediate results, but is unaffordable for most farmers. In spite of the growing awareness of low cost soil fertility technologies, the rate of adoption and continued use of the technologies remain limited. Experiences of agroforestry show that, though there is much interest in agro forestry among farmers, adoption rates are still low (CTA/MAFE, 2002). The study seeks to understand factors that influence farmer’s choices of the different soil fertility improvement technologies.

1.3 Rationale of the study

Research to date has predominantly focused on the biophysical aspects, with attention given mainly to yield benefits from researcher-managed plots. Studies have been done on biological aspects of soil fertility replenishment technologies and number of users of the different technologies separately in Malawi. However, few studies have been conducted on the socio-economic aspects of farming households and how they affect household choice of soil fertility improvement methods. Therefore the purpose of this study will be to add knowledge to the existing literature on agriculture technology adoption among small scale farmers in Malawi.

Uptake of soil fertility improvement technologies, such as agroforestry technologies by farmers is usually based on certain social (including acceptance rather than coercion) and economic benefits in addition to the biophysical aspects of the technologies (Thangata *et al.,* 2001). In order to scale up the use and promote wider adoption of improved agriculture technologies, it is important to identify factors that influence technology use and adoption by farm household; what category of farmers will use a given technology; why other farmers continue to use technologies and others do not. It is also important to establish the various constraints as regards to the use of a particular technology. Farmer perception of technology characteristics significantly affects adoption decisions (Adesina and Baidu-Forson, 1995). Therefore, in order to explain farmer’s adoption of soil fertility improvement technologies, it is important to understand the constraints of the technology.

Inorganic fertilizers and organic fertilizers are the available options for improving soil fertility for smallholder farmers in Malawi. In the study, the conditions that make farmers to use a combination of inorganic fertilizer and organic materials were studied. Further more, farmer's perception on use of inorganic and organic fertilizers as whether competitive or complimentary, was studied.

Adoption of technologies can not take place in a policy vacuum, but needs to be facilitated by appropriate policy and institutional incentives (Ajayi *et al.,* 2003). Therefore, the study tries to establish the impact of policy changes on farmer's use of different soil fertility improvement technologies and agriculture productivity. Understanding these factors, will provide insights for designing appropriate strategies, policies and programs that will promote adoption of soil fertility improvement technologies. The knowledge gained could be used by policy makers, researchers, extension providers and farmers to enhance relevance of technology use and likelihood of adoption with regard to farmer's environment and situations.

1.4 Research questions

In order to achieve the objectives of the research, the following research questions will guide the research:

1. What is the farmer's perception of current soil fertility levels?
2. What are the factors that influence smallholder farmer's use and adoption of the soil fertility improvement technologies?
3. Is there a complementary or competitive relationship in farmer use of inorganic fertilizers and organic soil fertility improvement methods?

2 LITERATURE REVIEW

2.1 Soil fertility in Malawi

Soil fertility is mainly related to top soil characteristics. Soil fertility largely depends on soil organic matter content, which besides supplying nutrients, ensures good physical conditions necessary for water infiltration, supply of soil moisture, aeration and plant root development (MoFFEA, 1998). Soil erosion and declining soil fertility ranks as serious environmental problems in Malawi, contributing to low crop yields (DREA, 1994). Although crop yields are not directly correlated to the amount of organic matter in the soil, the lack of it will cause the breakdown of soil structure, increased runoff, accelerate erosion and increase soil compaction that will prevent the development of a healthy root system and cause a reduction in nutrient and water availability to the plant (FAO, 1999 as in Environmental Affairs Department, 2002). Therefore, low crop yields are no longer attributed just to lack of rains, but also to declining soil fertility.

In Malawi, as in most developing countries, harsh climatic conditions, population pressure, land constraints, and the decline of traditional soil management practices have led to reduced soil fertility (Gruhn, 2000). Most soils in Malawi are deficient either in nitrogen (N), phosphorous (P) and sulphur (S) and micro nutrients or a combination of two or more nutrient elements (Mughogho, 1989 as in Environmental Affairs Department, 2002). However, N is the most deficient nutrient nearly in all soils in Malawi (Bundersons and Hayes, 1995) and P is the second limiting nutrient (Makumba, 2003).

The high population growth rate, create an imbalance between population and the natural resource base, significantly impacting on the overall context of the Malawi economy and the environment (MoFFEA, 1998). Since land is a constant natural resource, with increased population in Malawi, land holding sizes are small to meet food requirement. This has led to opening of new farm lands in marginal areas and continuous cultivation to meet consumption needs, resulting in loss of regenerative capacity of the soils in essential nutrients and environmental degradation, which in turn have resulted in declining agriculture production.

The majority of smallholder farmers in Malawi practice unimproved traditional methods of cultivation, leading to soil exhaustion, and increasing need for inputs. Most farmers apply no or minimum improved inputs, soil and water conservation technologies are not practiced, and generally, the adoption rate for most land husbandry technologies is low (MoFFEA, 1998). Most farmers are poor in resources, hence though the use of inorganic fertilizer may be recommended; most smallholder farmers cannot afford to use inorganic fertilizer. The organic matter from the crop residues and nutrients that are present in the crop residues can be used to improve the soil structure and fertility but these are also lost during the burning of the crop residues during land preparation (Environmental Affairs Department, 2002). Poor policy environment and lack of capacity by extension service with regard to soil fertility, has been highlighted as one contributing factor to declining soil fertility (DLRC, annual report 2004). These factors have resulted in acute soil fertility problems under smallholder farm conditions (Saka *et al.,* 1998).

The prevention of the degradation of the environment (including land) is enshrined under the new Constitution of Malawi adopted in 1994 and the government will ensure that measures are in place to reduce land degradation (Malawi Government, 2002). Several Malawian organizations are engaged in implementing activities that strengthen the capacity of communities to manage their natural resources (MoFFEA, 1998).

2.2 Policy background on soil fertility improvement initiatives

Policies provide guide and an environment for farmer decision making process. Farmers' decision for uptake and use of the soil fertility improvement technologies is to an extent influenced by the policy environment, goals and strategies in the country. Pre-independence agriculture in Malawi was based on colonial administration. The population was low and there were few estates. Shifting cultivation was a way of restoring soil fertility. Malawi gained independence in 1964 and the focus for a food secure country was a priority of the government. The government recommended the use of inorganic fertilizers for smallholders in order to improve crop production and to restore soil fertility. The government worked at promoting better land management system and increasing access to agriculture inputs, through subsidized fertilizer and credit. There was a parastatal monopoly on maize and fertilizer marketing (ADMARC). Subsidies for inorganic fertilizer prices and credit enabled both smallholder and commercial farmers to use inorganic fertilizers.

In the 1980's through the 90's structural adjustment, slowly led to the gradual removal of subsidies and breakdown of credit programs. This was a requirement by the World Bank and other donors (Sahn *et al.,* 1990). April 1995, all input and output prices were set free except for a maize price band (Kherallah and Govindan, 1997). The Smallholder farmers buy their fertilizer in local currency (Kwacha), and therefore devaluation has had a major impact on the price (Carr, 1997), since all fertilizers used in Malawi are imported. Public sector used to have monopoly in procurement and distribution of fertilizer till 1994, when fertilizer market was liberalized, since then any firm can import and sell to the smallholder or estate (Øygard *et al.,* 2003). Removal of fertilizer subsidies, liberalized fertilizer markets and devaluation of the Malawi Kwacha, (in mid 1990), resulted into an increase in fertilizer prices through the 1980's and 1990's (Figure 1).

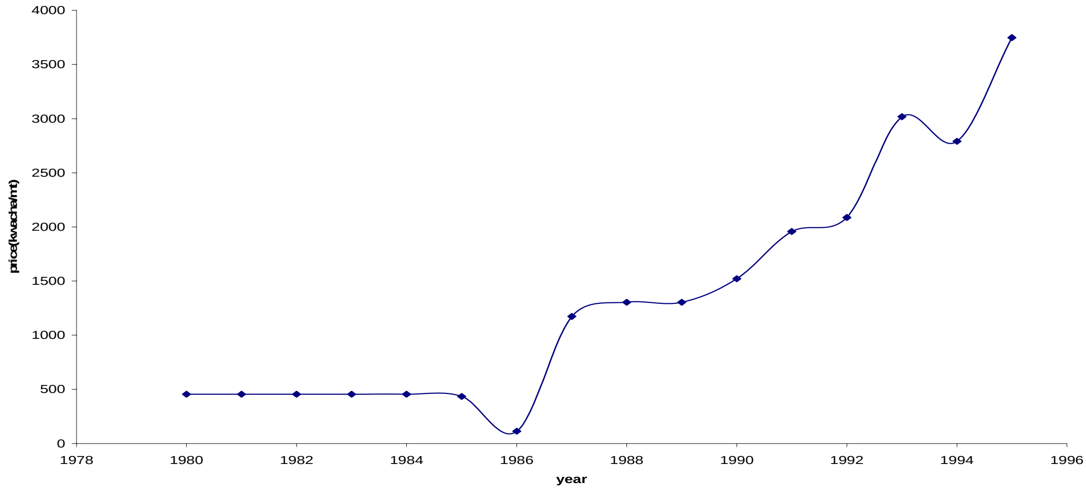


Figure 1: Inorganic fertilizer prices, Kwacha/ metric ton, in Malawi (1980-1996)
Source: FAOSTAT database (2006)

In Malawi, the use of inorganic fertilizers to replenish soil fertility declined by more than 50% between 1988 and 1997 (Carr, 1997). Mineral fertilizers used to be widely used, but poverty and the limited profitability of farming mean that less than 50% of smallholders use any fertilizer, and about 70% use less than one bag of fertilizer per hectare (Kanyama- Phiri *et al.,* 2000). Lack of credits, variable returns and high costs of fertilizer, make farmers seldom apply the recommended fertilizer rates and appropriate time (Sanchez *et al.,* 1997).

These changes presented a change in the socio economic environment of smallholder farmers. Low soil fertility is one factor that contributes to poor maize production. Maize is equated with food, therefore, government and farmers had to find a way for soil fertility improvement in order to improve conditions for subsistence household. The government put in place a number of programmes to increase use of inorganic fertilizers for poor smallholder farmers. For example, in the seasons 2000/01 to 2001/2002 the government distributed free agriculture input packs in the Targeted Input Programme (TIP), which included inorganic fertilizer (Øygard, 2005). The input pack targeted the poorest smallholder households. The input packet comprised a free pack of inorganic fertilizer and hybrid maize seed for cultivating 0.1 ha, a small amount of legume seeds for intercropping. This was accompanied by an extension message to help farmer to try the technologies under their own conditions and appreciating their results and adopting them. This contributed to an increase in fertilizer consumption in 2002. Currently, the government is running a rationed fertilizer subsidy program for smallholder farmers. Every smallholder household, for the 2005/06 season, is supposed to be allowed to buy at a heavily subsidized price, a limited amount of fertilizer (100 kg per maize growing household, plus 150 kg in addition for those who also grow tobacco) through two parastatals, ADMARC and SFFRF (Øygard, 2005). Therefore, fertilizer consumption is expected to increase and in turn improve agriculture production and food security in the country.

Despite the Government programmes to improve farmers' access of inorganic fertilizers, a large part of the population can not afford the cost therefore, still faced with declining crop yield due to declining soil fertility. In response to these challenges, the Government of Malawi is promoting use of alternative low cost soil fertility improvement technologies. Research has lead to the recommendation of a range of low external soil fertility input technologies, of proven effectiveness, for soil fertility improvement.

2.3 Soil fertility improvement methods

A number of soil fertility improvement technologies are being promoted by the government arm in the Ministry of Agriculture and non governmental organization, in order to improve agricultural sustainability and livelihood security. The soil fertility improvement technologies include inorganic fertilizer, livestock and compost manure, agroforestry and legumes, especially Soya beans, groundnuts and pigeon peas. Agroforestry include, simultaneous intercropping with

Gliricidia, undersowing and improved fallows of *Tephrosia vogelii* and *Sesbania sesban*, systematic inter-planting of *Faidherbia albida* and other soil improving trees.

2.3.1 Inorganic fertilizers

All fertilizers used in Malawi are imported and the government has been encouraging the use of high analysis fertilizer to save on transport and foreign exchange costs (Kherallah and Govindan, 1997). Use of inorganic fertilizers is one way of overcoming soil fertility depletion and increase crop yield. Biophysically there is nothing wrong with proper use of inorganic fertilizers, as they provide the same nutrients as organic sources (Sanchez *et al.,* 1997). However, if no organic matter is applied, continuous application of inorganic fertilizers may lead to reduction in productivity of clay soils which dominates Africa (Akinnifesi and Kwesinga, 2002).

In Malawi, new area-specific fertilizer recommendation have been developed considering profitability and soil texture (Waddington *et al.,* 2004), however, the majority of farmers use the blanket fertilizer recommendation which is 92 kg N/ha, 40 kg P and 20 kg K/ha for the hybrid maize in Malawi (Makumba, personal communication, 2006). Inorganic has to be applied twice, as a basal and top dressing. Application of basal and top dressing inorganic fertilizers ensures that crops have enough nutrients throughout their growth. Time of application is important because crops need to have sufficient nutrients at the right stages of growth. Fertilizer applied at tasseling is not fully utilized and results in low yield (Kumwenda *et al.,* 1996). Agronomic nitrogen use efficiency depends, among other things, on crop and crop variety, climatic factors, soil fertility, weed pressure, methods of application and rates of application (Kamanga *et al.,* 2001).

2.3.2 Agroforestry practices

Agroforestry involves deliberate growing of the trees, shrubs and grasses in and around crop fields in various ways to provide overall resource benefits. Agroforestry trees have great potential for improving soil fertility in areas dominated by N deficiency (Kwesiga *et al.,* 1999). In areas where P is also a major limiting factor, inorganic sources of P should be used. Besides improving soil fertility, agroforestry technologies provide benefits such as fuelwood, poles, fodder, and help reduce soil erosion (MoFFEA, 1998). The fuelwood from agroforestry systems is a highly valued added advantage in an area with an acute shortage of fuelwood (Maghembe *et* *al*., 1997 as in Ngugi 2002). Impact assessment of the agroforestry technologies in the ICRAF Zambezi Basin Agroforestry Project, showed that, the supply of firewood increased by 90% for farmers in Malawi and 26% reported to have spent less time on collecting firewood (Akinnifesi *et al.,* 2005).

Agroforestry was introduced in Malawi in 1984 by the Department of Agricultural Research of the Ministry of Agriculture (Makumba, 2003). In the study area, agroforestry technologies were predominantly introduced and promoted by ICRAF since 1994. Agroforestry technologies for soil fertility improvement being promoted include, intercropping of *Glicidia sepium* and maize, improved fallow and annual relay cropping.

2.3.2.1 *Intercropping of Glicidia sepium and maize*

Gliricidia sepium is a nitrogen-fixing tree from Central America which can tolerate continuous cutting back, can be mixed in and grown with crops in the field (Böhringer, 2001). Maize and *Gliricidia sepium* are established concurrently on the same plot. The maize is grown in row between the tree rows. The *Glicidia sepium* is established in every second furrow, spaced at a distance of 1.5m between tree rows and the trees are spaced at 90cm within row (Makumba, 2003). There are two maize ridges at a distance of 75 cm, between the *Glicidia sepium* tree rows. The tree growth is kept in check by pruning back at the beginning of the season and at regular intervals during the growing season to prevent maize shading (Ngugi, 2002). The nitrogen rich tree prunings are left on the plot to provide organic matter, which help to improve the soil's fertility and structure. *Gliricidia sepium* has coppicing ability therefore farmers can maintain the trees on farm without replanting for over 15year (Kwesinga *el at.,* 2003). The main objective is to achieve household food security in situations where the availability of land is limited, such as parts of southern Malawi, where population densities are over 100 persons/km^2 (Böhringer, 2001). *Gliricidia sepium* is termite resistant, drought tolerant and generally not grazed although it can be used for fodder if dried (MoFFEA, 1998).

