AN ANALYSIS OF TECHNICAL EFFICIENCY OF MIXED INTERCROPPING AND RELAY CROPPING AGROFORESTRY TECHNOLOGIES: A CASE OF ZOMBA DISTRICT IN MALAWI

BY

BONIFACE KAKHOBWE

BSc IN AGRICULTURE (MW)

A THESIS SUBMITTED TO THE FACULTY OF DEVELOPMENT STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL ECONOMICS

DEPARTMENT OF AGRICULTURAL AND APPLIED ECONOMICS

BUNDA COLLEGE OF AGRICULTURE

UNIVERSITY OF MALAWI

NOVEMBER 2007

TABLE OF CONTENTS

LIST OF TABLES		vi
LIST OF FIGURES		viii
DECLARATION		ix
DECLARATION BY SUPERVISORS		x
DEDICATION		xi
ACKNOWLEDGEMENTS		xii
ACRONYMS		xiii
ABSTRACT		xv
CHAPTER ONE		1
1.0	INTRODUCTION	1
1.1	Background Information to Malawi	1
1.1.1	Agriculture in Malawi	3
1.1.2	Agricultural Development Strategy	4
1.1.3	Agricultural Policy	5
1.1.4	Crop production in Malawi	6
1.1.5	Agroforestry	7
1.2	Rationale for the Study	8
1.3	Objectives of the Study	13
1.4	Hypotheses	13
1.5	Summary and Thesis Organisation	14
CHAPTER TWO		16
2.0	LITERATURE REVIEW	16
2.1	Introduction	16
2.2 1	Agroforestry Technologies	16
2.2.2	Economic Analysis of Agroforestry	18
2.2.3	Adoption of Agroforestry Technologies	23
2.3	Stochastic Frontier Production Model	27

2.3.1 Theoretical Framework 27
2.3.2 Stochastic Frontier Production Model Application 30

CHAPTER THREE 33

3.0 METHODOLOGY 33

3.1 Introduction 33
3.2 Smallholder Farm Survey 33
3.2.1 Study Area 33
3.2.2 Sampling Technique 34
3.2.3 Data Collection 35
3.2.4 Training of Enumerators and Questionnaire Pretesting 35
3.3 Models Specifications 36
3.3.1 Stochastic Frontier Production Models 36
3.3.2. Operational Definitions of Variables in Equations 1 and 2 38
3.3.3 Two Stage Least Squares (2SLS) Model 41
3.4 Analytical Approach 42
3.5 Limitations of the Methodology 42

CHAPTER FOUR 43

4.0 SOCIO-ECONOMIC CHARACTERISTICS OF HOUSEHOLDS 43

4.1 Introduction 43
4.2 Socio-Economic Characteristics 43
4.2.1 Household Size 43
4.2.2 Age of Household Head 44
4.2.3 Inorganic Fertilizer 44
4.2.4 Maize Seed 45
4.2.5 Land Size 45
4.2.6 Maize Yield 47
4.2.7 Cost of Production 47
4.2.8 Household Labour Availability 48
4.2.9 Gender of Household Head 49
4.2.10 Marital Status of Household Head 50

4.2.11 Education of Household Head 50
4.2.12 Access to Extension Services 52
4.2.13 Agroforestry Training 53
4.2.14 Year of Agroforestry Adoption 54
4.2.15 Period of Farming 54
4.2.16 Land Fragmentation 55
4.2.17 Club Membership 56
4.3 Concluding Remarks 56

CHAPTER FIVE 58

5.0 MODELS RESULTS AND DISCUSSIONS 58

5.1 Introduction 58
5.2 Stochastic Frontier Models Results 58
5.2.1 Technical Efficiency of Mixed Intercropping 59
5.2.2 Technical Efficiency of Relay Cropping 62
5.2.3 Technical Efficiency of Non-adopters 64
5.3 Comparison of Technical Efficiencies 66
5.3.1 Technical Efficiencies of Adopters and Non-Adopters of Agroforestry Technologies 69
5.3.2 Technical Efficiency Analysis per Extension Planning Area 70
5.4 Determinants of Technical Inefficiency 72
5.4.1 Determinants of Technical Inefficiency in Mixed Intercropping 73
5.4.2 Determinants of Technical Inefficiency in Relay Cropping 75
5.4.3 Determinants of Technical Inefficiency of Non-adopters 77
5.5 Technical Efficiency and Maize Production 78
5.6 Concluding Remarks 80

CHAPTER SIX 82

6.0 CONCLUSIONS AND RECOMMENDATIONS 82

6.1 Conclusions 82
6.1.1 Socio-economic Characteristics of Farmers 82
6.1.2 Technical Efficiency 83

6.1.3 Factors Determining Technical Inefficiencies 83
6.1.4 The Effect of Technical Efficiency 84
6.2 Recommendations 84
7.0 REFERENCES 86

APPENDIX 1: Mixed Intercropping and Relay Cropping Agroforestry Technologies Questionnaire 94

APPENDIX 2: Non-adopters Questionnaire 110

LIST OF TABLES

Table 1	Number of farmers practicing mixed intercropping and relay cropping agroforestry technologies, and non-adopters of agroforestry interviewed in Zomba district	34
Table 2	Conversion rates employed in estimating contribution to family labour of household members by availability of household member, gender and age category	39
Table 3	Socio-economic characteristics of farmers practicing mixed intercropping and relay cropping , and non adopters of agroforestry	46
Table 4	Cost of production of farmers practicing mixed intercropping and relay cropping and non adopters of agroforestry	48
Table 5	Gender of household head of farmers practicing mixed intercropping, relay cropping and non adopters of agroforestry	49
Table 6	Marital status of household heads of farmers practicing mixed intercropping, relay cropping and non-adopters of agroforestry	50
Table 7	Literacy level of farmers practicing mixed intercropping, relay cropping and non adopters of agroforestry	51
Table 8	Education level of farmers practicing mixed intercropping, relay cropping and non-adopters of agroforestry	52
Table 9	Extension access of farmers practicing mixed intercropping, relay cropping agroforestry farmers and non adopters of agroforestry	53

Table 10	Agroforestry training of farmers practicing mixed intercropping and relay cropping	53
Table 11	Year of adoption and period of farming experience of the farmers	54
Table 12	Land fragmentation of farmers practicing mixed intercropping, relay cropping and non-adopters	55
Table 13	Club membership of farmers practicing mixed intercropping, relay cropping and non-adopters	56
Table 14	Maximum log-likelihood stochastic estimates for mixed intercropping	60
Table 15	Maximum log-likelihood stochastic estimates for relay cropping	63
Table 16	Maximum log-likelihood stochastic estimates for non-adopters of agroforestry	65
Table 17	Technical efficiency of farmers practicing mixed intercropping, and relay cropping and non-adopters of agroforestry	67
Table 18	Technical efficiency of farmers practicing mixed intercropping, relay cropping and, non-adopters of agroforestry per Extension Planning Area	71
Table 19	Determinants of technical inefficiency of mixed intercropping	74
Table 20	Determinants of technical inefficiency of relay cropping	76
Table 21	Determinants of technical inefficiency of non-adopters of agroforestry	77
Table 22	Summary of Two Stage Least Squares of mixed intercropping, relay cropping and, non-adopters of agroforestry	79

LIST OF FIGURES

Figure 1	Map of Malawi showing Agricultural Development Divisions	2
Figure 2	Factors of production of mixed intercropping, relay cropping and non adopters of agroforestry	29
Figure 3	Technical efficiency of mixed intercropping, relay cropping and non adopters of agroforestry	68
Figure 4	Distribution of technical efficiency of agroforestry adopters of agroforestry	70
Figure 5	Distribution of technical efficiency per Extension Planning Area	72

DECLARATION

I hereby declare that the work in this thesis is the result of my own work and effort and has never been submitted for any award. Where other sources of information have been used, they have been acknowledged accordingly.