In the Shire Highlands in Malawi, as many as 2–4 pruning are obtained each year, giving 2–7 t/ha of biomass(Ngugi, 2002). The nitrogen equivalent that is added to the soil through the biomass ranges from 60 to 120 kg/ha/yr (Ikerra *et al.,* 1999). Maize yield in *Gliricidia sepium* plots during the first and second year of establishment are similar to those from non-fertilized plots (Ngugi, 2002). Yields from the third year onwards, however, are markedly increased by *Gliricidia sepium* manuring to an average of 1800–2500 kg/ha. Therefore, one limitation of the technology is the three year lag period before its benefits become visible (Böhringer, 2001). *Gliricidia* and *Leucaena* coppicing fallows at Chipata, Zambia, have maintained maize yields at 3.5t/ha over six seasons without fertilizer applications (Mafongoya *et al.,* 2001). Research at Makoka and application of the technology at nearby farms has shown that *Gliricidia sepium* intercropping helps to rejuvenate the soil and to improve soil fertility, without the use of fertilizer (ICRAF, 2006). Financial analysis, Table 1, has shown that *Gliricidia* has increased net benefit of 2.62 times over sole maize.

Table 1: Financial Analysis of *Gliricidia* system in Net benefits (Malawi Kwacha)

Production System	1995/96	1996/97	1997/98	1998/99	1999/00	Sum
Sole maize	6270	1742	4218	3070	(359)	14,941
Gliricidia intercropping	4857	1650	11808	14330	6635	39,280
Sesbania relay	6476	2853	10440	9817	4007	33,593

Source: Akinnifesi et al, 2005, On-Farm Assessment of Agroforestry Technologies for Fertility Replenishment in Malawi.

2.3.2.2 . *Improved fallow*

A piece of land is dedicated to fallowing with nitrogen fixing species for a minimum of two growing seasons, no crops are planted and the trees take up the entire field for at least one season (Böhringer, 2001). Therefore improved fallows benefit farmers in the form of increasing crop yield, representing increased returns to land and labour (Kwesinga *el at.,* 2003). Three tree species are favoured for improved fallow are; *Tephrosia vogelli*, *Tephrosia candida* and *Sesbania sesban*. This technology requires a substantial amount of land, therefore, fallowing to restore for soil fertility is a practical option where land is not a limiting factor like in northern and central regions of Malawi. Many parts of the southern region of Malawi including Zomba and Machinga, population is dense and the land holding sizes are very small and fragmented. However, even in areas where farm size is too small to accommodate fallows, niches where land is left fallow for one reason or another can be used for the improved fallow technology (CTA/MAFE, 2002). Farmers have also intensified improved fallows by intercropping during the first year when the trees are being established (Böhringer, 2001).

Two and three-year *Sesbania sesban*-based fallows have proved highly effective in soil fertility restoration in the region, particularly in Zambia (Ngugi, 2002). For example, maize grain yield following a 3-year *Sesbania sesban* fallow without N fertilizer in Chipata, Zambia was 2.27, 5.59 and 6.02 t/ha after 1, 2 and 3 years fallow respectively, compared with the control plots with 1.6, 1.2, 1.8t/ha after 1, 2 and 3 years of continuous cropping (Kwesiga *et al*., 1994 as in Ngugi, 2002). Over a six year period from 1988 to 1993, *sebania* improved fallows showed that they required less than half the amount of labour needed for one hectare of continuously cropped maize (Kwesinga *el at*, 2003).

The main requirement for the technologies success is the availability of land, high demand for labour, availability of water and need for pest protection (Bohringer, 2001). In Malawi over 1000 farmers were experimenting with improved fallows, relay cropping and mixed intercropping with *Gliricidia* (ICRAF, 1998). Economic analysis showed a higher cost benefit ratio in maize production per hectare over a five year cycle, for farmers using *Tephrosia*, *Sesbania* and *Glicidia* as fallow options as compared to farmers planting maize continuously without any form of fertilizer (Table 2). Use of inorganic fertilizers also showed a higher cost benefit ratio over unfertilized maize (Table 2), therefore farmers growing unfertilized maize operated at a loss, considering investments in labour and other inputs.

Table 2: Financial profitability of maize production systems under improved fallow per hectare over a five-year cycle

Enterprise /Land use subsystem	Net present value (US$)	(US$) per year	Benefit Cost ratio
maize without fertilizer	130	26	2.01
maize with fertilizer	499	100	2.65
Glicidia sepium fallow	269	54	2.91
Sesbania fallow	309	62	3.31
Tephrosia Vogelli fallow	233	47	2.77

Source: Ajayi, O. 2004 'Regional Highlights: Economics, Policy & Characterization for Scaling up Agroforestry options' (Akinnifesi et al., 2005).

2.3.2.3 *Annual relay fallow cropping*

Nitrogen fixing trees are planted into a field at a time when crops, preferably maize, have already been established (Kwesinga *el at.,* 2003). This reduces competition between crop and tree shrub for resources. *Tephrosia vogelli, T. Candida*, *Sesbania sesban and Sesbania macrantha and Crotalia spicies* agroforestry species are preferred for this technology. The tree rows are spaced at a distance 4.5m and the intra row trees spacing is 30 cm (Makumba, 2003). Planting of trees is delayed for about two weeks after maize has been planted at the onset of the season. After harvesting the maize crop, the trees are left to grow during the ensuing dry season, utilizing residual moisture. At the beginning of the next season, these trees are chopped and woody parts removed before incorporating all the leaves and litters into the soil as green manure. The process is repeated annually (ICRAF, 2006). The technology would be suitable for the densely populated southern Malawi, where farm sizes are too small to accommodate normal rotational fallows. The advantage of this system is that farmers do not have to wait for the fallow phase of 2 years in the sequential system, or for the initial period of tree establishment for coppicing fallows (Akinnifesi *et al.,* 2005). Limitations of the technology include labour for establishing the trees every year and dependency on late rainfall for trees to become established (Böhringer, 2001). During drier years, the trees produces less biomass hence its residual benefits to the maize crop diminishes (Kwesinga *et al.,* 2003).

Makoka Research Station, Malawi, demonstrated higher maize yields from relay-cropped plots than from plots that had been continuously monocropped with maize without fertilizers, although the application of fertilizers resulted in the highest yields of all (Ngugi, 2002). Studies in Sogani watershed in Machinga, show that, Agroforestry proved superior over fertilized and unfertilized maize in a very difficult year and poor soils (Table 3). Maize yield was increased by 68% over sole maize in *Tephrosia* and *Sesbania* annual relay fallows.

Table 3: Maize yields at Songani Watershed, Machinga, 1998 (n=48 farmers)

Treatment	Maize grain Yield (kg/ha)	%Yield Increase over sole unfertilized maize
Unfertilized maize (maize stover)	327	0
Sesbania biomass only	591	81
Tephrosia biomass only	548	68
Pigeonpea biomass only	348	0.06
Maize + half N dose (48kgN)	1137	248
Sesbania + half N doze(48 kgN)	1645	403
Tephrosia + half N doze(48 kgN)	1451	344
Pigeon pea + half N doze(48 kgN)	1188	263

Source: Kamanga, B.C.G., G.Y. Kanyama-Phiri and S. Minae (1999). African Crop Science Journal 7: (4) 355-363

2.3.3 Livestock manure

In areas where there are sufficient livestock, the manure from the kraal or khola is one of sources of organic fertilizer. The organic material from livestock helps bind the soil particles to improve structure, and also improve the ability of the soil to hold nutrients (MoFFEA, 1998). In Malawi livestock holdings are reduced in recent years, that means less manure is available. Due to limited availability of livestock manure, farmers prefer to integrate the use of livestock manure with other form of technologies, which include the use of livestock manure as a compost booster. The manure may be applied at each planting pocket maize field. Research shows that the most efficient use of manure is to combine it with some inorganic fertilizer (Murwira, 1994). Station-placement or dribbling into the planting furrow, rather than broadcast application, are promising ways of increasing the crop yield benefits from cattle manure (Kumwenda *et al.,* 1996)

2.3.4 Compost manure

Compost manure is affordable and easy to make, using maize stalks and other biodegradable substances. Use of compost can help soils to retain both water and nutrients hence an alternative to inorganic fertilizers. The most common practice for composting in Malawi involves use of pit which is dug, 1 m deep and 1.5 in widths. The composting materials which include crop residue, dry leaves, grass or municipal wastes and manure, are moistened and left in a pit for varying lengths of time to decompose. The composting time vary from 3 to 6 months before the compost is mature and ready to use.

The fertilizer value and other benefits of the material will depend on the source materials, the conditions under which it was made and the maturity of the compost when it is applied (Canadian Organic growers, 1992). In general, however, the process results in a net improvement in soil fertility, and crop yield (ibid).

The use of compost manure has been relatively low over the years, since 1994. However, the launch of compost manure by the State President in 2002/ 2003 boosted use of compost manure by smallholder farmer. The involvement of the State president portrayed the importance of the technology and governments commitment in promotion of low cost soil fertility improvement technologies agriculture production.

2.3.5 Early ploughing and crop residue management

Undertaken soon after harvest while the soil is still moist, allows incorporation and decomposition of trash and crop residues which improves the organic matter status of the soil and reduces the fertilizer requirement of the next crop. Although the nutrient content of maize stover is relatively low, stover can contribute to the productivity of the soil (Kumwenda *et al.,* 1996). Early ploughing also removes transpiring plants/weeds and leaves a broken soil layer which helps conserve the moisture in the soil for the next crop (MoFFEA, 1998). Therefore unless crop residues have to be destroyed to prevent diseases or pest as in tobacco or cotton, crop residues have to be incorporated into the soil for maintenance of soil fertility and structure. However, it is noted that improperly managed crop wastes can reduce plant growth in the following season (ibid).

2.4 Farmer technology adoption

Farmers make decisions about adopting new technologies as part of the overall strategy for ensuring subsistence and cash income needs. Farmers will invest in improving land and fertility if it is a critical part of their livelihood strategy. The different livelihood strategies pursued by farmers have significant implications for the types of technologies they adopt (Thangata *et al.,* 2001).

Adoption potential, from farmer's perspective can be considered to have three components: feasibility, profitability and acceptability (Swinkles and Franzel, 1997). Feasibility is the capacity of the farmer to manage technology. The farmer should have the required information and resource to maintain the soil fertility improvement technology (ibid). Technologies that are promoted should therefore take into account the resource limited farm households. Technology characteristics plays a role in influencing diffusion process and farmers decision making of adoption of technologies (Vedeld and Krogh, 2001), as regards to farmers resources and capability to manage the technology. The economic constraints of a household to access resources influence the ability and willingness to adopt technological innovations (Vedeld 1990). Higher income farmers may be less risk averse, have more access to information, and have greater capacity to mobilize resources including information hence a high level of innovativeness can be expected from them (Reij and Waters- Bayer 2001). However, for soil fertility improvement technologies, poor farmers may be more willing to adopt low cost technologies, like organic fertilizers. Farmers' knowledge of the usefulness of improving their soil fertility will enhance their willingness to substitute inorganic fertilizer, which is expensive, with low cost technologies.

Profitability is concerned with the financial benefit obtained from using the technology. The benefits should be higher than the use of an alternative technology as well as the current practice (Franzel, 1999). Innovations should have relative advantage compared to others such as saving time, reducing drudgery or improving income level (Vedeld and Krogh, 2001). However sometimes agricultural innovations fail to meet expected benefit due to: unpredictable climatic conditions, which are very crucial for agricultural innovations; and poor implementation if farmer does not understand how the technology works, or the complexity of the technology.

Acceptability of technologies depends on willingness of the farmer in using a certain technology depending on household characteristic and goals. In addition to profitability and feasibility farmer will consider certain criteria as such as risk, gender aspects, cultural acceptance and compatibility with the enterprise in order to accept a technology (Vanclay and Lawrence, 1994). Farmers will adopt technologies that do not require major changes in the management system of the farm, cultural and social values. Add-on technologies are likely to be adopted than practices that require major land use change, even where significant economic advantages can be demonstrated in the case of the latter. Therefore to increase acceptability of technology it is important to identify and analyze the factors that affect adoption in differing households.

Transfer of technology to the farmers has an important influence on adoption of technology. Farmers lack information and knowledge about innovations, hence the innovation diffusion model, by Negatu and Parikh (1999), argues that a technology has to be transmitted from a researcher to farmers through competent extension services (Rogers, 1995). The dynamics of transfer of knowledge is partly a political issue (Scoones, 1994). To make extension more effective in serving farmers needs and institutionally more sustainable, the Government of Malawi and its partners in the agricultural sector have formulated a demand driven extension service (Malawi Government, 2002). This approach allows farmer participation in the delivery system by providing a forum for multidirectional communication between farmers and extension staff. This integrates local knowledge in the system of extension service, therefore fostering the adoption of agricultural technologies including soil fertility improvement technologies. For efficient service delivery, the extension worker pre-service and in-service training is essential for technical preparation and dissemination of extension messages.

Agricultural research has developed technologies that have not been fully adopted by smallholder farmers because of high cost of the technologies and inadequate linkage between the research, extension and farmers needs (Malawi government, 2002). This requires enhancing the partnership between research and farmers. Researchers and farmers together need to understand the circumstances, problems, and preferences of rural households and how these vary among different types of farmers. Participatory techniques are available to ensure that farmers take the lead in this diagnostic process (Chambers *et al.,* 1989).

Communities are heterogeneous in socio economic characters, including gender, age, sex, marital status, occupation and education levels. These characteristics reflect differences in decision making related to preferences and utility of resources (Vedeld, 1990). Those who are prompted to adopt innovations have similar characteristics, they have frequent contact with extension workers, have higher levels of education, have positive attitude to change and relative income and standard living (Ban and Hawkin, 1988).

3 METHODOLOGY

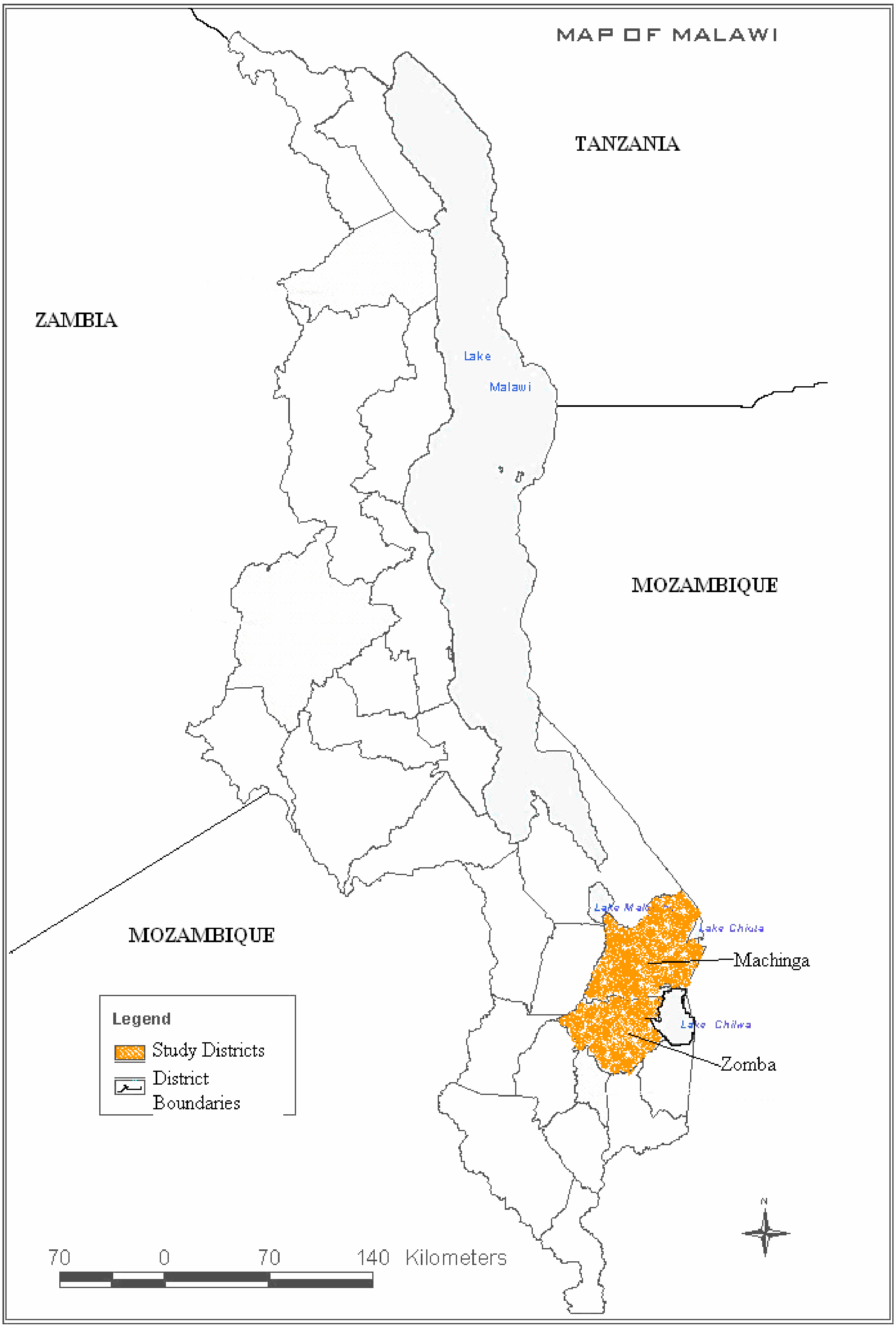
3.1 Description of study area

3.1.1 Location and demography

Malawi a landlocked country in Southern Africa (9^o to 17^o S and 33^o to 36^o E), covers an area of 118,484 square kilometers, of which 61% is arable land, 20% is water bodies and 19% is covered by human settlements, public infrastructure and forest reserves. The country is bordered by the republic of Tanzania to the North and North east, Mozambique to the East, south and South west and by Zambia to the west. The climate is tropical continental with two distinct seasons, the rainy season from November to April and the dry season from May to October. Annual rainfall in Malawi ranges from 700 to 1800mm. The rains start in the Southern Region and progress northwards. The mean annual minimum and maximum temperatures for Malawi range from 12 to 32 degrees Celsius.

The study was conducted in Zomba and Machinga districts in southern Malawi (Map 1). Agricultural activities in the area are coordinated under Machinga Agricultural Development Division (MADD). Farmer interviews were conducted in Thondwe, Dzaone, Malosa and Mtubwi, Extension planning areas (EPA) under the MADD. These EPAs were selected on the basis that a number of organizations e.g. ICRAF, World Vision, Hunger project, Greenline Movement and Ministry of Agriculture have worked with the farmers from these EPAs on various soil fertility improvement technologies.

The average land holding size in the area is less than 0.4 ha. The people in the area have a matrilineal system, which has an effect on access and ownership to land. Land is largely owned through inheritance. The study area is close to the municipality of Zomba, where most of the farm produce is sold on the markets.



Map 1: Map of Malawi showing the study districts

3.1.2 Livelihoods in the study area

The main source of livelihoods in the study area is agriculture. Most of the farmers have fragmented farm plots and face food shortages on an average of two to three months of the year. Farmers sell their agriculture produce like maize, bean and groundnut for cash income, and supplement with vegetables. Selling is done within the village and near by market points which are at an average distance of 2km. To diversify their income sources, farmers take up seasonal wage labour on other farms and own small scale business. Labour for the household farms largely depends on household size and members.

Though farmers are aware of different credit institutions, few farmers take credit for their agricultural activities and small scale business. The main reason for not taking on loans was the fear of not being able to pay back with interest and not meeting the criteria which include collateral. Few tobacco farmers however, access credit in the form of agriculture inputs, like fertilizer and seed. To enhance social capital, farmers belong to different farmer and village development groups.

3.1.3 Soils and climate

The soils in the area are alfisols and ultisols of moderate fertility, with clay loam occurring in the lower slopes and sandy loam in the upper slopes (Kamanga, 2002). Most of the fields in the upper slopes are characterized by rock outcrops. Annual rainfall range from 800 to 1,200 mm and the mean annual temperature is 22.5 ^{o} C. The rainfall season normally begins in October and finishes in April. However, experience has shown that when maize is planted in October it suffers at least two weeks of dry spell between end of October and beginning of November (Makumba, 2003). The rainfall season is followed by little rains in June / July, known as *Chiperoni* rains. These rains are of great importance as they provide moisture to enhance decomposition of the semi buried crop residues incorporated at the time of ridge making.

3.1.4 Farming practices

Maize is the most important crop in the study area as it is the staple food. Maize based intercropping dominates in the southern part of Malawi (Makumba 2003). Other important crops are cassava, pigeon peas, groundnuts, beans, soybeans and pumpkins. Smallholder farmers also own vegetable gardens in the dambo areas, for cash income as well as household nutritional supplements. Tobacco and rice are also grown for cash income. Due to small land holding sizes and the urge to satisfy basic household consumption needs, smallholder intercrop maize with two or more other crops. Pulses like pigeon pea and beans are always intercropped with maize.

Farming activities for the growing seasons starts in July for smallholder farmers in southern Malawi (Makumba, 2003). Land clearing which involves; removal and partial burying of crop residues and weeds, takes place from July to August. Pulses intercropped with maize (e.g. pigeon peas) and cassava, are harvested in September and October. This is followed by ridge making by breaking old ridges from previous cropping season in October and November. New ridges spaced at 75cm apart, are made every growing season. Previously the ridges were spaced at 90cm apart, but the new recommendation is 75 cm (Min. of Agriculture, 1996). Maize and groundnuts are planted first followed by pulses (e.g pigeon peas, common beans, and cow beans) from late November through January. Maize is planted in planting pockets that are 75cm apart within the row and pigeon peas planted between these pockets. The first weeding is done 3-4 weeks after planting, from December to January, followed by the second weeding, 6-8 weeks later, in February. Harvesting of the common beans begins in March through to April, while maize and groundnuts are harvested in May and June.

3.2 Survey methods

The research team which comprised of five people was trained on a number of relevant aspects of the research prior to the interviews. This was meant to help the team on understanding the objectives of the research. A draft questionnaire was pre-tested on ten farm household in Lilongwe district, a different area from the study area. The results of the pretest helped in the restructuring of the final questionnaire by paraphrasing or rephrasing questions that were unclear to both the respondent and interviewer, incorporating missing variables and omitting irrelevant questions. During the survey, 97 farmers mostly heads of households were interviewed. However in their absence, a household member conversant with farm activities was interviewed.

3.3 Data collection methods

3.3.1 Household questionnaire

A structured questionnaire composed of both open and closed ended questions was used to collect data. The sample was stratified according to farmers that practice agroforestry and those that don't practice agroforestry in an Agriculture Extension Planning Area (EPA). A total of 25 households were interviewed per EPA, 10 household practicing agroforestry that were attached to ICRAF project and 15 households that were not attached to ICRAF and hence assumed not to be practicing agroforestry. However, some of the 15 none agroforestry households were found to have adopted some agroforestry technologies in their crop production. This then increased the number of farmers actually practicing agroforestry in some EPAs. The sample for the structured questionnaire was randomly selected to make sampling suitable for statistical testing and representative.

The questionnaire consisted of general questions, which included demographic and socio economic characteristics of the respondents and their household. The questions also focused on the different soil fertility improvement technologies that respondents are aware of, are trying or have adopted, factors influencing use, and constraint associated with use of the technologies. The questionnaire was also used to capture information on use of inorganic fertilizers and organic fertilizers.

3.3.2 Key informants interviews

In addition to the questionnaire, interviews with key informants such as local leaders and elder farmers (above 45 years age) were conducted using a checklist to supplement the questionnaire. This was done to establish farmer's perception with regards to the policy changes and its impacts on agriculture productivity over the years. A questionnaire targeted at policy makers, was also used as a tool to relate farmers' experiences and the actual Government policies on land use and management. The questionnaire was in the form of a checklist.

3.4 Data weakness

Considering the time of research coincided with farm land preparations for the next growing season, it was difficult to find household heads, hence some spouses might have been giving different information. Conducting the interview in the presence of other household members, like older children, minimized the problem. In understanding farmer decision making process, income flows and crop yields are critical. However, collection of this data was difficult since data was based on recall and not records. Farmers do not record their income inflows and outflows, therefore income levels used are estimated annual income levels. The farmers however, were able to describe changes in yield qualitatively but could not quantify the changes. The study did not collect enough data on labour allocation of household for different agricultural activities. This has made it difficult to calculate the labour productivity in use of a particular soil fertility improvement technology in their farming practice. Labour productivity of an agricultural technology is important for continuity in use of a particular technology.

3.5 Methods of analysis

The data was analyzed in Statistical Package for Social Science (SPSS) and STATA software. Descriptive statistics such as, percentages were used to describe farmer perception of the current level of soil fertility and farmers use and constraints of different soil fertility improvement technologies. Logistic regression was used to analyze factors affecting adoption of different soil fertility improvement technologies. Chi-square-test was also used to analyze the effect of different variables on use of different soil fertility improvement technologies.

4 RESULTS AND DISCUSSION

4.1 Farmer's perception of soil fertility problems

Understanding the soil fertility problems from farmer's point of view is crucial in analysis of the adoption potential of soil fertility improvement technologies. Farmers will adopt technologies that contribute positively to their livelihood. Hence, if soil fertility problems are viewed critical for their livelihood; farmer's likelihood for adoption is enhanced. Farmers possess a lot of knowledge about the trend of soil fertility in Malawi. Farmers over 40 years of age were asked to describe the soil fertility changes over the years, 90% described the soil fertility levels as low as compared to 20 years ago. About 10% of the farmers describe that the soil fertility levels are improving with the introduction of new technologies, such as, agroforestry.

Farmers attributed these change to a number of factor including the social and economic changes. In early years of 1950 to 60s, there were very few estates and the population was manageable, hence fallowing was used to restore soil fertility. Population grew over the years and hand holding sizes declined and fallowing became impossible. The soils were being over mined due to continuous cultivation leading to declining soil fertility. Decline in soil fertility caused low agriculture production. Fertilizer was introduced to increase agriculture production to meet the consumption needs of the growing population, which was making extensive agriculture practice impossible. However over the years, fertilizer prices have become costly for smallholder farmers, making it difficult for farmers to apply the recommended rate, at the appropriate time and annually. Therefore farmers continue to cultivate on the plots leading to continued decline in soil fertility. Farmers also claim that continued use of inorganic fertilizer reduce the soil fertility and agriculture production. This could be attributed to the decline in organic matter in the soil, which besides supplying nutrients, ensures good soil conditions necessary for plant growth.

The majority of farmers are aware of the soil fertility problems, as 73 % of the interviewed farmers perceive the current level of soil fertility as low, while 20 % believe that the soil fertility is still manageable whilst only 7% perceive the fertility in their farms as still high (Figure 2). Farmers that perceive soil fertility levels as high have either access to inorganic fertilizer or just reallocated and open a new farming plot.

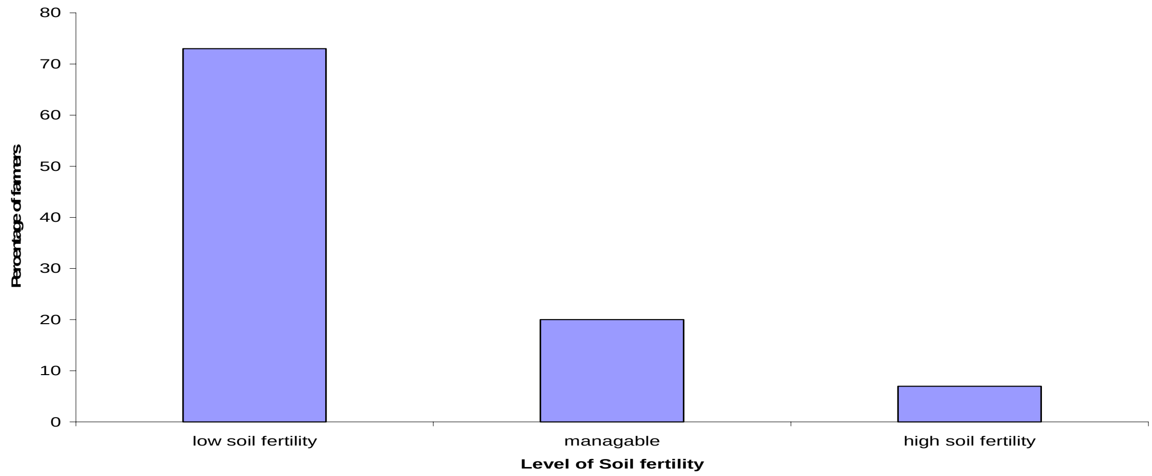


Figure 2: Farmers perception of the current soil fertility level

According to the farmers, continued cultivation on the same piece of land without fallowing over the years has led to declining soil fertility for most farm plots. Although farmers are aware of the soil fertility problems in the area, farmers continue to cultivate and overexploit the available natural resources with little input, in order to meet household consumption needs. Most farmers (62%), therefore, perceived that soil fertility will continue to decline. However, 21 % of the farmers perceive that soil fertility will increase whilst 17% perceive that there will be no changes at all (Figure 3). Introduction of the low cost, organic soil fertility improvement technologies gives farmers an option for resorting soil organic matter and improve fertility levels.

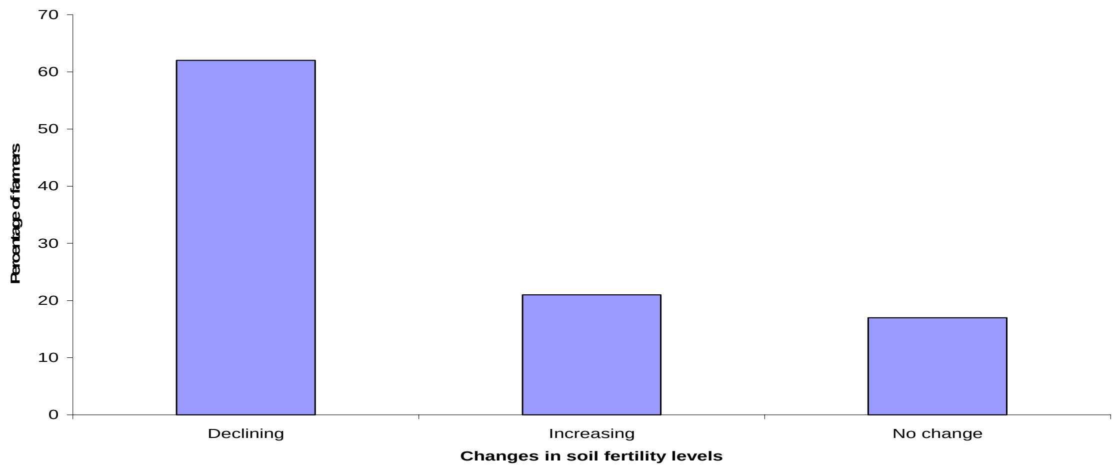


Figure 3: Farmer's perceived future changes in soil fertility levels

Continuous cropping with little or no mineral inputs was expressed as one of the causes for declining soil fertility by 67% of the farmers. Farmers have been cultivating on the same farm land continuously for years without fallowing, therefore soils have been mined of the nutrients and the soils ability to produce high crop yield has declined. Soil erosion and deforestation and increase in population, were other factors that farmers noted that contributed to loss of soil fertility. This shows that farmers are knowledgeable of the soil fertility problems, the causes and the resulting effect on agriculture production and food security. Hence, farmers are willing to invest in measures that will maintain and improve soil fertility.

4.2 Adaptation to declining soil fertility

In order to improve agriculture production and food security with regard to the existing soil fertility problems, farmers have adapted a range of soil fertility improvement technologies. Figure 4, shows the percentage use for various technologies.