Signature: ________________

Boniface Kakhobwe

Date: ________________

DECLARATION BY SUPERVISORS

We hereby declare that this thesis is from the student's own work and effort and it has been acknowledged where he has used other sources of information. This thesis has been submitted with our approval.

MAJOR SUPERVISOR: ___________________________________

DR JULIUS H. MANGISONI

DATE: ___________________________________

SUPERVISOR: ___________________________________

PROFESSOR MOSES M. KWAPATA

DATE: ___________________________________

SUPERVISOR: ___________________________________

DR HENRY PHOMBEYA

DATE: ___________________________________

SUPERVISOR: ___________________________________

PROFESSOR ABDI K. EDRISS

DATE: ___________________________________

DEDICATION

This work is dedicated to my beloved parents, Mr and Mrs S.G. Kakhobwe. Dad, your quick departure in this world almost made me give up. You should have waited to see the fruits of your advice. Your unforgettable words motivated me to reach this far. To Mum, Anabetha, this is the product of your encouragement.

To my wife Chisomo, your moral and spiritual support has helped me to finalise this work. You are behind all my successes.

ACKNOWLEDGEMENTS

I am grateful to RUFORUM for supporting my training in the Department of Agricultural and Applied Economics at Bunda College through Dr Julius H. Mangisoni's Economics of Agroforestry Project.

I want to thank my supervisor, Dr Julius H. Mangisoni and members of the supervisory committee: Professor Moses B. Kwapata, Dr Henry Phombeya and Professor Abdi K. Edriss. They provided detailed, thoughtful, and constructive comments on my numerous drafts of this thesis. I am also grateful to Dr Franklin Simtowe for assisting with data analysis, Dr Njoloma for useful comments on the drafts and Professor Ekwamu Adipala, Professor Vincent Saka and Professor James Banda for coordinating the programme.

Save the Children Federation management, particularly Jennifer Froistad, Paul Mecartney, Lesley Holst, Brenda Yamba and Ethel Yabu deserves my heartfelt thanks for granting me leave of absence and for moral support toward my education.

Thanks to the International Centre for Research in Agroforestry (ICRAF), the Agricultural Extension Development Officers (AEDOs) and the participating farmers of Thondwe, Dzaone and Malosa Extension Planning Areas (EPAs) for supporting my field work, and Bunda College Library for providing literature for this study.

Special thanks to my family. Duncan and Gladwel, your patience was marvelous.

ACRONYMS

AA	Adopters of Agroforestry
ADD	Agricultural Development Division
ADMARC	Agricultural Development and Marketing Corporation
ARDN	Adaptive Research and Dissemination Network
C	Carbon
CAN	Calcium Ammonium Nitrate
CCP	Chance Constrained Programming
CD	Cobb-Douglas
DADO	District Agricultural Development Office
EPA	Extension Planning Area
GDP	Gross Domestic Product
Ha	Hectare
ICRAF	International Centre for Research in Agroforestry
IMF	International Monetary Fund
K	Potassium
Kgs	Kilograms
MAFE	Malawi Agroforestry Extension Project
MI	Mixed Intercropping
MK	Malawi Kwacha
MLE	Maximum Likelihood Estimation
MLL	Maximum Log-Likelihood
MLRM	Multiple Linear Regression Model
MoA	Ministry of Agriculture
N	Nitrogen
NA	Non-Adopters
NSO	National Statistical Office
OLS	Ordinary Least Squares
P	Phosphorus
PASAD	Policy Analysis and Sustainable Agricultural Development in Central, Eastern Europe and Southern Africa
PPF	Production Possibilities Frontier

RC	Relay Cropping
RDP	Rural Development Program
SAP	Structural Adjustment Program
SARPN	Southern African Regional Poverty Network
SF	Stochastic Frontier
SFPM	Stochastic Frontier Production Model
SFRFM	Smallholder Fertilizer Revolving Fund of Malawi
SPS	Starter Pack Scheme
SPSS	Statistical Package for Social Scientists
TE	Technical efficiency
TIP	Targeted Input Program
TVC	Total Variable Cost
2SLS	Two Stage Least Squares

ABSTRACT

The study was conducted in Zomba district with the main objective of assessing technical efficiency (TE) of mixed intercropping (MI) and relay cropping (RC) agroforestry technologies (AT). Study population consisted of 101 and 74 farmers practicing MI and RC agroforestry technologies, respectively, and 120 non-adopters of agroforestry (NA).

Analyses involved three separate estimations of MI and RC agroforestry technologies, and NA of agroforestry stochastic frontier production functions (SFPF). Technical inefficiency (TI) components were simultaneously estimated with the TEs during the estimation of the SFPFs. Factors responsible for TI were separately regressed on the TI components of the three categories of farmers.

Mean TE of MI, RC and NA were 0.62, 0.57 and 0.46, respectively. Results showed that the farmers have TIs with 51%, 33% and 38% of MI, RC and NA, respectively producing maize below the mean TE levels. Results also showed that age and education of household head in MI, age of household head and land fragmentation in RC and period of farming and land fragmentation in NA determine TI.

The following recommendations were made in the study. There is need to address TIs by increasing accessibility and use of inorganic fertilizer, and by improving the quality of training of the farmers. There is also need to reduce TE variations through intensification of extension contact with the farmers. Finally, similar research should be extended to alley cropping and improved fallow agroforestry technologies.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information to Malawi

Malawi is in the southern part of Africa bordered by Tanzania in the north, Zambia in the west and Mozambique in the east and the south (Figure 1). The country is located between latitudes 9^o to 18^o South and longitudes 33^o to 36^o East. It occupies an area of 11.8 million hectares of which 9.4 million is land with the remaining part comprising Lake Malawi and other small lakes and rivers. The country has three distinct topographical areas. These are the high-attitude plateaus ranging from 1400 m to 2300 m above sea level; the medium-altitude plateaus between 800 m and 1400 m; and the rift valley plains between 50 m and 800 m above sea level along the lakes and the Shire River (Malawi Government, 2002).

The country is divided into three administrative regions, namely, the Southern, the Central and the Northern region. Each region is divided into districts. There are 13 districts in the South, 9 districts in the Centre and 6 districts in the North giving a total of 29 districts for the whole country (National Statistical Office (NSO), 2004).

The human population of Malawi is estimated at 12 million (NSO, 2004). The national poor population is estimated at 52.4%. The Southern region has the largest poverty rate of 60% followed by the Northern and the Central regions with poverty levels of 54% and 44%, respectively (Malawi Government, 2005).

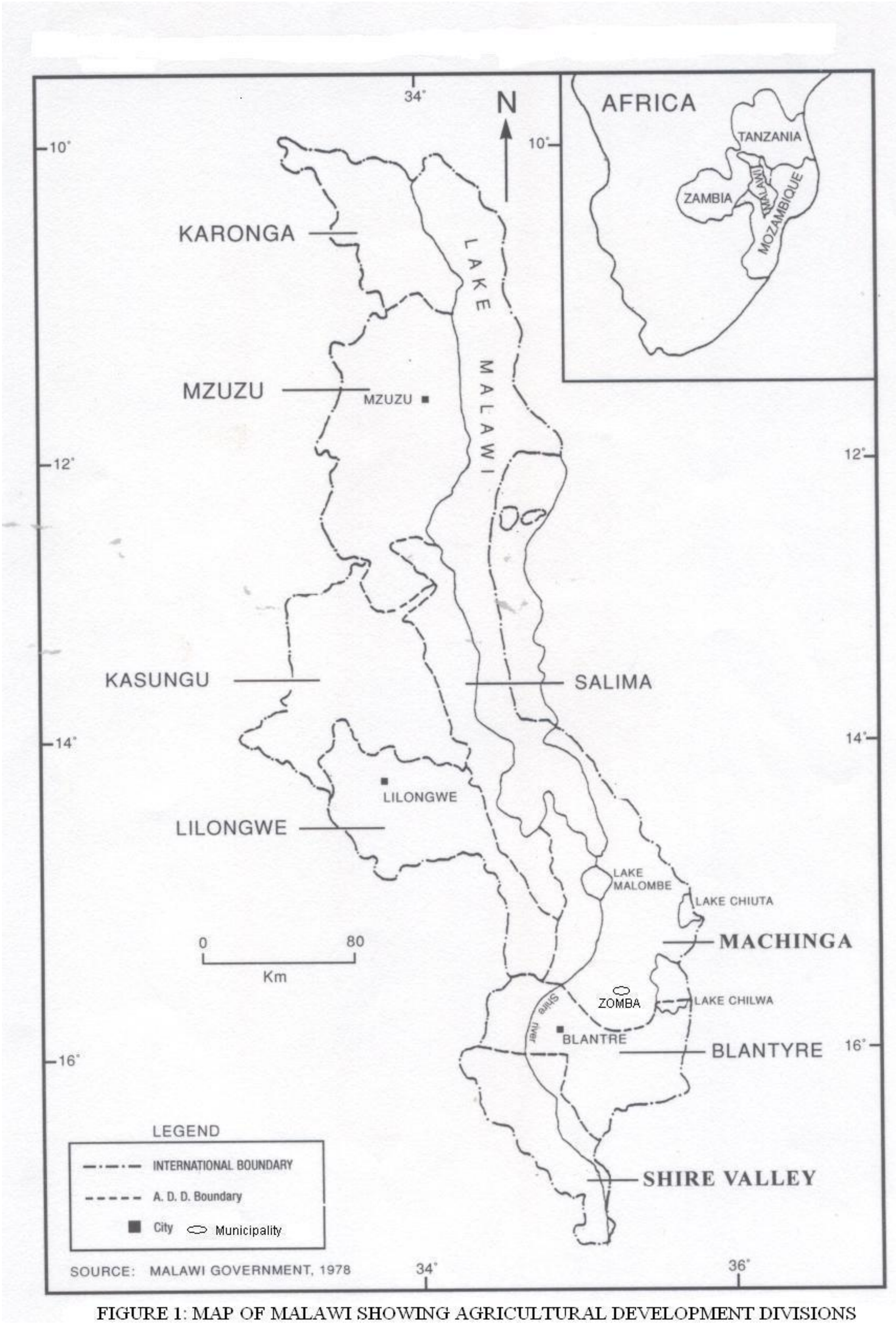


FIGURE 1: MAP OF MALAWI SHOWING AGRICULTURAL DEVELOPMENT DIVISIONS

1.1.1 Agriculture in Malawi

Agriculture is the backbone of the country's economy. The sector contributes more than 35% of Gross Domestic Product (GDP) and about 93% of foreign exchange earnings (Malawi Government, 2005). Tobacco accounts for about 60% of the foreign exchange earnings while tea, sugar and coffee account for approximately 20% of the foreign exchange earnings of the country (Gromwell and Kyegombe, 2005). Agriculture is an important source of livelihood for 71% of the rural population because it provides more than 80% of total employment and accounts for 65.3% of total income of the rural poor. The agricultural sector occupies 5.3 million hectares of land representing 56% of the 9.4 million hectares of the country's land area (Malawi Government, 2000).

The agricultural sector is dualistic comprising of estate and smallholder systems. The estate system mainly produces cash crops such as tobacco, tea, sugarcane and coffee. The smallholder system largely produces food crops like maize, cassava, vegetables, beans and ground nuts (Malawi Government, 2005). About 84% of the national agricultural production comes from about 2 million smallholder farmers that cultivate on average 0.5 hectares of land (Chirwa, 2005).

Agricultural production is limited by several factors. These include poor access to agricultural inputs, poor infrastructure, low adoption of technologies and environmental depletion such as declining soil fertility, land degradation and deforestation, which threaten both the productivity and sustainability of natural resources (Malawi

Government, 2005). The government put in place strategies in order to address these problems and develop the sector.

1.1.2 Agricultural Development Strategy

The Ministry of Agriculture and Food Security (MoAFS) is responsible for all agricultural programs in the country. The Ministry is divided into 8 Agricultural Development Divisions (ADDs). ADDs are structured as ecosystem-related and geographically based subdivisions within the three regions of the country (Figure 1). The ADDs are Shire Valley, Blantyre and Machinga in the Southern Region; Lilongwe, Salima and Kasungu in the Central Region; and Mzuzu and Karonga in the Northern Region. The ADDs are divided into District Agricultural Development Offices (DADOs) which are divided into Extension Planning Areas (EPAs). The EPAs are further divided into sections. The Ministry is organised into 6 departments which exist at all levels. The departments are; Agricultural Research and Technical Services, Animal Health and Industry, Crop Production, Agricultural Extension Services, Administration and Land Resources Conservation (Noragric, 2006).

Land Resources and Conservation department deals with all issues related to prevention of land resources degradation, restoration of degraded land resources and developing technologies to sustain the land resource base. Some of the practices promoted by the department are use of organic manure, agroforestry, contour ridges, box ridges and contour vegetation strips. Sustainable agricultural development in Malawi emphasises on rational use of natural resources especially soil and water. Inappropriate use of soil and water resources results in low crop yield (Malawi Government 2005).

In order for the agricultural development strategy to be effective, the country needs a guiding agricultural policy. The MoAFS is also responsible for the agricultural policy formulation and regulation.

1.1.3 Agricultural Policy

The Constitution of Malawi recognises access to food as a right of each individual (Malawi Government, 2005 and Southern African Regional Poverty Network (SARPN), (2003). The responsibility of the government is to ensure equality of opportunity for food. It is partly on this basis that agricultural policies are formulated in order to create an enabling environment for the sector development.

The country's agricultural policy is developed in line with several guiding documents. Some of the key documents are the Malawi Growth and Development Strategy, Malawi Economic Growth Strategy, Malawi Vision 2020 and the Millennium Development Goals. The agricultural policy mainly aims at promoting and facilitating agricultural productivity to ensure food security, increased incomes and creation of employment opportunities. To achieve this, there is need for sustainable management and utilization of natural resources, adaptive research and effective extension delivery system, promotion of value-addition, agribusiness and irrigation development (Malawi Government, 2006).