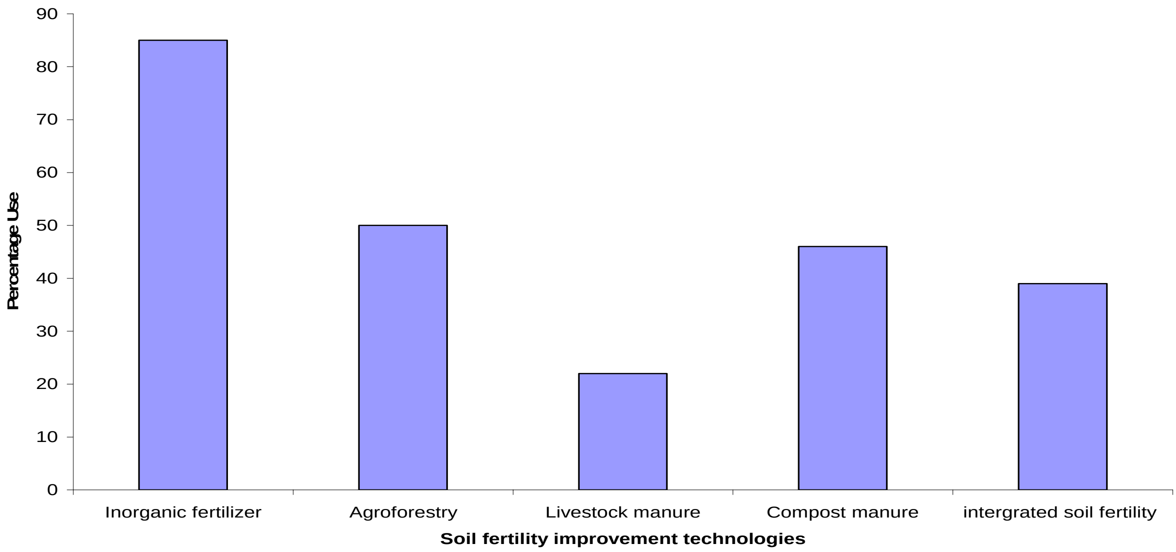


Figure 4: Percentage of farmers using different of soil fertility improvement technologies

Inorganic fertilizers are used by 85 % of the farmers interviewed. Farmers mainly apply urea and ammonium nitrate to maize and phosphate fertilizers to tobacco. Inorganic fertilizers are easy to use, not bulky and have immediate effect on crop production, therefore farmers prefer to use inorganic fertilizer as compared to organic fertilizer. Smallholder farmers have to feed themselves as well as the soil, principally they will be interested to use soil fertility technologies that raises crop yields and provide food in short term (Weddington *et al.,* 2004).

High prices are a major constraint for farmer use of inorganic fertilizers. Farmers are unable to apply the recommended rate, at appropriate time and to the whole farm. Only 25% of the farmers interviewed were able to apply the recommended rates and 38% managed to apply to the whole farm. Inorganic has to be applied twice, as a basal and top dressing; however, farmers prefer to apply inorganic fertilizer only for top dressing. Though the country has a number of agro products selling points, most markets were at an average distance of 5 km from a farmer, making it difficult for farmers to travel, especially in the local area where transport systems are undeveloped and inaccessible during rainy season. Therefore, farmers tend to apply inorganic fertilizer late and fertilizer application becomes unproductive.

According to farmers, use of inorganic fertilizer is risky because; first, yields and output prices can vary widely on a year-to-year basis, so farmers fear that in any given year their crop income will not be able to cover their costs. Second, since crop yields depend on rainfall patterns, in dry years the crop response to fertilizer can be poor

About, 22% of farmers use livestock manure. Use of livestock manure was related to ownership of livestock. Most farmers in Zomba and Machinga do not own livestock, hence the limited use of livestock manure. In the study area, farmers use extensive methods for feeding their livestock, hence manure is collected at night. If farmers change their livestock system, then more manure can be collected. Due to limited availability of livestock manure, farmers prefer to integrate the use of livestock manure with other technologies. Livestock manure is used as a compost booster by 64% of the farmers. Livestock manure is also applied at each planting pocket as a basal dressing in maize field and later top dressed by inorganic fertilizers and mixed in agro forestry plots. Since inorganic fertilizer use is limited, application of livestock manure as a basal dressing, compliments inorganic fertilizer. This makes nutrient, from livestock manure, available for plants during vegetative stage, and nutrients from inorganic fertilizer, during the productive stage. Therefore, the crucial growth stages of the crop are synchronized with available nutrients in the field. Most farmers have fragmented farming plots, and 78% of farmers using livestock manure described transporting the manure to distant plots is a major constraint in use of livestock manure. This is because transporting the manure requires a lot of labour and time. Hence, livestock manure is mostly applied around homestead and dimbas (vegetable gardens).

Compost is affordable and easy to make from a combination of maize stalks and other biodegradable substances. However, only 46% percent of the interviewed farmers used compost manure as a soil fertility improvement technology option. About 60 % of the farmers using compost manure described time as one limiting factor in using compost manure. The composting time vary from 3 to 6months before the compost is mature and ready to use, therefore it is time consuming to make adequate manure for farm plots. Compost is described as bulky, by 64% of the farmers using compost manure. Labour and transportation are the major constraints in the use of compost as described by 95% of the farmers using compost manure. Therefore, distance to farming plot is an important aspect in use of compost.

Since farmers use materials with low nutrient levels, the effectiveness of compost on crop production is heavily compromised. Therefore, farmers prefer to add inorganic fertilizers or combine compost with other fertilizer in order to increase crop yields. Farmers expressed ignorance on the recommended technique for application of the compost manure.

Agroforestry technologies are practiced by 53% percent of the farmers interviewed (Figure 4). Though financial analysis from different studies shows a higher profitability in use of agroforestry, the uptake is relatively low. Agroforestry takes longer to yield potential benefits, hence the low percentage of farmers using agroforestry as compared to the percentage of farmers using fertilizer.

In the study area, agroforestry technologies for soil fertility were predominantly introduced and promoted by International Center for Research in Agroforestry (ICRAF) in partnership with the Ministry of Agriculture since 1994. The agroforestry technologies that have been promoted are, intercropping of *Glicidia sepium* with maize and *Sesbania* relay cropping with maize (Makumba, 2003). About 83 % of the farmers interviewed, acquire agroforestry germplasm and technical support from ICRAF. The agroforestry technologies being practiced by farmers in the study area include; intercropping of *Glicidia sepium* with maize, improved fallow and mixed cropping. Intercropping of *Glicidia sepium* with maize, is the most preferred technology, used by 91 % of that farmer who practice agro forestry. Only 7% of farmers practicing agroforestry practiced improved fallow as a soil fertility improvement technology and 2% practiced mixed cropping. However, almost all farmers practice maize and pigeon peas intercropping, which is part of the farming system in the area. Farmers prefer to use different tree species for agroforestry (Figure 5).

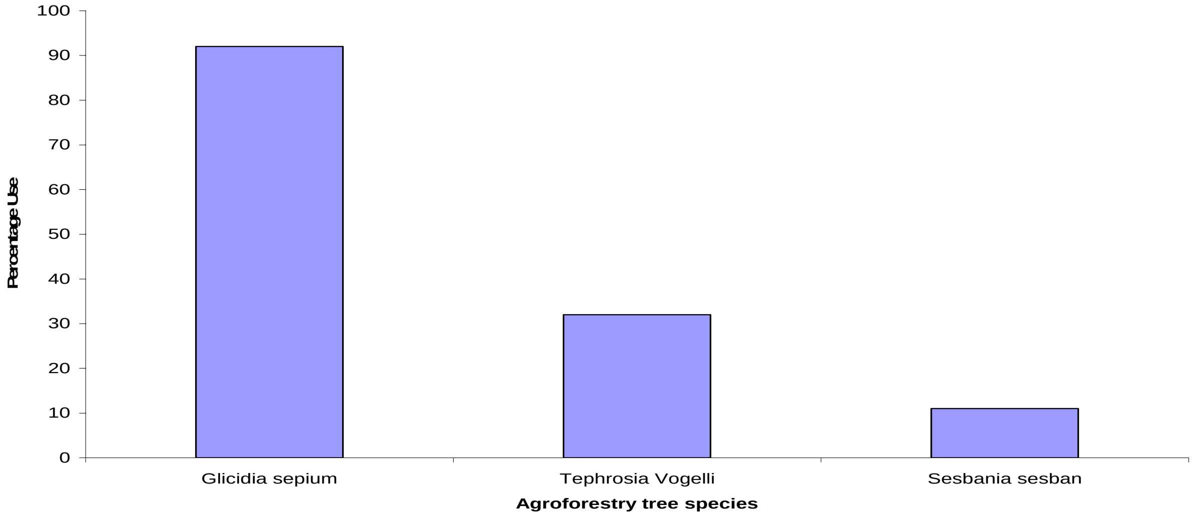


Figure 5: Farmers preference of different agroforestry tree species

Glicidia sepium is used by 92 % of farmers, *Tephrosia vogelli* and *Sesbania sesban* are used to a minor degree. Farmers expressed the ease in management as the major influencing factor in choice of species. *Glicidia sepium* is said to be less labour demanding as it has coppicing ability, and do not have to be replanted every one or two years. *Sesbanian sesban* was observed to host pest, hence difficult to manage, as it need pest control mechanisms. *Glicidia sepium, was* introduced as a research trial in most farmers field, hence the seed was readily available. Therefore germplasm availability is another factor contributing to high percentage of farmers using *Glicidia sepium*.

The technology has also been part of researcher and farmer research for over 10years, hence used by most farmers. However, more than 50% of farmers using the technology have practiced it for less than five years and a few over eight years (Figure 6). Indicating that most farmers in the study area are still in the trial and adopting stage.

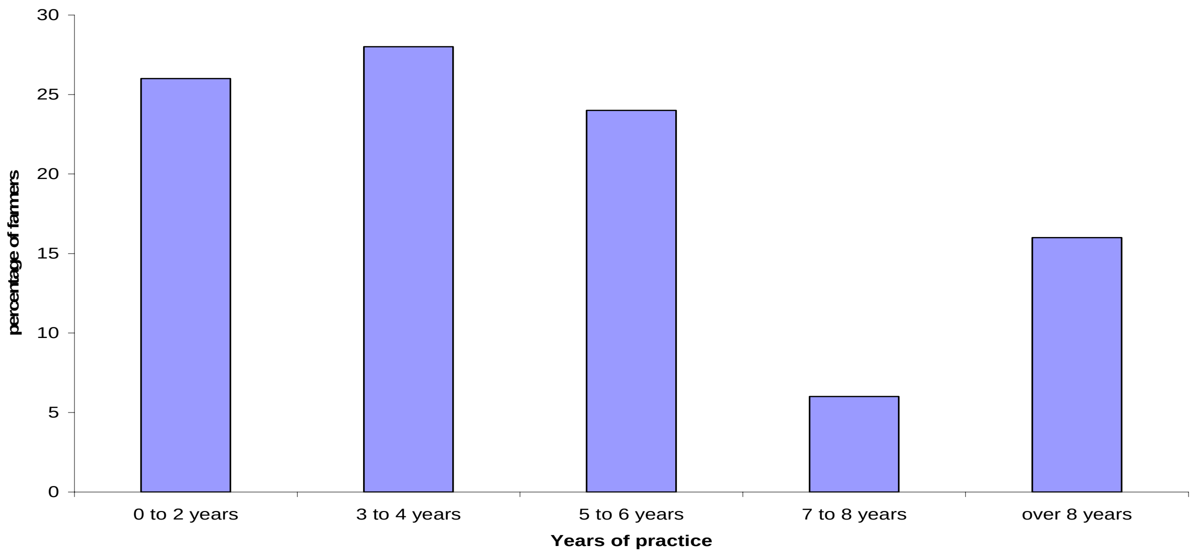


Figure 6: Percentage of farmers practicing agroforestry technologies according to years of practice

The research component by ICRAF, included provision of seed for the trial plot and technical support providing labour at different management stages of the tree species. After the research component stopped, some farmers have stopped due to management problems and labour constraints. Furthermore, 78% of the farmers practicing agroforestry, especially intercropping of *Glicidia sepium* and maize, are maintaining the agroforestry plots at 0.1 acre, which was the size of research plot. Therefore, though the technologies have been promoted for over 10 years, the number of farmers that have practiced agroforestry for over 6 years is relatively low and there is little expansion in size of agroforestry plots. Farmers avoid risks and will abandon a technology once their perceived benefits diminish significantly or do not seem to offset costs involved (Nakhumwa, 2004). Therefore, after the research phase, farmers had little incentives to continued use of the technologies and this led to abandonment of technology by most of the farmers. However, some farmers are willing to try agroforestry after seeing positive results from innovative and experimenting farmers.

Farmers highlighted a number of constraints in use of agroforestry technologies. Labour was described as the major limitation by 85% of the farmers, while 63% describe lack of technical support from ICRAF and government extension services. About 79% of the farmers described the lag period before realizing benefits of using agroforestry as one limiting factor in use of agroforestry technologies. Farmers are unwilling to wait for two years before realizing the benefits of the technology.

An integrated soil fertility improvement method in this study, is understood as, the use of inorganic fertilizers and organic fertilizers combined on the same field. This is practiced by 39% of the farmers interviewed. Since the real prices of fertilizer have increased in recent years and the maize to fertilizer price ratio has fallen, farmers have responded by experimenting with different alternatives. Integrated soil fertility improvement method is one of the alternatives under farmer experimentation. Farmers use organic and inorganic fertilizers consecutively, where the organic fertilizers which include compost, agroforestry tree leaves and live stock manure as a basal dressing and inorganic fertilizer for top dressing. The main reasons for combining organic and inorganic fertilizers as described by farmers include; farmers want to organic fertilizers to supplement on the available inorganic fertilizers, improve crop yields, reducing fertilizer costs, soil conditioning, and maximize land productivity.

Farmers have observed that the use of organic fertilizers alone result into green and health crop, however the yield is very low. Therefore, application of inorganic fertilizer as top dressing, results in high yields. This can be due to the fact that organic fertilizers applied very early in the season; hence with the first rains leaching of the nutrient material takes place making nutrients less available to the crop during maturity. Time of application is critical, because the crop needs to have enough nutrients at the right stages of growth (Kumwenda *et al.,* 1996). Therefore, the use of the two forms of fertilizers is complimentary. This method was said to be cheaper and more effective by 65 % of the farmers. However, labour and transport was highlighted as a major limitation in the use of the technology.

Use of soil fertility improvement methods depended on choice of crop (Figure 7).