In order to attain sustainable management and utilization of natural resources, agricultural policy relates to National Land Resources Management Strategy which calls for efficient, diversified and sustainable use of land based resources (Malawi Government, 2000). Activities identified include; production, maintenance and dissemination of appropriate soil organic matter building technologies, promotion of appropriate soil and water conservation practices and promotion of aforestation in degraded areas (Malawi Government, 2006).

In addition to the agricultural policy, the Malawi Government (2005) developed a Guide to Agricultural Production and Natural Resources Management Handbook. This works as a reference material for crop production and land husbandry in the country.

1.1.4 Crop production in Malawi

The country's major food crops are maize, groundnuts, cassava, pulses, sorghum, sweet potatoes and rice. Maize is intensively grown and is the staple crop of the country. The intensive production is pursued on over 60% of smallholder land (Snapp *et al*., 2002).

Natural disasters, such as drought, floods and crop destruction by pests and diseases, have had adverse effects on the country's national crop production. Most smallholder agriculture is rain-fed. This makes domestic food availability highly vulnerable to climatic variation. Since 1990, the country has experienced severe food shortages in 1992, 1994, 1997, 2001 and 2002 precipitated by drought or heavy rains (IMF, 2002).

In order to address the problems affecting crop production, government promotes cropping systems that ensure sustained food availability and crop diversification. Some of these practices are agroforestry interactions such as mixed cropping, intercropping, strip cropping, relay cropping and winter cropping (Malawi Government, 2005). Other attempts to sustain crop production include promotion of animal manure and compost, as a substitute and complement to inorganic fertiliser. These efforts have not been successful because livestock holdings are generally low, limiting the availability of animal manure; by the high labour demands of compost making; and by the low level of nutrients produced in comparison with soil fertility needs (Gromwell and Kyegombe, 2005). Agroforestry is another intervention that has also been employed in the country to improve maize production (Neupane and Thapa, 2001).

1.1.5 Agroforestry

Agroforestry is a collective term for land-use systems and technologies, where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land management unit as agricultural crops and/or animals, either in some form of spatial arrangement or temporal sequence. In agroforestry systems, there are both ecological and economical interactions between the different components (International Centre for Research in Agroforestry (ICRAF), 1993). Agroforestry provides fuelwood, fodder, fruits, medicine, shade, poles for infrastructure construction and income through poles and tree seed sales in addition to restoring and conserving soil fertility (ICRAF, 2003).

In Malawi, agroforestry extension activities were first initiated in 1982/83 cropping season by the Ministry of Agriculture. These activities started in Ntcheu Rural Development Program (RDP) of Lilongwe Agricultural Development Division (ADD) which is one of the eight ADDs in the country. The main objective was to control soil and water erosion on sloping hillsides and to improve and/or restore soil fertility. Agroforestry technologies that were demonstrated were alley farming and contour buffer/grass strip (Mwakalagho, 1990).

Many agroforestry programs/projects are implemented in Malawi to promote the technologies. One such project was the Malawi Agroforestry Extension Project (MAFE) that aims at increasing the adoption of agroforestry and soil conservation practices to improve farm productivity and natural resource management. MAFE has been instrumental in testing, adapting and extending agroforestry technologies. The agroforestry practices promoted for soil improvement and wood products are: interplanting of soil fertility improving trees, annual undersowing with *Tephrosia vogelii*, improved planted fallows using soil fertility improving trees/shrubs and planting multipurpose trees in homesteads as woodlots and along farm boundaries (Bunderson *et al.*, 2004).

1.2 Rationale for the Study

Malawi as an agro-based country faces many challenges to maintain and sustain household and national food security levels. The country's annual maize requirement is

2.1 million tonnes. For a long time, the country's emphasis on domestic maize production has been on food availability believing that this is significantly cheaper than imported maize (European Union, 2006).

The production of maize is mainly affected by declining soil fertility and the problem has reached critical levels in the past decades (Policy Analysis and Sustainable Agricultural Development in Central, Eastern Europe and Southern Africa (PASAD), 2005). Soils in Malawi lose nutrients at annual rates of not less than 40 kg of nitrogen (N), 6.6 kg phosphorus (P) and 33.2 kg potassium (K) per hectare (ha) (Makumba, 2003).

In order to address the soil nutrients loss, farmers have mainly relied on inorganic fertilizers to increase maize production. However, prices of inorganic fertilizers are high resulting in low application rates of less than 10 kg/hectare among smallholder farmers (PASAD, 2005). For example, an average price of a 50 kg bag of high analysis fertilizers like 23:21:0 + 4S, UREA and Calcium Ammonium Nitrate (CAN) increased nearly fifteen times from an average of MK100.00 in 1994/95 to over MK1500 in 2004. In 2007, the average market price for UREA was MK 3,450. CAN was selling at MK3, 230 while 23:21:0 + 4S was selling at MK3,750 per 50 kg bag (Smallholder Fertilizer Revolving Fund of Malawi (SFRFM), 2007) and (Farmers World, 2007).

Historically, the exorbitant price of inorganic fertilizers was addressed by relatively widespread access to seasonal credit. However, the seasonal credit facility collapsed in the early 1990s when the Structural Adjustment Programs (SAPs) were introduced. The

SAPs were employed with influence from the International Monetary Fund (IMF) and World Bank. Under the SAPs, input subsidies were removed, agricultural markets were deregulated and liberalized. It was believed that government interventions through the Agricultural Development and Marketing Corporation (ADMARC) distorted prices and other market signals. Limited commercial imports of inorganic fertiliser, and trader uncertainty of the longevity and scale of Targeted Input Program (TIP) and Starter Pack Scheme (SPS) contributed to inorganic fertilizer shortages, high prices and low uptake (Gromwell and Kyegombe, 2005).

SPS was launched in 1998/99 agricultural season with an aim of increasing fertilizer and other inputs accessibility to the poor resource farmers. The scheme was changed to TIP in 2001/02. In 2005/06, the government adopted an Input Subsidy Programme (ISP) which is currently being implemented (Malawi Government, 2006).

Besides inorganic fertilizer, there are organic fertilizer technologies that have been promoted over the past years. Research by Kamanga *et al.* (1999), Snapp *et al*. (2002), Snapp *et al*. (1998) and Snapp and Silim (2002) demonstrated the beneficial effects of including leguminous crops in the smallholder farming system to provide nitrogen. One such crop is soybeans which is self-inoculating and fixes nitrogen from the air into the soil. Agroforestry is another option that is being promoted to restore nitrogen in the soil. Apart from nitrogen provision, the trees add organic matter to the soil, thus improving soil structure and inhibiting soil erosion (Kwesiga *et al*., 2003).

Agroforestry has potential for enhancing food production and farmers' economic conditions in a sustainable manner through its positive contributions to soil fertility and household income (Neupane and Thapa, 2001). National aim of agroforestry is to improve food security, agricultural sustainability and the conservation of the natural resource base by addressing problems faced by smallholder farmers. The problems include: low and declining soil fertility, increasing soil erosion and water run-off on steep slopes and shortage of fuel wood (Malawi Government, 2005).

Despite the potential of agroforestry to restore soil fertility, most agroforestry research has been on biological performance of trees and technology adoption without adequate consideration of the technological context (Scherr and Muller, 1991). In Malawi, agroforestry research has been dominated by agronomic based studies. For example, Chilimba *et al.* (2004) evaluated promising agroforestry technologies for smallholder farmers in Malawi. It was found out that intercropping of maize between hedgerows of trees and use of foliar biomass of shrubs or trees as organic fertilizer give significant yield over unfertilized maize in Malawi. Kamanga *et al.* (1999) studied intercropping of perennial legumes for green manure additions to maize fields in southern Malawi. Other agronomic studies in Malawi were done by Kwesiga *et al.* (2003), Makumba *et al.* (2006), Kabambe *et al.* (2004) and Carr (2004).

Economic studies on agroforestry technologies both in Malawi and across Africa have also sidelined the technological component. These include Malawian studies by Mkandawire *et al.* (2004), Mangisoni (1999), Nyirenda (2002) and Selenje and

Mwakalagho (1990). Nyirenda (2002) evaluated the performance of improved fallows in Central Malawi by applying Binary Logit Model. Mangisoni (1999) assessed the profitability of erosion control technologies by comparing optimal net revenues from agroforestry/vetiver grass combination and non-agroforestry practices using Chance Constrained Programming (CCP). Other economic studies outside Malawi were done by Degrande (2001), Bamire and Manyongo (2003) and David and Rausen (2003). All these economic analyses on agroforestry have not handled efficiency of agroforestry technologies.

This study was a first attempt in Malawi to assess efficiency of agroforestry but only focused on technical efficiency of agroforestry. The study focused only on technical efficiency of mixed intercropping and relay cropping agroforestry technologies in order to assess how maize produced by farmers practicing the technologies differs from the maximum they can obtain per unit area.

Technical efficiency may not be a guarantee for household food security. A farmer can have technical efficiency of one (on the frontier) and still be food insecure hence the call for this study. The Malawi Government, ICRAF and other partners will incorporate the information generated by this study in their programs.

1.3 Objectives of the Study

The main objective of the study was to assess the technical efficiency of mixed intercropping and relay cropping agroforestry technologies among smallholder farmers in Malawi. The specific objectives were:

1. To evaluate the technical efficiency of mixed intercropping and relay cropping technologies on smallholder farms in Zomba.
2. To identify factors that determine technical efficiency of agroforestry farmers in Zomba.
3. To determine the effect of technical efficiency of mixed intercropping and relay cropping agroforestry technologies on maize production among smallholder farmers in Zomba.
4. To assess the socio-economic characteristics of farmers practicing mixed intercropping and relay cropping agroforestry technologies.

1.4 Hypotheses

The following hypotheses were tested in the study.

1. Farmers practicing mixed intercropping and relay cropping agroforestry technologies are technically inefficient.
2. There are no factors that determine the technical efficiency of mixed intercropping and relay cropping agroforestry technologies.
3. There is no relationship between maize production and mixed intercropping and relay cropping technical efficiency.
4. There are socio-economic differences among farmers practicing mixed intercropping and relay cropping agroforestry technologies.

1.5 Summary and Thesis Organisation

The foregoing Chapter has presented the geographical, economic and agricultural background to Malawi, national agricultural development strategy and agricultural policy. In the process of introducing agriculture in Malawi, Chapter One presented challenges of crop production and government responses to the challenges. Agroforestry was introduced as a response to declining soil fertility in Malawi. The Chapter also presented the rationale for the study by highlighting research gaps in agroforestry and later introduced objectives and hypotheses of the study.

Chapter Two will present literature review. The reviewed studies are in areas of agroforestry agronomic research, economic analysis and agroforestry technologies implementation in Malawi. The Chapter further reviews studies that applied Stochastic Frontier Production Model (SFPM). The SFPM is the focus in this study.

Chapter Three narrates the methodology. The Chapter starts with description of study area, sampling and data collection. Later the stochastic frontier production model is discussed. The Chapter concludes with limitations of the methodology.

Chapter Four presents the Socioeconomic Characteristics of Survey Households. Chapter Five will present results of the SFPM, estimated technical efficiency levels of mixed and relay cropping agroforestry technologies and impacts of the technical efficiency on maize production and the effect of mixed and relay cropping agroforestry technologies on maize production. Chapter Six concludes the study and presents policy recommendations.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter reviews agroforestry technologies and some of the related agroforestry studies. The emphasis is on agroforestry research, economic analyses and adoption. Literature on Stochastic Frontier Production Model (SFPM) is also reviewed in the chapter.

2.2.1 Agroforestry Technologies

Smallholder farmers in Malawi are encouraged to use technologies that improve crop productivity. Some of these technologies include agroforestry, inorganic fertilizer and organic manure. Main agroforestry systems in Malawi are alley cropping, improved fallow, mixed intercropping and relay cropping.

In relay cropping, maize is planted at the onset of rain, but planting of the trees/shrubs is delayed for about two weeks after the maize has been planted. Recommended trees/shrubs for the technology in Malawi are *Tephrosia vogelii, Sesbania sesban* and *Cajanus cajan.* Seed rate for *Tephrosia vogelii* is 5 kg per hectare while seed rates for *Sesbania sesban* and *Cajanus cajan* are 2 kg per hectare and 7.5 kg per hectare respectively (Malawi Government, 2005). Spacing for direct sowing of the trees with maize on ridges of 75 – 90 cm is 30 cm (2 seeds per station). Trees/shrubs continue growing on the piece of land after the crop has been harvested, forming a short-term fallow during the dry season. The trees are cut and all the leafy biomass is incorporated into the soil before the next rain season (Makumba, 2003).

In mixed intercropping, agroforestry tree species are intercropped with maize. Tree species being promoted in this technology are *Gliricidia sepium, Leucaena diversifolia* and *Senna spectabilis*. The recommended tree spacing is 1.8m while interplant spacing is 0.9m (Malawi Government, 2005). Soil nutrients are added to the soil through nitrogen fixation and/or incorporation of prunnings (green manure) to the soil. Mixed intercropping and a fraction of the recommended fertilizer rate can obtain yields at par with recommended rates of fertilizer (ICRAF, 2003).

Improved fallows involve deliberate planting of fast-growing legumes for rapid replenishment of soil fertility. Key services provided by fallows include fuelwood production, recycling of other nutrients besides Nitrogen (N), provision of Carbon (C), weed suppression, *Striga* control and improved soil water storage (Sanchez, 1999).

Tephrosia vogelli is the most successful tree species under improved fallows in Malawi but *Cajanus cajan* and *Sesbania sesban* may also be used. In the first year, 3 seeds per station of *Tephrosia* or *Cajanus* are sown on every ridge of maize (75-90 cm apart). In case of *Sesbania sesban,* seedlings are interplanted on every ridge between maize planting stations (75cm-90 cm apart). If *Sesbania sesban* is directly sown, 5-8 seeds are planted per station between maize planting stations. Maize production is abandoned in the second year and resumed in the third season (Malawi Government, 2005).