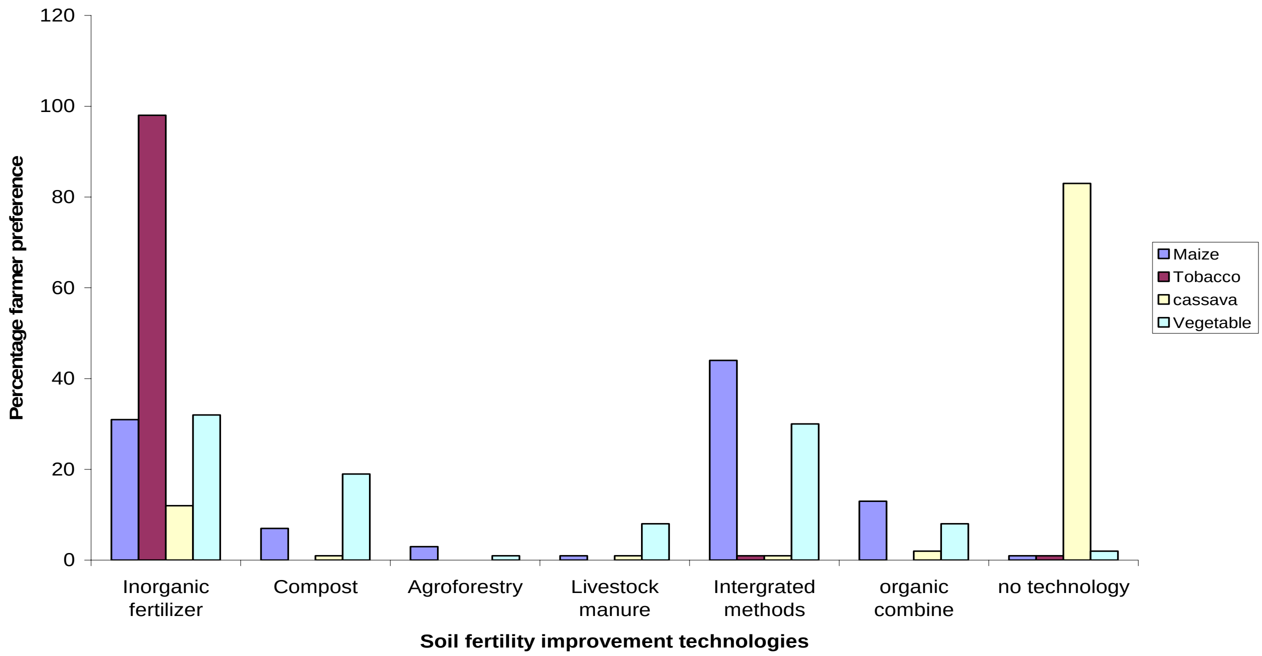


Figure 7: Preference of farmers soil fertility improvement technology use depending on crop type

Tobacco is a cash earning crop, therefore despite the high inorganic fertilizer cost, farmers are willing to use them to maximize income, hence the high percentage of farmers using inorganic fertilizer for tobacco production (Figure 7).Tobacco farmers in the area, have access to inorganic fertilizer on credit, as lending institutions are assured that farmers will be able to payback. Therefore, high percentage use of inorganic fertilizer use in tobacco as compared to maize which is primarily grown for food. Farmers expressed ignorance in the use of organic soil fertility improvement technology in tobacco production. Farmers use fertilizer on cash crops which are grown for local markets or export, hence responding to the profit potential (Wallace, 1997).

Use of integrated soil fertility improvement methods ranks as the most preferred method for maize production. Since maize is grown for substance, farmers are less willing to use inorganic fertilizers alone, considering the prices. Therefore the different forms of fertilizers are used supplementary to improve maize yield. Farmers describe use of integrated methods as effective for maize production considering the production costs and yield ratio. Agroforestry practice is mainly for maize production. This is due to compatibility of the agroforestry practice and the farm enterprise. Farmer will therefore, consider technology compatibility with the enterprise in order to accept a technology (Vanclay and Lawrence, 1994). About, 83% of the farmers expressed no need for soil fertility improvement technology use in cassava crop (Figure 7). Farmers in the area do not apply fertilizer to cassava, traditionally. However, cassava and maize intercropping is a common practice in the study area. Therefore, cassava crop taps on the residual nutrient applied to maize. Compost is labour intensive, and requires a lot of time to mature; it is therefore, difficult for farmer to make enough compost for the whole farm. Therefore farmer prefer to use compost manure in vegetable production, as vegetable plots are small in size. Farmers supplement the farm plots with vegetable gardens for both household use and cash income. Therefore, farmers are willing to apply inorganic fertilizers and integrated methods for vegetable production to maximize income (Figure 7). Livestock manure is mostly used for vegetable production.

Inorganic fertilizer is used as a soil fertility improvement technology ranked as a preferred option across positions of the landscapes (Figure 8). Fertilizer has immediate effect in yield, its not bulky and easy to use; therefore most farmers would prefer to use it for the different terrain categories.

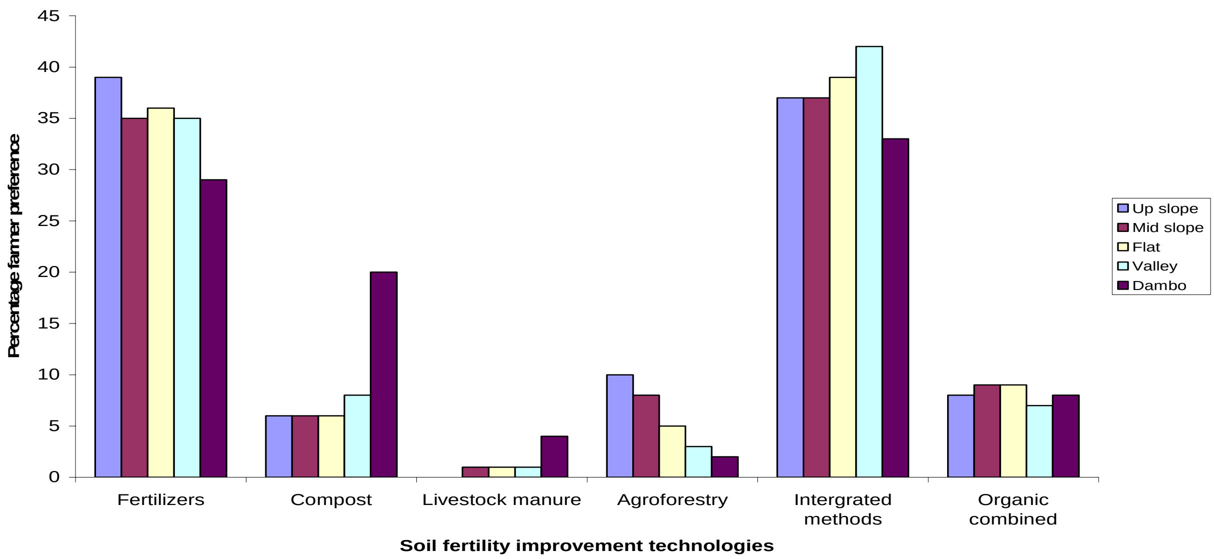


Figure 8: Preference of farmers soil fertility improvement technology use according to terrain category

Integrated soil fertility methods are highly preferred for flat and valley areas. Organic fertilizers are bulky and labour intensive, hence it is easy to use in the lower areas as compared to uplands. Farmers still practice the organic methods in upland, for restoration of organic matter, since farmers claim that continued use of inorganic fertilizer alone degrade the soil and reduce soil fertility. The most common organic method in the uplands is agro forestry, as it serves a dual purpose for soil fertility improvement as well as control of soil erosion. Livestock manure is the least preferred method for soil fertility improvement. The collection of droppings from free ranged system of feeding is difficult. Use of livestock manure and compost are ranked high in dambo areas as compared to the other terrain categories. This is because farmers use dambo for vegetable gardens which are usually small in size.

4.3 Factors influencing use of soil fertility improvement technology

Farmers make decisions about adopting new technologies as part of the overall strategy for ensuring improved livelihoods. In the study, 99% of the farmers use different technologies to improve soil fertility. The overall reason for using soil fertility improvement technologies was to improve crop yield. However the choice of a particular soil fertility improvement technology depended on a number of factors, including physical and socio economic factors. Technology characteristics largely influence the household decision making of use and adoption of a technology. Farmers weigh the household capacity and potential in relation technology characteristics before use and adoption of technologies. Household characteristics vary in a community hence different households adopt different soil fertility improvement technologies depending on the household characteristic.

4.3.1 Inorganic fertilizer

Inorganic fertilizer has immediate effects on crop production, therefore a good option for improving soil fertility. Household use of inorganic fertilizers however is determined by their capacity to meet the increasing inorganic fertilizer prices. Logistic regression show a number of socio economic factors will significanlty affect household use of inorganic fertilizer. These factors are inherited land, farmers growing vegetables and access to credit (Table 4).

Table 4:Logistic regression showing factors affecting farmer use of Inorganic fertilizer

Variables	Coefficient	Standard Error
Gender of household head	.3841206	1.078657
Occupation of household head	-.0309514	.3318091
Inherited land	**3.422843**	**1.157183****
Off-farm labour income	-.1225051	.3642768
Trade income	.283765	.3300853
Participation in farmer group	-.5993456	.9191315
Farmers growing tobacco	.7950944	1.361354
Farmers growing groundnuts	1.218297	.8407408
Farmers growing cassava	-.6186818	.9042334
Farmers growing soybeans	.8218975	1.607666
Farmers growing bean	1.350879	1.219536
Farmers growing nandolo	.9207883	.8741593
Farmers growing vegetable	-1.109912	1.108399
Cattle stock	-1.40755	1.59934
Goat stock	.2281942	.4090349
Poutry stock	-.0108141	.2390953
Access credit	-.3354613	.3185798
Constant	-4.898802	2.447034

*10% significance level, ** 5% singificance level *** 1% significance level

All the farmers interviewed had land. However, increase in inherited land will increase the use of inorganic fertilizer ($p \leq 0.05$). Farmers with farm land will prefer to use inorganic fertilizers as one option of improving soil fertility and agriculture production for household consumption needs and cash income.

The lack of cash and access to credit is important in farmer's decision making at household level and central to farmer's use of a technology. Malawi government attributes the low rate of technology adoption in the smallholder agricultural sector to the problem of incomplete financial markets (Government of Malawi, 2002). Logistic regression (Table 4) and cross tabulation (Table 5) shows that there is no clear effect of credit on the use of inorganic fertilizer in this study. Only 15% of the farmers interviewed take credit; 85% of the farmers using inorganic fertilizer don't access credit. This is because; the majority of farmers using inorganic fertilizers do not have access to credit due to, lack of credit facilities, fear of not being able to pay back and not meeting the criteria. Farmers purchase inorganic fertilizer from their own savings, remittances or other off farm activities.

Table 5: Inorganic fertilizer use by access to credit

	Inorganic fertilizer		
Credit	**Yes %**	**No %**	**Total cases %**
Yes	15 (12)	20 (3)	15 (15)
No	85 (70)	80 (12)	85 (82)
Total	100 (82)	100 (15)	100 (97)

Education level and occupation of household level has an impact in use of inorganic fertilizer ($\chi^2 = 3.158$, $p \leq 0.05$, d.f = 4). The higher the level of education the more use of inorganic fertilizers. Farmers with a higher level of education like secondary and tertiary education were capable of running small scale trades, finding artisan jobs that had a stable income. About 96% of the farmer that have job use inorganic fertilizer. Farm households that have a stable cash income can afford to use inorganic fertilizer. Though inorganic fertilizer is a good option for improving soil fertility, for many households the cash requirement to buy inorganic fertilizer exceeds their total annual cash income (Twomlow *et al.,* 2001).

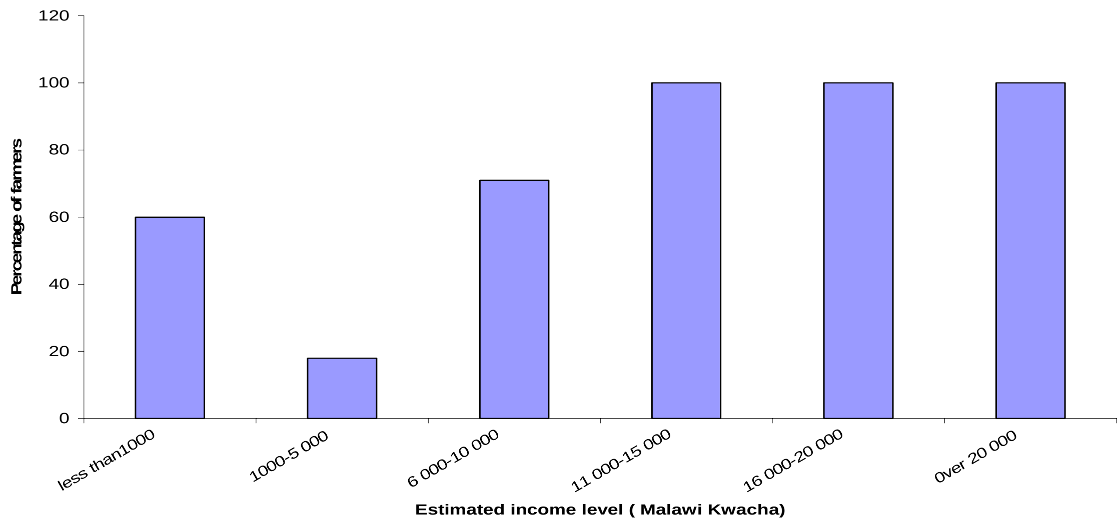


Figure 9: Percentage of farmers using inorganic fertilizer at different estimated annual labour income levels (Malawi Kwacha)

Increase in income level, will increase farmer use of inorganic fertilizers (Figure 9). Farmers with annual incomes above MK 10000 (approximately US$ 100) are rich farmers. Therefore, they can afford to use inorganic fertilizer for their crop production. Inorganic fertilizer use by farmers is constrained by its high cash cost and risky returns (Wallace, 1997). Farmers with large income levels are rich, hence less risk averse and can invest in inorganic fertilizer as input for soil fertility improvement. The high percentage of farmers that use inorganic fertilizer but earn less that MK 1000 annually (approximately US$ 10), can be attribute to farmers benefiting from targeted input programme by the government as well as remittance from children that work away from home. The targeted input programme may have increased access of inorganic fertilizers to all farmers, thereby reducing the variability in fertilizer use. Hence, this may have affected the results of the logistic analysis giving few factors being significant.

4.3.2 Agroforestry

Technology management has an influence in the profitability of technology use, including agroforestry practices. Agroforestry technology characteristics play an important role in farmers' decision to practice agroforestry. This is in regards to farmer's household resources and capability to manage the technologies. Logistic regression output (Table 6) highlight a number of factors that significantly affect the use agro forestry technologies. These factors are availability of farm land, trade income, tobacco growing and livestock (goat) holding size.

Table 6:Logistic regression showing factor affecting farmer use of agroforestry technologies

Variables	Coefficient	Standard Error
Gender of household head	-.6892673	.5938938
Occupation of household head	.2730469	.1907945
Inherited land	**-1.714789**	**.7102465 *** **
Rented land	**-1.430019**	**.884403 * **
Off- farm labour income	-.0117322	.1990047
Trade income	**-.3232287**	**.1799663 * **
Participation in farmer group	.1865032	.53875
Farmers growing tobacco	**1.459769**	**.6854543 ** **
Farmers growing groundnuts	-.3299291	.5471217
Farmers growing cassava	-.8540761	.5312411
Farmers growing soybeans	.563703	.9085114
Farmers growing bean	-.4104468	.6182003
Farmers growing nandolo	.5528302	.5528644
Farmers growing vegetable	-.4243725	.6930413
Cattle stock	-.5566682	.8736726
Goat stock	**.5301935**	**.2620845 ** **
Poutry stock	-.068235	.1526704
Access credit	-.7709884	.8005905
Constant	3.377141	1.73107

*10% significance level, ** 5% singificance level *** 1% significance level

Increase in the number of farmers inheriting land will reduce the use of agroforestry technologies ($p \leq 0.01$). Parents partition their land to give to their female children when they get married, resulting is reduced land holding size. Since some agro forestry technologies require a substantial amount of land, increase in number of farm families inheriting land reduces use of agroforestry technologies in the area. A modeling study in Kasungu, Malawi, predicted that where sufficient land is available, adoption of improved fallow technologies will occur (Thangata *et al.,* 2001). Therefore, agroforestry technologies that are promoted in an area should therefore take into account the resource limited farm households as well as the land holding sizes in the area.

About 13% of the farmers rent land in order to increase operational land holding size and increase crop yields. The maximum yield potential for using some agroforestry technologies takes number of growing seasons. Maize yields in *Gliricidia sepium* plots during the first and second year of establishment are similar to those from non-fertilized farmers' plots (Ngugi, 2002). Since renting land is usually on annual basis, farmers will prefer to use alternative technologies with immediate results on rented land to maximize profitability. Therefore, increase in rented land will reduce the use of agroforestry technologies ($p \leq 0.1$). In Zambia, farmers who did not plant improved fallow attributed their decision to labor constraints, lack of access to land and unwillingness to wait for two years before realizing the benefits of the technology (Ajayi *et al.,* 2003).