In alley cropping, trees (often leguminous) are planted in hedgerows between open spaces (‘alleys’) after every four to five maize crop ridges at spacing of 45 – 90 cm (Malawi Government, 2005). The hedgerow species are periodically pruned (both above ground and below ground), and the prunnings are applied to the soil where the crop is growing. These prunnings add carbon and nutrients to the soil (Jordan, 2004).

2.2.2 Economic Analysis of Agroforestry

In Malawi, intercropping of maize between hedgerows of trees and use of foliar biomass of shrubs or trees as organic fertilizer have been giving significant yield increases over unfertilized maize. Recognizing the promise of agroforestry technologies, the Ministry of Agriculture and Irrigation started a national strategy to scale up the technologies for large-scale adoption in Malawi (Chilimba *et al.,* 2004). Mkandawire *et al*. (2004) applied a probit regression model to study smallholder farmers' willingness to invest in agroforestry technologies in Zomba district of Malawi. The variables used were sex, age, marital status of the farmers, education, land ownership, land holding size, food security status, ownership of livestock, number of agroforestry tree species, labour use, fertilizer use, source of income and number of years the agroforestry technology has been used. The analysis revealed that farmers who were married and who owned livestock were willing to take up agroforestry by investing in tree seedlings. These results suggested that in southern Malawi, agroforestry research should pay greater attention to integrated farming systems that include use of trees as folder for livestock.

An analysis of ICRAF's agroforestry research and development during the 1990s indicated that tree fodder banks greatly increase fodder production and enrich livestock diets with protein supplements (Kwesiga *et al.,* 2003). When an agroforestry system has an objective of providing livestock feeds, an optimal mix of crop-livestock-tree production is required to achieve the maximum productivity from their interactions.

Babu *et al.* (1993) developed a model of optimal use of green manures and livestock feed from tree component and animal manure from livestock component for field crop production. The model was used to analyze the economic role and potential contributions of crop-livestock-tree production systems to nutrient recycling. The model results showed that unless steady-state levels of the stock of green leaf biomass and animal manure and their use, as organic manure and animal feed, are determined for various tree and livestock species and for various levels of substitution with chemical fertilizers and commercial animal feed, the crop-livestock-tree production systems may not be sustainable.

Lapar and Pandey (1999) carried out a microeconomic analysis of contour hedgerows in Philippine uplands. The results showed that adoption depends on several farm and farmer characteristics and the relative importance of these factors differs across sites. Non adopters cited high cost of establishment and maintenance as the major constraints to adoption of hedgerows. This study further indicated that in the more marginal environments, on-site benefits alone may not be sufficient to justify investment in soil conservation. Chikowo *et al*. (2003) also observed that improved or planted fallows using fast-growing leguminous trees are capable of accumulating large amounts of nitrogen through biological nitrogen-fixation and subsoil nitrogen capture.

In Zimbabwe, more than 50% of farmers leave land fallows of sizes varying from 0.5 to 1.0 ha (11-13% of the total landholding). Research findings showed that two-year long planted fallow of *Sesbania sesban* and *Cajanus cajan* significantly increase maize yields at an originally degraded and nutrient-depleted field, confirming the effectiveness of planted fallows in raising fertility (Nyakanda *et al*., 2004).

In the humid lowlands of West Africa, an economic analysis of *Cajanus cajan* fallows compared with natural fallow showed that *Cajanus* fallows are profitable under most tested scenarios, both in terms of returns to land and labour. Improved fallows with *Cajanus cajan* are a good response to shorten natural fallows for households in the humid lowlands of Cameroon with land constraints. However, wide dissemination of the technology requires a targeted extension approach and adequate seed supply strategies, which should be based on joint efforts between farmers, extension services and research (Degrande, 2001).

David and Rausen (2003) studied wood production, soil replenishing potentials and economic returns of five improved fallow systems: *Sesbania sesban*, *Calliandra calothyrsus*, *Alnus acuminate*, *Tephrosia vogelii* and *Acanthus pubescens* in Uganda. These were compared with traditional bush fallow and continuous cropping systems. Results showed an increase in nitrogen levels by 82% in *Sesbania* fallows systems and 37.8 % in *Calliandra* fallows. Cumulative maize yield after fallow increased significantly in the *Tephrosia*, *Alnus*, *Calliandra* and *Sesbania* fallow systems.

Neupane and Thapa (2001) examined the impact of an agroforestry intervention by Nepal Agroforestry Foundation in 1993-94 on farm income. A cost-benefit analysis showed that agroforestry system was more profitable than the conventional one. Results also showed that introduction of mulberry trees (*Morus alba*) for sericulture could further enhance the profitability of an agroforestry-based system.

In Zimbabwe, Ayuk and Jera (2004) assessed the level of soil fertility and food security problems and soil fertility improvement practices to characterise land users as a first step in developing scaling up strategies for improved fallows. Descriptive statistics and correlation analysis indicated that farmers utilize a variety of strategies to improve fertility status of their soils. The implication is that farmers are more likely to be receptive to new ideas about soil fertility improvement. However, for efficient scaling up, key socio-economic variables need to be identified and combined with biophysical knowledge of the target areas. The study also found out that the use of implements, master certificate, membership in clubs or association, frequency of contact with extension workers and tenure over field had a strong correlation with the practice of improved fallows.

The use of participatory research methods in evaluating tree legumes has received little attention among researchers because of widely-held assumption that data generated in this way are qualitative and not amenable to statistical testing. Using a participatory tool known as *bao* game, Kuntashula and Mafongoya (2005) showed that 112 farmers in eastern Zambia highly rated 11 agroforestry trees for soil fertility improvement, source of fuel wood, light construction materials, poles and fodder. *Leucaena collinsii* was rated highest for provision of all the above benefits. *Gliricidia sepium, Acacia angustissima* and *Calliandra calothyrsus* had high scores for soil fertility improvement, while *Senna siamea, Leucaena esculenta* and *Leucaena pallida* were rated highly for fuel wood provision and pole production. These latter species with the exception of *Senna siamea* were also rated highly for light construction materials. This research shows that data generated using the *bao* game can be quantitatively analysed in a statistically rigorous manner.

Asynchrony between nitrogen released by organic materials and the nitrogen demand by the crop leads to low nitrogen use efficiency. Optimizing the time of application can increase the nitrogen recovery. A field experiment by Makumba *et al*. (2006) determined the effects of time of application of *Gliricidia sepium* prunnings and of the addition of small doses of inorganic nitrogen fertilizers on nitrogen recovery and yield of maize. Six split applications of *Gliricidia* prunnings in October, December and February were compared in the study. Results showed that higher nitrogen uptake and maize yields are obtained when *Gliricidia* prunnings are applied in October than when applied in December and February. Split application of prunnings prolonged mineral nitrogen availability in the soil until March but did not increase nitrogen uptake and maize grain yield compared to a sole application in October. Combinations of *Gliricidia* prunnings and inorganic fertilizer increased maize yield over prunnings alone. The study also concluded that application of *Gliricidia* prunnings in October is more efficient than application in December and February.

2.2.3 Adoption of Agroforestry Technologies

The development of agroforestry technologies and agroforestry tree species has been growing faster than their adoption by farmers. Adoption is critical for sustainability of any technology. Bello (1990) stipulated that agroforestry systems that enable the smallholder farmer to increase food production on a small piece of land can be easily adopted.

Assessment of adoption potential is a key element of a participatory, farmer-centred model of research and development. The assessment assists to improve efficiency of the technology development and dissemination process, helps document the progress made in disseminating new practices, demonstrate the impact of investing in technology development, provide farmer feedback for improving research and extension programmes, and help to identify the policy and other factors contributing to successful technology development programmes as well as the constraints limiting the achievements (Franzel *et al*., 2001).

Carr (2004) assessed the reasons for the failure of agroforestry technologies adoption and the remedy for the situation in Malawi. The reasons identified include inappropriate technology, lack of appreciation of farmers' labour constraints and the absence of a striking short-term impact on productivity. The response to this has been the development of more appropriate technologies and the intensification of formal extension. The study recommended that fresh initiatives that make greater use of the extensive informal networks in Malawi should be explored.

Thangata and Alavalapati (2003) examined the adoption of intra-row cropping of *Gliricidia sepium* with maize in Malawi. The differences between adopters and non-adopters of *Gliricidia sepium* in terms of their age, number of active members of the family, extension contact and income sources were examined. Results from logistic regression analysis suggested that age of the farmer, extension contact and the number of people who contribute to farm work are important variables in determining the adoption of mixed inter-cropping agroforestry technology. It was observed that farmers modified technologies to suit their situation, suggesting that local participation is important in technology development.

Lack of an effective dissemination pathway has been an obstacle for scaling up agroforestry technologies in Eastern Province of Zambia. The Adaptive Research and Dissemination Network (ARDN) examined the effectiveness of government agricultural extension service, farmer-trainer and traditional leader dissemination pathways for scaling up agroforestry technologies. Seventy percent of farmers indicated that farmer-trainers were more effective for extension of improved fallows than the other channels. About 92% of the sample farmers were aware of the improved fallow technology but only 33% of them had adopted the tree fallows. The farmer-trainers were the source of initial information to 41% of farmers who were aware of the technology (Kabwe *et al.*, 2004).

Community members in Zambia used the wealth ranking method to identify the different wealth groups in their communities, to determine each household's wealth status, and to assess the association of wealth and different types of households with the planting of improved tree fallows. There were no significant differences between the proportions of women and men planting improved fallows. However, there was some evidence of association between planting improved fallows and wealth. Twenty two percent (22%) of the 'poor' group and 16% of the 'very poor' group were planting improved fallows suggesting that there are no barriers preventing low-income households from practicing the technology. Whereas the use of mineral fertilizer is strongly associated with high-income male farmers, improved fallows appear to be a gender-neutral and wealth-neutral technology. Poor farmers appreciate improved fallows because it permits them to substitute small amounts of land and labour for cash which is their most scarce resource (Phiri *et al*., 2004).

Bakengesa *et al.* (2004) assessed the influence of different natural resource management policies on the adoption of agroforestry technologies in the Shinyanga region of Tanzania. In the study, over 90% of right ownership was with men. Insecurity on land and tree tenure resulted in low adoption of agroforestry technologies among farmers. Results indicated that implementation of policies related to land, mining, agriculture and livestock greatly influence the implementation of forest policy. It was noted that no single policy can be implemented in isolation from other policies.

The World Agroforestry Centre and its partners evaluated species such as S*esbania sesban, Leucaena leucocephala, Gliricidia sepium, Calliandra calothyrsus, Acacia angustissima* and *Zizyphus mauritiana* for their suitability in agroforestry systems in

Zimbabwe. On the basis of the evaluations, improved fallows of *Sesbania sesban* and *Cajanus cajan* and fodder banks using *Acacia angustissima*, *Calliandra calothyrsus* and *Leucaena* species have been promoted. However, the uptake of these technologies have been low with less than 500, 000 farmers (about 1% of the total number of farmers in the country) actually using these technologies. Nyathi *et al.* (2004) cited national capacity building and institutional strengthening, provision of adequate good quality germplasm and linking farmers to markets as critical components of the strategy for scaling up the benefits of agroforestry in Zimbabwe.

2.3 Stochastic Frontier Production Model

2.3.1 Theoretical Framework

Consider a smallholder farmer that has a bundle of inputs. Let the inputs be L and K. Assume that the farmer is rational and intends to allocate these inputs to two enterprises to maximize profits. From production economics, the farmer has to produce on Production Possibilities Frontier (PPF). Using the two inputs, the farmer wants to produce x and y.

Let L_x = amount of input L used in producing x ;

K_x = amount of input K used in producing x;

L_y = amount of input L used in producing y; and

K_y = amount of input K used in producing y

Mathematically, this scenario can be represented as below:

Maximise: $y = f(L_y, K_y)$

subject to $x = g(L_x, K_x)$ where: $L_y + L_x = L$ and $K_y + K_x = K$

By solving this maximization problem, the farmer can identify efficient levels of production of x and y. These optimal levels of x and y can be denoted as x* and y* respectively. The x* is produced using optimal input levels L_x* and K_x* while y* is produced using L_y* and K_y*.

Upon identifying the optimal levels of the production functions, the farmer thinks of assessing the economic efficiency of the two enterprises. Economic efficiency is decomposed into technical and allocative efficiency. Technical efficiency is based on input and output relationships. This farmer can be technically inefficient when the actual or observed output from the given input mix is less than the maximum possible. In terms of allocative inefficiency, it can arise when the input mix is not consistent with cost minimization. It can occur when he can not equalize marginal returns with true factor market prices.

This farmer knows that each of the two enterprises at hand has a maximum possible level of output. These are frontier levels of outputs. Using the notations above, the frontier output levels are x** and y** for x and y, respectively. The farmer does not want to produce at any other levels below x** or y**. This farmer explores ways of measuring the current levels of technical efficiency/inefficiency for the two enterprises. The farmer can get this by estimating his stochastic frontier function. This can give the farmer the level of technical efficiency/inefficiency and the factors responsible for the technical efficiency/inefficiency. The technical efficiency ranges from 0 to 1 and the farmer can produce within this range. If the results indicate that he is inefficient, he can move to the frontier by addressing the identified factors behind the inefficiency.

Figure 2 summarizes the above scenario where the depicted picture can represent both enterprises. One of the enterprises can be MI or RC with maize as the output in each technology.

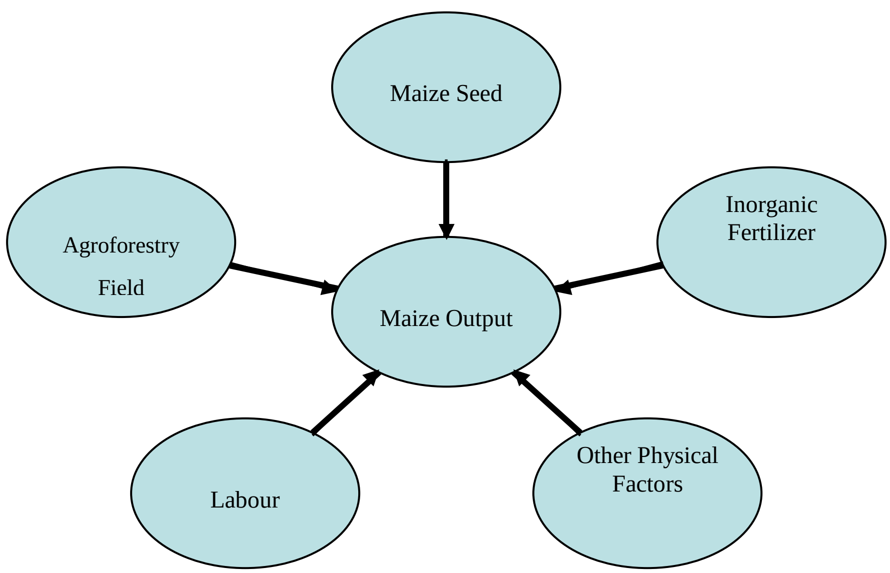


Figure 2: Factors of production in mixed intercropping or relay cropping

Factors in the production of maize include agroforestry field, maize seed, inorganic fertilizer, labour and other physical factors. The stochastic frontier production function can be estimated using these factors of production. The production can either be on the frontier or below it due to technical inefficiencies. When production is on the frontier, it means that the actual maize output equals the maximum possible maize output. If production is below the frontier, it means that the actual maize output is below the maximum possible maize output.