Management practices for agroforestry technologies depend on labour availability for successful use of agroforestry technologies in farming practices. In the study area, provision of labour depends on household member, hence households involved in off farm trade for livelihood, may be constrained in division of labour and time between off farm trade and farm activities. Therefore, increase in trade income will reduce the use of agroforestry technologies ($p \leq 0.1$). However, farmers with increased income from trade can afford to use inorganic fertilizers as an option for soil fertility improvement.

Farmers that grow tobacco for cash income in the area, have access to information, capacity to mobilize labour resources, relatively less risk averse and more innovative. Therefore, they will practice agroforestry more than poor farmers. Hence, more farmers growing tobacco have adopted agroforestry technologies ($p \leq 0.05$). However, the relationship between continued adoption of agroforestry technologies (i.e. improved fallow) and wealth status of farmers is non-linear, as adoption will only increase up to a certain wealth level, beyond which it dropped sharply (Ajayi *et al.,* 2003).

Livestock holding size are currently small in Malawi. Few farmers own cattle, hence ownership of small ruminants like goats are important as protein sources of the households and they also reflect the wealth of households. Farmers that own livestock are rich, less risk averse and innovative, therefore the probability that increase in goat holding size will increase the use agroforestry technology ($p \leq 0.05$). Farmers that own livestock, can be able to sell livestock in order to generate income to purchase food, therefore more likely to allocate land for agroforestry practices (e.g. improved fallow), than farmers without livestock.

In the study area, 58% of the farmers that practice agro forestry have attained a certain level of education. Education enhances farmer's knowledge, understanding and attitude towards innovations. Education provides farmer with skills that enable simple calculations for deciding economic benefits of technology and keeping of farm records. Therefore, enhances farmer's rational decision making on use of technologies. However, percentage of farmers practicing agroforestry varied with different education levels (Figure, 10).

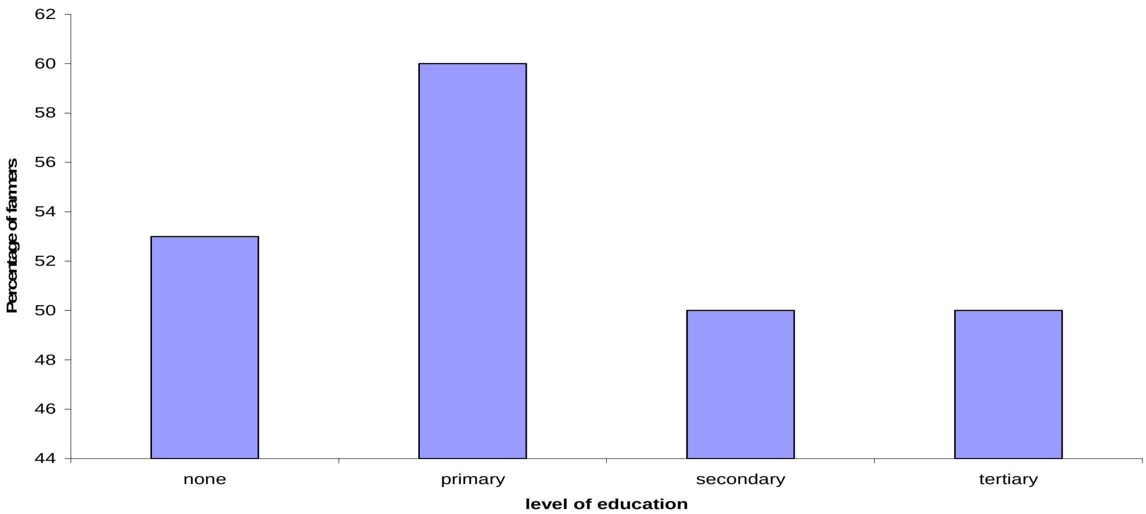


Figure 10: Percentage of farmers practicing agroforestry according to levels of education

Level of education had an impact in the farmers practicing agro forestry, Figure 13, (χ^2 = 2.308, p≤ 0.05, d.f = 8). The higher the education, the lower percentage of farmers practices agro forestry. Farmers with a higher level of education have access to off farm jobs and credit for business. Therefore, they are capable of using inorganic fertilizer as an option for soil fertility technology.

The number of months a households experience food shortage, reduces the amount of time they allocate in agriculture activities on own plots. The percentage of farmers practicing agro forestry declined with increase in number of months household faces food shortage (Figure 11). The families members are mostly spending time hiring out labour to other farm families, to meet the immediate food requirement. About 66% of the farmers that harvesting enough yield to last for whole year practiced agro forestry as compared to 49% of the farmers that do not harvest enough. Many households are forced to sell their labor in return for food or cash which in turn agriculture efforts on their own plots (Kumwenda *et al.,* 1996)

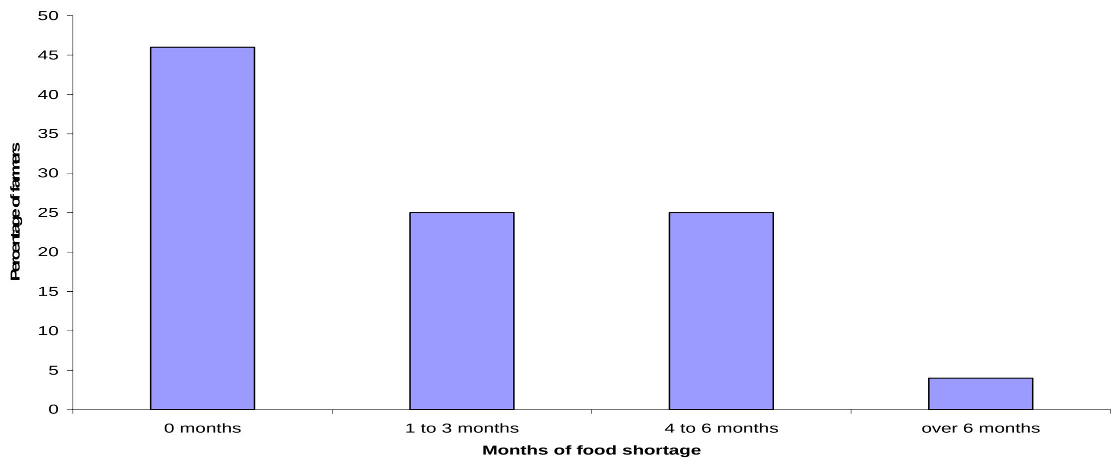


Figure 11: Percentage of farmers practicing agroforestry according to months they experience food shortage

4.3.3 Compost manure

A majority of farmers in the study area described availability of labour, time and composting material as main factors that influencing farmer's use of compost. Most female headed families (55%) use compost as a soil fertility improvement technology option as compared to the male headed families (Table 7). Female household heads tend to have lower incomes than male household heads (Quisumbing *et al.,* 1995). Therefore since they are poor, farmers will adopt use of compost manure as it requires little or cash input.

Table 7: Compost manure use by gender

	Compost Manure use		
Gender	**Yes %**	**No %**	**Total cases %**
Female	55 (25)	52 (27)	54 (52)
Male	45 (20)	48 (25)	46 (45)
Total	100 (45)	100 (52)	100 (97)

Logistic regression (Table 8), show a number of factors that significantly affect household use of compost manure. These factors are off farm labour income, participation in farmer groups, growing of groundnuts, common bean and vegetables and livestock (goat) holding size.

Table 8: Logistic regression showing factors affecting farmer use of compost manure

Variables	Coeffient	Standard Error
Gender of household head	.5486332	.703284
Occupation of household head	-.2501528	.2031387
Inherited land	-.5721599	.72699
Rented land	-.8362531	1.062201
Off-farm labour income	**-.6879626**	**.2694278 *** **
Trade income	-.0155092	.1863841
Participation in farmer group	**2.070005**	**.6726553*** **
Farmers growing tobacco	.0360059	.7205725
Farmers growing groundnuts	**1.184578**	**.748691 * **
Farmers growing cassava	.678942	.6391221
Farmers growing soybeans	1.122044	1.302566
Farmers growing bean	**-1.750944**	**.8106946 ** **
Farmers growing nandolo	.0645934	.665132
Farmers growing vegetable	**1.60391**	**.8071364 ** **
Cattle stock	.4274181	.8912715
Goat stock	**.6434525**	**.2933899 ** **
Poutry stock	.2189787	.1730882
Access credit	.0229829	.8747818
Constant	-7.024701	3.056755

*10% significance level, ** 5% singificance level *** 1% significance level

Increase in off-farm labour income will reduce the use of compost manure for soil fertility improvement ($p \leq 0.01$). Compost making is a labour intensive technology, and is unlikely to be adopted by households with limited labour supply. Households with working members, lack labour to allocate for compost making and use of inorganic fertilizers will be a good option.

Farmers with increased off-farm labour income are richer farmer and are capable of buying inorganic fertilizer. Therefore, use of inorganic fertilizer will be profitable as regard to time and labor allocation than use of compost manure.

Increase in farmer participation in different farmer groups[1] will increase the use of compost manure for soil fertility improvement ($p \leq 0.01$). Farmers lack information and knowledge about innovations (Rogers, 1995) and sometimes agricultural innovations fail to meet expected benefit due to poor implementation if farmer does not understand how the technology works, or the complexity of the technology. Farmer participation in farming groups enhances their knowledge and understanding of a particular technology, through sharing information and training on different agricultural practices from different institutions. Since the fertilizer value of compost manure depends on the source materials, the conditions under which it was made and the maturity of the compost when it is applied, the knowledge gained enables farmers to realize potential benefits in use of compost manure as farmers will learn proper procedures and materials to use in compost making.

Increase in groundnuts growing will increase the use of compost manure for soil fertility improvement ($p \leq 0.1$). Farmers in the study area do not apply compost manure or inorganic fertilizer in groundnut fields. Though groundnut haulms are used as feed for livestock, farmers also use groundnut haulms as one of the materials for compost making, because of its high Nitrogen content. Therefore in areas with no livestock, groundnut haulms can be used as a compost manure booster.

Common bean is intercropped with maize in the study area. Farmers believe that this improves soil fertility, and will give the same results as using compost. The residues from common bean are buried during land preparation to enhance soil fertility and yields for subsequent season, due to the incorporation of the organic matter. Therefore, increase in common bean growing will reduce use of compost manure ($p \leq 0.1$).

---

[1]Farmer groups are agriculture groups formed in a village. The group's main objective is to improve agriculture production through sharing of agriculture information. The groups also serve as a forum for farmer training by government as well non government institutions.

Compost manure making involves a lot of labour and it is time consuming to make sufficient manure for the large plots. Farmer prefers to use compost manure in vegetable production, as vegetable plots are small in sizes. Therefore, increase in vegetable growing will increase the use of compost manure ($p \leq 0.05$).

About, 64% of the farmers using livestock manure use it as a compost booster, in order to produce good quality manure. Goats are important and common livestock type owned by farmers in the study area. According to farmers, goats are cheaper to purchase, cheap to manage and feed, of nutritive value to humans, and a source of manure. Since goat manure can be used in compost making, increase in goat stock will increase use of compost manure ($p \leq 0.05$).

4.3.4 Livestock manure

Livestock manure is one of sources of organic fertilizer. Farmers use of livestock manure is significantly affected by a number of factors, including off farm labour income, trade income, participation in farmer groups, tobacco growing and livestock holding size.

Table 9:Logistic regression showing factors affecting farmer use of livestock manure

Variables	Coefficient	Standard Error
Gender of household head	.9711514	.9248476
Occupation of household head	.1433803	.2605689
Inherited land	.1869782	.9456465
Rented land	-1.433982	1.151358
Off-farm Labour income	**-.7606461**	**.310868*****
Trade income	**.3320584**	**.2114547***
Participation in farmer group	**1.685499**	**.7659729 ****
Farmers growing tobacco	**-2.491845**	**1.121016 ****
Farmers growing groundnuts	-.0992433	.8004682
Farmers growing cassava	-.9908084	.7694063
Farmers growing soybeans	.9237827	1.463799
Farmers growing bean	-.1682037	.9734341
Farmers growing nandolo	-1.006072	.7915209
Farmers growing vegetable	-.0310698	.8351828
Cattle stock	**3.396599**	**1.482898 ****
Goat stock	**1.298511**	**.4692651 *****
Poutry stock	**1.048047**	**.2892396 *****
Access credit	1.812934	1.263169
Constant	-2.444622	2.107499

*10% significance level, ** 5% singificance level *** 1% significance level

Increase in off-farm labour income will reduce the use of livestock manure for soil fertility improvement ($p \leq 0.01$). Farmers will use technologies according to their resource. Farmers with increased off-farm labour income have the ability to buy inorganic fertilizers, hence capable of using inorganic fertilizers for soil fertility improvement. Households will use a particular soil fertility technology depending on household cash inflow and resource availability.

Increase in trade income will increase use of livestock manure ($p \leq 0.1$). Farmers grow vegetables for both household cash income and most of the farmers involved in trade, sell their vegetable. Vegetable plots are small and where labour is available and livestock manure can be collected, it makes sense to invest in production of vegetables (Scoones and Toulmin, 1999). Livestock manure is cheaper as it does not involve cash input, hence farmers will opt to use livestock manure for vegetable plot, in order to reduce costs and maximize benefits.

Farmer participation in different farmer groups will increase the use of livestock manure for soil fertility improvement ($p \leq 0.1$). Farmers participating in farmer groups, share information and obtain agriculture training from different institutions. Farmer participation in farming groups enhances their knowledge and understanding of a particular technology. This helps farmers to use a technology properly; enabling farmers to realize the desired benefit of using the technology. Therefore, increased farmer participation in farmer groups may lead to increased use of livestock manure.

Increase in tobacco growing will reduce use of livestock manure ($p \leq 0.05$). Farmers that grow tobacco for cash income are relatively rich farmers, and have access to inorganic fertilizer on credit from agro-dealer. Therefore, use of inorganic fertilizer will be a more profitable option for soil fertility improvement as regard to labor allocation and time required for collection and application of livestock manure.

In the study area, use of livestock manure is limited by the small livestock holdings. Since the use of livestock manure depends on availability of livestock, increase in cattle, and goats as well as poultry holding size will increase use of livestock manure ($p \leq 0.05$) and ($p \leq 0.01$), respectively. Farmers regard goats and poultry keeping is a cheap and easy to manage, therefore farmers prefer to keep goat and poultry as compared to cattle.

4.3.5 Integration soil fertility improvement method

Farmers combine organic and inorganic fertilizers for soil fertility improvement consecutively, in order to improve crop production. A number of factors affect farmer's use of integrated method (Table 10).These factors are off farm labour income, participation in farmer group, tobacco and common bean growing and livestock (goat) holding size.

Table 10: Logistic regression showing factors affecting use of integrated methods

Variables	Coefficient	Standard Error
Gender of household head	-.392649	.7016332
Occupation of household head	.2109372	.2344229
Inherited land	-.3339836	.7375056
Rented land	-1.113016	1.113284
Off-farm Labour income	**-.5164875**	**.257264 ****
Trade income	.2762122	.1997919
Participation in farmer group	**-1.123338**	**.6669556 ***
Farmers growing tobacco	**2.153679**	**.8272868 *****
Farmers growing groundnuts	.9249179	.6232795
Farmers growing cassava	-.6579089	.5944396
Farmers growing soybeans	.7555292	1.000594
Farmers growing bean	**-1.899875**	**.7747987 *****
Farmers growing nandolo	-.2163041	.6464215
Farmers growing vegetable	.3877997	.7587605
Cattle stock	-.2720607	.9246779
Goat stock	**.8108403**	**.3141576 *****
Poutry stock	-.1656213	.1852415
Access credit	-1.593927	1.046366
Constant	1.217894	1.747805

*10% significance level, ** 5% singificance level *** 1% significance level

Analysis of low input of organic alternatives shows that harvesting, transforming and corporating the necessary biomass are often costly in terms of land and labour requirements to be considered by farmers (Scoones and Toulimin, 1999). However fertilizer prices limit most farmers in use of inorganic fertilizer alone, and integrated methods is an option for low income farmers. As household income increase, farmers will be able to buy inorganic fertilizers. High income farmers are therefore, capable of using inorganic fertilizers only for agriculture production. Therefore, increase in off-farm labour income will reduce the use of integrated methods for soil fertility improvement ($p \leq 0.05$).

Increasing in tobacco growing will increase use of integrated soil fertility methods ($p \leq 0.05$). Integrated soil fertility methods require attention to timing and placing of inputs so that synchrony between nutrient release and plant uptake is enhance (Myers *et al.,* 1994). Few studies have been done on the recommended combination of organic and inorganic fertilizers hence still under research. According to farmers, integrated soil fertility improvement method is one of the alternatives for improving soil fertility that farmers are experimenting. Soil management technologies require a substantial farmer investment in form of land, labour or cash, which can be a barrier to local experimentation (Twomlow *et al.,* 2001). Wealthier farmers have access to resource and may be able to assume risks; therefore they are more likely to experiment using integrated methods for crop production than poor farmers. Since farmers that grow tobacco for cash income are relatively rich farmers, they will be able to practice integrated methods for soil fertility in non cash crops fields.

Increase in growing of common bean will reduce use of integrated soil fertility methods ($p \leq 0.05$). Common bean is intercropped with maize in the study area, farmers believe that this improves soil fertility, and will yield to the same results as organic fertilizer. Farmers perceive application of organic manure to a maize-common beans plot as a duplication of efforts and not effective in terms of labour input, therefore no incentive for farmers to use organic fertilizer on maize-common bean plots. Farmers perceive maize-common bean intercropping as one form of integrated soil fertility methods. This may contribute to the low use of integrated soil fertility methods[2], with increase in farmers growing of common bean.

Increase in goats holding size will increase use of integrated soil fertility methods ($p \leq 0.01$). Livestock manure is one of sources of organic fertilizer. The organic material from livestock improves soil structure and soils ability to hold nutrients leading to improved soil productivity. Therefore, farmers prefer to integrate the use of livestock manure with inorganic fertilizer. Farmers apply livestock manure as a basal dressing at each planting pocket and later apply inorganic fertilizers as a top dressed. Goat is the common livestock type in the area, therefore the increase in goat, holding size will have a positive effect on farmer use of integrated soil fertility methods.

[2] Integrated methods in the study did not consider intercropping as one way of integration.

Increasing farmer participation in groups will reduce use farmer use of integrated soil fertility method ($p \leq 0.05$). Farmer groups have specific objective. Farmers that participate in farmer groups obtain training on use of specific technologies in order to realize potential benefits from the technology. Integrated methods for soil fertility improvement are still under experimentation. Therefore, farmer trainers have little knowledge on use of integrated methods and do not recommend integrated methods to farmers. Farmers participating in farmer groups have specific knowledge on use of a specific technology. For maximum benefits, farmers participating in farmer groups will tend to use one specific technology rather than combining different technologies.

4.4 Access to technical support

Agricultural extension and research are part of the policy instruments that the Government of Malawi uses to achieve its agricultural goals. Farmers get agriculture information from agricultural research and extension service, NGO's and friends. About 58% get information from agricultural extension staff, 20% from agriculture researchers. Promoting use and adoption of agriculture technologies, including soil fertility improvement technologies, among local farmers therefore, largely depends on the public agricultural extension service. Farmers described the role of extension services to be; sensitizing, training and monitoring farmers on agricultural practices. Farmers believe that extension system can help improve productivity, through provision of knowledge and timely transfer of agriculture information. Knowledge will enhance farmers understanding of technology and change it attitude towards an innovation, hence farmers can exploit the potential benefits in using the technology. However farmers expressed inadequate visits by extension officers in the area. This is attributed to the shortage of extension service staff in the Ministry of agriculture (Malawi Government, 2002).

5 CONCLUSION

Farmers described the soil fertility as low compared to 20 years ago. Farmers attributed these change to a number of factor including increase in population, small land holding sizes, continuous cultivation and increase in price of inorganic fertilizer. Farmers stated that soil fertility level as low and that soil fertility level will continue to decline. Farmers are willing to invest in soil fertility improvement technologies, in order to improve agriculture production.

Farmers have adapted a range of soil fertility improvement technologies to improve soil fertility. These include inorganic fertilizer, agroforestry, compost manure, livestock manure and integrated methods. Inorganic fertilizers are used by a majority of the farmers, because inorganic fertilizers have immediate result on crop yield. High prices are a major constraint in using inorganic fertilizers. Use of livestock manure for soil fertility improvement is limited by the small livestock holding sizes in the study area. Livestock manure is mostly used around homestead and dimbas (vegetable gardens). Use of compost manure for soil fertility improvement, is affordable and easy to make. However, compost is bulky, labour intensive. Therefore, it is difficult to produce enough for big plots and transport it to distant plot.

Agroforestry is also practiced for soil fertility by farmers in study area. The main constraints for practicing agroforestry are high labour demand, lack of technical and the long lag period before the benefits become tangible. *Glicidia sepium* is used by a majority practicing agroforestry. The majority of farmers have not been able to expand use of agroforestry to other parts of farm plot. Most farmers still maintain 0.1 acre plot. Farmers use organic and inorganic fertilizers in combination (integrated methods). Farmers integrate methods in order to supplement on the available inorganic fertilizer, improve crop yields, and reduce fertilizer costs.

The choice of technologies depended on crop type. Cash earning crops and maize cultivating, farmers are willing to use inorganic fertilizer. Inorganic fertilizer ranked as the preferred option across positions of the landscapes. Farmers will prefer to use organic fertilizers in lower areas. However, farmers still practice the agroforestry in upland, for soil fertility improvement and soil conservation.

Use of different soil fertility improvement technologies is affected by different factors. Use of inorganic fertilizers was determined by households' capacity to meet the cost. Ownership of land and high levels of household income will increase use of organic fertilizer, and vegetable growing will reduce use of inorganic fertilizer.

Household's use of agroforestry was affected by household ability to plant and manage tree species. Size of available land holding was found to be associated with the establishment of agroforestry. Increase it trade income reduced use of agroforestry technologies. The majority of farmers practicing agroforestry have obtained primary education. However, percentage of farmers practicing agroforestry declined with increase in level of education. The percentage of farmers practicing agroforestry also declined with increase in number of months household faces food shortage. These farmers are engaged in off farm activities in order to meet the immediate consumption need.

Farmer's use of compost manure was affected by labour availability, time and availability of composting material. More female headed families use compost manure than male headed families. Increase in vegetable growing will increase use of compost manure. Farmer participation in different farmer groups and increase in household labour income will increase use of compost and livestock manure. Increase in livestock holding size will increase use of livestock manure. A number of factors affect farmer's use of integrated method. Though rich farmers are more willing to experiment with integrated methods, increased household income level will reduce the use of integrated methods for soil fertility improvement. Common bean intercropping with maize in the study area is one form integrated method for soil fertility improvement. The use of one soil fertility method does not exclude the use of the other.

The technology characteristic, feasibility, profitability, acceptability will influence farmers choice for different soil fertility improvement technologies. Household characteristics vary in a community hence; different households adopt different soil fertility improvement technologies depending on the household capacity to manage the technology. Household cash income, land and labour availability dominates decision making on use and adoption of different soil fertility improvement technologies at household level.

6 REFERENCE

Adesina, A.A., and Baidu- Ferson, J., (1995). Farmers Perception and Adoption of New Agricultural Technology: Evidence from Analysis of Bukina Faso and Guinea, West Africa, *Agriculture Economics, 13.*

Ajayi, O.C., Franzel, S., Kuntashula, E. and Kwesiga, F., (2003). Adoption of Improved Fallow Technology for Soil Fertility Management in Zambia: Empirical Studies And Emerging Issues. *Agroforestry Systems* 59: 317–326.

Akinnifesi, F., DeWolf, J., and Matakala, P., (2005). On farm Assessment of Agroforestry Technologies for Soil Fertility Replenishment in Malawi. ICRAF, Malawi.

Akinnifesi, F., and Kwesinga, F., (2002). Can Agroforestry Make a Difference as an existing Strategy for the Starter Pack Scheme in Malawi? *Malawi Journal of Agricultural Science.*

Ban, A., and Hawkins, H., (1988). Agriculture Extension. Longman scientific and technical, New York.

Bekele, W. (2003) Economics of Soil and Water Conservation: Theory and Empirical Application to Subsistence Farming in the Eastern Ethiopian Highlands. Doctoral thesis,Dept. of Economics, *Acta Universitatis agriculturae Sueciae. Agraria vol. 411.* (diss-epsilon.slu.se/archive/00000362/)

Bekunda, M.A., Bationo, A., and Ssali, H., (1997). Soil Fertility Management in Africa: A Review of Selected Research Trials. In: Buresh R.J., Sanchez P.A. and Calhoun F. (eds.), Replenishing Soil Fertility in Africa. *Soil Science Society of America, Madison, Wisconsin, USA, pp. 63–79.*

Bunderson, W.T., and Hayes, I.M., (1995). Agricultural and Environmental Sustainability In Malawi. Paper presented at the Conference on Sustainable Agriculture for Africa, Cote d'Ivoire. July, 1995.

Böhringer, A. (2001). Facilitating the Wider Use of Agroforestry for Development in Southern Africa. *Development in Practice.*

Canadian Organic Growers (1992) www.eap.mcgill.ca/MagRack/ 3.03.06)

Carra, S.J. (1997). A Green Revolution Frustrated lessons from Malawi Experience. A Paper Presented at the First All Africa Crop Science Congress Held in Pretoria South Africa. January 1997.

Chambers, R., Pacey, A., and Thrupp, L., (1989). Farmers first. Farmers Innovation and Agricultural research. Intermediate Technology Publications, London.

CTA/MAFE, (2002). Agroforestry in Malawi and Zambia: Summary Report of CTA/MAFE *study visit.* Technical Centre for Agriculture and Rural development, The Netherlands.

Department of Land Resources Conservation, (2004). Annual Progress Report, Ministry of Agriculture, Malawi government.

DREA (1994). National Action Plan. Department of Research and Environmental Affairs *Volume 1: The Action Plan*. Lilongwe.

Donova, W.G. (1996). The Role of Inputs and Marketing Systems in the Modernization of Agriculture. Breth, S. A (eds) Achieving Greater Impact Research Investments in Africa..

Environmental Affairs Department, (2002). State of Environment Report. Ministry of Mines, Natural Resources and Environment, Environmental Affairs Department. www.**malawi**.gov.mw/mines/ environAffairs

Economist Intelligence Unit (2004). Country Profile.

FAOSTAT Agriculture Database, 2005. www.faostat.fao.org/faostat/collection, 2006.

Franzel, S. (1999). Socioeconomic factors affecting the adoption potential of improved tree fallows in Africa. *Agroforestry Systems* 47: 305–321, 1999.

Gruhn, P., Francesco Goletit, F., and Yudelman, M. (2000) Integrated Nutrient Management, Soil Fertility, and Sustainable Agriculture: Current Issues and Future Challenges. *Food, Agriculture, and the Environment Discussion Paper 32.* International Food Policy. September 2000.

ICRAF. (2006). (www.world**agroforestry**.org, 26.02.06).

ICRAF. (1998). Building on a Solid Foundation: Achievements, Opportunities and Impact. ICRAF, Nairobi, Kenya.

Ikerra1, S.T., Maghembe, J.A., Smithson, P.C., and Buresh, R. J., (1999). Soil Nitrogen Dynamics and Relationships with Maize Yields in A Gliricidia–Maize Intercrop In Malawi. *Plant and Soil* **211:** 155–164.

Kamanga, B.C.G. (2002). Understanding Farmer's Agricultural Environment in Malawi. Risk Management Project Working Paper 02-01. CIMMYT-Malawi.

Kamanga, B.C.G., Shumuradyarira, Z., and Waddington, S. (2001). On/farm Comparison of Fertilizer Application Practices to Assess Nitrogen Use Efficiency with Maize in Zimuto Communal Area, Zimbabwe. Risk Management Project, CIMMTY Natural Resources Group, Harare Zimbabwe. Seventh Eastern and Southern Africa Regional Conference. February, 2001., pp 519-529.

Kamanga, B.C.G., Kanyama-Phiri, G.Y., and Minae, S. (1999). Intercropping Perennial Legumes for Green Manure Additions to Maize In Southern Malawi *African Crop Science Journal, pp. 355-363*.

Kanyama-Phiri, G.Y., Snapp, S.S., Kamanga, B. and Wellard, K. (2000). Towards Integrated Soil Fertility Management in Malawi: Incorporating participatory approaches in agricultural research. *Managing Africa's Soils No. 11. IIED, UK. 27*

Kherallah, M. and Govindan, K. (1997). The Sequencing of Agricultural Market Reforms in Malawi. Market and Structural Studies Division International Food Policy Research Institute, MSSD Discussion Paper No. 13. 1997.

Kwesiga, F., Akinnifesi, F.K., Mafongoya, P.L., McDermott, M.H. and Agumya, A. (2003). Agroforestry Research and Development in Southern Africa During The 1990s: Review and Challenges Ahead. *Agroforestry Systems* **59:** 173–186, 2003.

Kwesiga, F., Franzel. S., Place, F., Phiri, D., and Simwanza, C.P. (1999). Sesbania Sesban Improved Fallows in Eastern Zambia: The inception, development and farmer Enthusiasm. *Agroforestry Systems* **47:** 49–66, 2003

Kumwenda, J.D.T., Waddington, S.R., Snapp, S.S., Jones, R.B., and Blackie, M.J., (1996). Soil Fertility Management Research for the Maize Cropping Systems of Smallholders in Southern Africa: A Review. NRG Paper 96-02. Mexico, D.F.: CIMMYT.

Makumba, W.(2003). Nitrogen use Efficiency and Carbon Sequestration in Legume Tree- based Agroforestry system: A case study of Malawi. Ph. D Thesis Wageningen University and Research Center, Wegeningen, The Netherlands. 2003.

Malawi Government, (2002), *Malawi Poverty Reduction Strategy paper*. Final Draft. Lilongwe, Malawi.

Malawi Government, (1994), *National Environmental Action Plan (vol, 2).* Lilongwe, Malawi

Ministry of Forestry, Fisheries and Environmental Affairs, (1998). *State of Environment Report.* Lilongwe, Malawi.

Ministry of Agriculture Irrigation and Livestock Development (1996). Guide to Agricultural Production. Lilongwe, Malawi.

Murwira, H.K. (1994) Synchrony relationships of nitrogen release and plant uptake in a Zimbabwean sandy soil amended with manure and fertilizer. African Crop Sci J 2: 69–77.

Myres, R.J.K., Palm, C.A., Cuevas, E., Gunatilleke, I., and Brossard, M.(1994). The Synchronization of Nutrient Mineralization and Plant Nutrient Demand, In Woomer, P.L and Swift, M.J.(Eds). The Biological Management of Tropical Soil Fertility. Wiley, Chichester.

Mafongoya, P.L., Katanga, R., Mkonda, A., Kuntashula, E. and Chirwa, T. 2001. *ICRAF-Zambia Agroforestry Project: Progress Report to Sida, January-December, 2000.* ICRAF, Nairobi, Kenya.

Nakhumwa, T.O. (2004). Dynamic Costs of Soil Degradation and Determinants of Adoption of Soil Conservation Technologies by Smallholder Farmers in Malawi. Doctoral Thesis. University of Pretoria, South Africa.

Negatu and Parikh,(1999). The impact of perception and other factors on the Adoption of Agricultural Technology in the Moret and Jiru Woreda (district) Of Ethiopian. Ethiopia

Phiri A.D.K, Kanyama- Phiri, G.Y. and Snapps, S. (1999) Maize and sesbania production in relay cropping at three landscape positions in Malawi . *Agroforestry Systems* **47**: 153–162.

Reij, C. and Waters-Bayer, A. (2001). Farmers innovation in Africa. A source of Inspiration for Agricultural development. Earth scan Publication Ltd, Sterling, VA, U.K.

Quisumbing, A.R., Brown, L.R., Feldstein, H.S., Haddad, L and Pena, C. (1995). Women: The Key to Food Security. Food Policy Report. International Food Policy Research Institute, Washington DC.

Rogers, E. (1995). Diffusion of innovations. Free press, New York.

Saka, A.R., Kumwenda, J.D., Phombeya, H.S.K., Itimu, O.A., Allison, A.G., Kamangira J.B., and Bunderson, W.T. (1998). Integrating Pigeon peas into Smallholder Farming Systems to Improve Soil fertility and Crop Yields in Malawi. A Paper Presented at the Soils and Agricultural engineering Commodity Group Meeting. August 1998. Malawi.

Sanchez, P.A., Soule, S.M., Place, F.M., Buresh, R.J., Izac, A.N., Mokwunye, A.U., Kwesinga, F. K., Ndiritu, C.G and Woomer, P.L. (1997). Soil Fertility Replenishment in Africa: An Investment in Natural Resource Capital. Special Publication, No. 51.

Scoones, I and Thompson, J. (1994). Beyond Farmers First. Rural People’s knowledge, Agricultural Research and Extension Practice. Intermediate Technology Publications. London.

Scoones, I. and Toulmin, C. (1999). Policies for Soil Fertility Management in Africa. A report for the Department for International Development.

Sahn, D., Arulpragasam, J. and Merid, L. (1990). Policy Reform and Poverty in Malawi. A Survey of a Decade of Experience. Cornell Food and Nutritional Policy Program. New York.

Swinkles, R. and Franzel, S. (1997). Adoption Potential of Hedgerow Intercropping In Maize-Based Cropping Systems In The Highlands Of Western Kenya. Economic and Farmers' Evaluation. Cambridge University Press, *Expl Agric. pp. 211±22.3*

Thangata, P.H., Hildebrand, P.E. and Gladwin, C.H. (2001). Modeling Agro forestry adoption and Household Decision making in Malawi. African Studies Quarterly. *On line journal for African studies.*

Twomlow, S.J. and Rusike, J. and Snapp, S. (2001). Biophysical or Economic Performance- Which Reflects Choice of Legumes 'Best Bets' in Malawi. Seventh Eastern and Southern Africa Regional conference. Feb 2001, pp519-529.

Vanclay, F. and Lawrence, G. (1994) Farmer Rationality and the Adoption of **e**nvironmentally Sound Practices; A Critique of the Assumptions of Traditional Agricultural Extension. European Journal of Agricultural Education and Extension, 1994 - bib.wau.nl

Whiteside, M. and Carr, S. (1997) Encouraging sustainable smallholder agriculture in Malawi. Agricultural Services Reform in Southern Africa: Service and policies needed to support sustainable smallholder Agriculture in Malawi. Environment and Development Consultancy Ltd, Hillside Uk.

Vedeld P, (1990). Household Viability and Change Among Tugens- A case study of the house hold Resource allocation in the semi arid Barango District, Nomadic Peoples: 133 -151

Vedeld, P. and Krogh, E. (2001). Good Agronomy. Social institutions among Norwegian Farmers. Agriculture University of Norway, Norway

Waddington, S., Sakala, W.D. and Mekuria, M. (2004). Progress in lifting soil fertility in Southern Africa. "New directions for a diverse planet". Proceedings of the 4th International Crop Science Congress, 2004. www.cropscience.org.au

Wallace, M.B. and Knausenberger, W.I.(1997). Inorganic Fertilizer Use in Africa:Environmental and Economic Dimensions Applied Research. Winrock International Environmental Alliance Arlington, Virginia, U.S.A.September 1997 www.encapafrica.org/MEO_Course/Module9--Special_Topics (2006.04.20)-

Øygard, R. (2006). Malawi's Persistent Food Crisis (draft). Norwegian University of Life Sciences. December 6, 2005 www.aae.wisc.edu/seminars/papers(2006.04.08)

Øygard. R, Roberto Garcia. R., Guttormsen. A. G., Kachule. R., Mwanaumo.A., Mwanawina. I., Sjaastad.E. and Wik. M. (2003). The Maze of Maize: Improving Input and Output Market Access for Poor Smallholders in Southern African Region, the Experience of Zambia and Malawi. Department of Economics and Resource Management Report No. 26. Agricultural University of Norway, A report commissioned by NORAD, September 2003.

7 Appendix 1: Household survey questionnaire

Household number	
Name of respondent	
Name of enumerator	
Date	
Region	
District	
EPA	
Village	
Time started	
Time finished	

1.0 Household data

Gender	Female 1 Male 2
Age(years)	Below 20 1 20 – 30 2 31 - 40 3 41 - 50 4 51 – 60 5 Above 60 6
Education level	None 1 Primary 2 Secondary 3 Tertiary 4 Adult literacy 5 Other (specify) 6
Main household occupation	smallholder farmer 1 Semi commercial farmer 2 Wage laborer 3 Artisan 4 Housewife 5 Business person 6 Others 7
Number of children and dependants	

2.0 Do you own land? 1) Yes
2) No

3.0 How did you acquire land?

Acquisition of land	Land size
Lease	
Chief	
Purchased	
Inherited	
Tenancy	
Rent	
Others (specify)	

4.0 a) Do you use any soil fertility improvement technology? 1) Yes 2) No

b) If yes, which technologies do you use?

1) Inorganic fertilizer
2) Compost manure
3) Livestock manure
4) Agro forestry technologies
5) Integrated methods

c) If no, why?

1) Soil already fertile
2) Don't know any method (why)
3) Expensive
4) Others (specify) ____

5.0 What do you think are the main factors, which can lead to the use of soil fertility improvement technologies?

1) Ownership of land
2) Labor access
3) Capital access
4) Climatic and geographic changes
5) Political changes
6) Changes in prices of agricultural inputs and outputs
7) Changes in Agricultural policies
8) Others (specify) ___________________________________

6.0 Can you describe the historical changes in soil fertility improvement and management over the years? **(Farmers above 40 years)**

____

____

____

7.0 How do you perceive these changes?

____

____

8.0 What impact has the changes have had on agricultural production over the years? **(Farmers above 40 years)**

____
____
____

9.0 a) Do you have access to credit? 1) Yes 2) No

b) If yes, for what purpose do you take credit?

____
____

c) In what form is the credit?

____
____

d) Why do you take up credit?

____
____

e) What are the conditions for accessing credit?

____
____

10.0 If you don't access credit, why?

____
____

11.0 a) Do you hire labour? 1) Yes
2) No

b) If yes,
1) Permanent throughout the year
2) Temporary for a particular work (specify) ______________________________

c) How many people do you hire? ______________________________

12.0 a) Do you have off farm job? 1) Yes (specify)
2) No

b) If yes, how much do you earn annually? ______________________________

13.0 a) Do you have off farm trade? 1) Yes (specify)
2) No

b) If yes, how much do you earn annually? ______________________________

14.0 Do you belong to a farmers group or cooperative? 1) Yes (specify)
2) No

15.0 a) Do you get enough yields to last the whole year?
1) Yes
2) No
b) If no, how many month do you experience food shortage in a year?
____

16.0 a) Do you sell any of the farm products? 1) Yes
2) No

b) If yes, where do you sell? (Indicating the distance)
____

17.0 What were the main crops grown in the last 12 months?

Type of crop	**Area cultivated**	**Distance from home to farm**	**Quantity harvested**	**Quantity of losses**	**Amount consumed**	**Quantity sold**	**Present In stock**
Maize							
Tobacco							
Groundnuts							
Cassava							
Soybeans							
Beans							
Leafy Vegetables							
Other(specify)							

18.0 Do you have any livestock?

Livestock type	**Present stock**
Cattle	
Goats	
Chicken	
Others	

19.0 a) Do you use livestock manure for soil fertility improvement strategy? 1) Yes
2) No
b) If yes, how do you use livestock manure only?
1) Livestock manure alone
2) Integrate with other methods (specify) ______________________________

20.0 a) Do you compost your livestock manure or just apply straight into the field?

1) Compost
2) Apply straight into the field
3) Others (specify) ____

b) Why did you choose to use the method described in **20 a**?

____

21.0 a) Do you apply to the whole farm land? 1) Yes
2) No

b) If no, why? ____

22.0 Can you describe the changes in crop yield since you started using livestock manure?

1) Increased 3) Declined
2) No change 4) Can't tell

23.0 If crop yield has increased, by how much has yield increased?

Type of crop	Area applied with manure	Previous yield (# bags or Kg/ha)	Current yield (# bags or Kg/ha)	Yield increase (# bags or Kg/ha)
Maize				
Tobacco				
Groundnuts				
Cassava				
Soy beans				
Beans				
Leafy vegetables				
Others(specify)				

24.0 What are the major constraints of using livestock manure for farm production?

____
____

25.0 a) Do you use compost manure? 1) Yes
2) No

b) If yes, why did you choose to use compost manure?

____
____

26.0 a) Do you apply to the whole farm land? 1) Yes
2) No

b) If no, why? ____

27.0 How can you describe the changes in yield since you started using compost manure?

1) Increased 3) Declined
2) No change 4) Can't tell

28.0 If crop yield has improved, by how much has yield increased?

Type of crop	Area	Previous	Current yield (#	Yield increase (#

	applied with manure	yield (# bags or Kg/ha)	bags or Kg/ha)	bags or Kg/ha)
Maize				
Tobacco				
Groundnuts				
Cassava				
Soy beans				
Beans				
Leafy vegetables				
Others(specify)				

29.0 What are the major constraints of using compost manure for farm production?

____

____

30.0 a) Have you ever used Agroforestry technologies for soil fertility improvement?

1) Yes

2) No

b) If yes, how did you know about Agroforestry technologies?

____

c) How did you acquire the Agroforestry germplasm and technical support?

____

d) For how long have you been practicing Agroforestry? ______________________

31.0 a) Are you still using the Agroforestry technologies?

1) Yes 2) No

b) If no, why did you stop?

1) Labour supply 3) Not effective

2) Expensive 4) lack of seed

5) Others specify

32.0 a) What kind of Agroforestry techniques do you use for soil fertility?

1) Improve fallow

2) Mixed cropping

3) Simultaneous intercropping (***Gliricidia***)

4) Relay cropping

5) Others (specify) ____

b)Which AF tree species do you use

1) Gliricidia 4) Tithonia

2) Sesbania 5) Pigeon pea
3) Tephrosia 6) Others (specify)___________________________

33.0 Why did you choose these technologies?

____
____

34.0 a) Do you apply the agroforesrty technologies to the whole farm land? 1) Yes
2) No

b) If no, why? ____

35.0 a) How much land is allocated to each of the AF technology?

Agro forestry technology	Area under technology (acres)
Improve fallow	
Natural fallow	
Mixed cropping	
Simultaneous intercropping (***Glicidia sp***)	
Relay cropping	
Others (specify)	

36.0 a) How can you describe the changes in yield since you started using Agroforestry technologies?

1) Improved 3) Declined
2) No change 4) Can't tell

37.0 If crop yield has improved, by how much has yield increased?

Type of crop	Area applied cultivated	Agroforestry technology	[1]Previous yield (# bags or Kg/ha)	Current yield (# bags or Kg/ha)	Yield increase (# bags or Kg/ha)
Maize					
Tobacco					
Groundnuts					
Cassava					
Soy beans					
Beans					
Leafy vegetables					
Others(specify)					

38.0 What are the major constraints on the use of Agroforestry technologies?

____
____

For inorganic fertilizer user

39.0 Where do you buy inorganic fertilizer (Indicating distance)?

____

40.0 Do you apply the recommended rate for inorganic fertilizer to your crops? 1) Yes
2) No

41.0 a) Do you apply the inorganic fertiliser to the whole farm land? 1) Yes
2) No

b) If no, why? ____

42.0 How can you describe the changes in yield since you started using inorganic fertilizer?

1) Increased 3) Declined

2) No change 4) Can't tell

43.0 If crop yield has improved, by how much has yield increased?

Type of crop	Area applied cultivated	Inorganic fertilizer	[1]Previous yield (# bags or Kg/ha)	Current yield (# bags or Kg/ha)	Yield increase (# bags or Kg/ha)
Maize					
Tobacco					
Groundnuts					
Cassava					
Soy beans					
Beans					
Leafy vegetables					
Others(specify)					

[1]Yields obtained before using inorganic fertilizer

44.0 Why don't you use other organic materials for soil fertility improvement (***If don't combine methods***)?

1) Labour supply 4) Don't know them

2) Expensive 5) Others specify

3) Not effective

45.0 What are the major constraints of using inorganic fertilizer for farm production?

____

____

46.0 a) Do you use a combination of fertilizer and organic materials (integrated method) on the same field?

1) Yes 2) No

b) If yes, why do you combine inorganic fertilizer and organic materials?

___

___

47.0 a) What type of organic materials do you use for integration soil fertility improvement method?

___

___

b) How do you apply the two forms of fertilizer? *(Simultaneously or Consecutively)*

___

c) What fertilizer rates (inorganic) do you use for the integrated method?

___

___

48.0 a) Do you use intergrated methods to the whole farm land? 1) Yes
2) No

b) If no, why? ___

49.0) a) For how long have you been using integrated the methods?___

b) Do integrated methods have an impact on crop yield?
1) Increased over inorganic fertilizer alone
2) No change
3) Declined
4) Can't tell

50.0 If crop yield has improved, by how much has yield increased?

Type of crop	Area applied cultivated	Previous yield (# bags or Kg/ha)	Current yield (# bags or Kg/ha)	Yield increase (# bags or Kg/ha)
Maize				
Tobacco				
Groundnuts				
Cassava				
Soy beans				
Beans				
Leafy vegetables				
Others(specify)				

51.0 What are the major constraints of using integrated soil fertility improvement methods for farm production?

___

52.0 a) What is your opinion on the use of organic materials for soil fertility improvementwithout adding fertilizer?

___

____

b) What is your opinion on the use of inorganic fertilizer for soil fertility improvement without adding organic material?

____
____
____

53.0 Why don't you use inorganic fertilizer in your field? ***(Non inorganic fertilizer users)***

1) Limited supply　　　4) Land is fertile (why)
2) Expensive　　　5) Others specify
3) Not effective

54.0 What is your opinion on the use of integrated soil fertility improvement management?

____
____

55.0 How much labor is required for management of the soil fertility improvement technology?

Agro forestry Technology	Number of adult people involved in the activity	Area of land worked	Hours/ days	# of children involved in the work
Improve fallow				
Natural fallow				
Mixed cropping				
Simultaneous intercropping (***Gliricidia***)				
Relay cropping				
Livestock manure				
Compost manure				
Fertilizer				
Others (specify)				

56.0 What soil fertility improvement technologies do you prefer to use for each of the following crops?

Type of crop	**soil fertility improvement technique**
Maize	
Tobacco	
Groundnuts	
Cassava	
Soy beans	

Beans	
Leafy vegetables	

57. 0 What kind of technologies do you use for soil fertility improvement, for the different land site (Soil catenae)?

Land site	soil fertility improvement method(s)
Steep slopes (hill sides)	
Mid slope	
Flat area	
Valley bottom	
Dambo (Wetlands)	
Others (specify)	

58.0 Where did you get information for soil fertility improvement technologies?

1) Extension worker   4) Both
2) Researcher   5) Others (specify)
3) Friends

59.0 If extension worker or research scientist, from which institution or organization?

1) Government
2) NGO (specify) ______________________________
3) Others (specify) ______________________________

60.0 Explain the role of extension service in soil fertility improvement technologies adoption?

____

61.0 What role do fellow farmers in adoption of soil fertility improvement technologies play?

____

62.0 When does a farmer practicing soil fertility technologies become an adopter?

____