2.3.2 Stochastic Frontier Production Model Application

Technical Efficiency is normally measured by the Stochastic Frontier Production Model (SFPM) but Cobb-Douglas (CD) function is also used. The weakness of the CD function is that the technical efficiency indices vary depending on the number of farmers involved in the study and the combination of farmers. When CD function is used the results are area-specific and cannot be extrapolated to a larger area. CD function fails to specifically identify the factors causing inefficiencies in production. A deterministic frontier production function may remove the short fall in the technical efficiency measures of the CD function (Edriss and Simtowe, 2003).

Edriss and Simtowe (2003) applied the SFPM in groundnuts to estimate technical efficiency and to identify factors that determine the level of efficiency of farmers in Malawi. The study examined both physical and non-physical factors of production that might be responsible for the existence of technical inefficiencies on the smallholder groundnut farms. Physical factors of land and seed density were found to be statistically significant in determining TE on the smallholder groundnut farms. Similarly, access to farm credit and improved groundnut seed variety were non-physical factors found to determine the efficiency of groundnut production. About 75% of groundnut farmers were below the average TE index of 0.496 indicating that considerable technical inefficiencies exist in groundnut farms.

Shanmugam (2003) measured the farm-specific TE of rice, groundnuts and cotton farms in Tamil Nadu in India using the SFPM. Results showed that land, irrigation, labour and fertilizer inputs are the significant determinants of output of almost all crops in the state. The average TE values of raising selected crops varied from 68-82% depicting a scope for raising output without additional resources. The study further noted that farmers with larger areas were more efficient in cultivating cotton.

Mythill and Shanmugam (2000) estimated the TE of rice growers in the same area of Tamil Nadu using unbalanced panel data of 234 rice farms. The results showed that TE varies widely (ranging from 46.5% to 96.7%) across the sample farms and is time invariant. Mean TE was 82% indicating scope for raising output without additional resources. The gap between realized and potential yield highlighted the need for improving farm level extension services.

Iraizoz *et al.* (2003) applied the SFPM in Navarra, Spain to assess the TE of horticultural production using tomato and *Asparagus.* Tomato and *Asparagus* were noted to be relatively inefficient, with potential in both cases for reducing input use or increasing output. The results were similar for both the parametric or non parametric frontier. Estimated measures of TE were positively related to partial productivity indices and negatively related to cultivation costs per hectare.

Reinhard *et al*. (1999) used a stochastic translog production frontier to estimate technical and environmental efficiency of Dutch Dairy Farms. Nitrogen surplus from the application of excessive amounts of manure and chemical fertilizer was treated as an environmentally detrimental input. The other input variables in the model were labour and capital. Results showed that the mean output-oriented TE was high (0.894) but the mean input-oriented environmental efficiency was only 0.441. Overall, intensive dairy farms were both technically and environmentally more efficient than extensive farms implying that intensive dairy farms are appropriate for Holland.

Sarker *et al*. (1999) used statistical measures and SFPM to determine the profitability, and technical, allocative and economic efficiency of commercial poultry farms using data from 30 poultry farms in Gazipur, Bangladesh. Both ordinary least squares (OLS) and maximum likelihood estimation (MLE) methods were used in the analysis and the independent variables used were labour, feed, median and electricity. Results indicated that poultry farming was a profitable business and that large farms were the most profitable. The estimated TE of the poultry farms was 0.92 and overall allocative efficiency was 0.69. The estimated economic efficiency was 0.62 indicating that there exists potential to increase profits from the available resources through improved efficiency.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Introduction

This chapter presents the methodology of the study. It includes a description of the study area, sampling technique, training of enumerators and questionnaire pretesting and data collection. Later the stochastic frontier production model is discussed. The Chapter concludes with limitations of the methodology.

3.2 Smallholder Farm Survey

3.2.1 Study Area

The study was conducted in Zomba district in the Southern region of Malawi. The district has a total land area of 2,580 Km^2, an estimated population of 699,186 and has seven Extension Planning Areas (EPAs) namely; Thondwe, Dzaone, Malosa, Nsondole, Mpokwa, Ngwelero, Chingale. The average family size for the district is 6 people and the average farm size is about 0.5 hectares (NSO, 2005). The district was purposefully chosen because it has a large number of farmers practicing mixed intercropping (MI) and relay cropping (RC) agroforestry technologies than the other districts.

3.2.2 Sampling Technique

Study population consisted of farmers practicing mixed intercropping, and relay cropping agroforestry technologies and non-adopters (NA) of agroforestry technologies in Thondwe, Dzaone and Malosa Extension Planning Areas (EPAs). The three EPAs were purposefully chosen because there are more farmers practicing mixed intercropping and relay cropping agroforestry technologies than the other EPAs. The purposeful selection was chosen to enhance active farmer participation in the research. The entire populations of 101 mixed intercropping and 74 relay cropping agroforestry practicing farmers were interviewed. Simple random sampling was used to identify 120 NA of agroforestry of the three EPAs. A total of 295 farmers were interviewed in the study (Table 1).

Table 1: Number of farmers practicing mixed intercropping and relay cropping agroforestry technologies and non-adopters of agroforestry interviewed in Zomba district

EPA	MI agroforestry practicing farmers interviewed	RC agroforestry practicing farmers interviewed	NA of Agroforestry interviewed	Total
Thondwe	63	53	91	207
Dzaone	31	15	28	74
Malosa	7	6	1	14
Total	101	74	120	295

3.2.3 Data Collection

The study used both primary and secondary sources of data. Primary data was collected using structured questionnaires through interviews with the agroforestry and non-agroforestry farmers for a period of one month (September, 2006). There were different questionnaires for adopters of agroforestry technologies and non adopters. The questionnaire for adopters was used to collect data from farmers practicing mixed intercropping and relay cropping agroforestry technologies. The questionnaires were designed to capture data on farmers' production activities and production-related socio-economic factors. The household interviews provided data on land allocated to MI and RC agroforestry technologies, maize yield from the agroforestry portions, labour availability, time of prunning, extension contact, household income and production costs. In addition, background information on age, sex, marital status of household head and education of household head was also collected. Secondary sources of data involved review of relevant literature from ICRAF, Ministry of Agriculture and policy documents.

3.2.4 Training of Enumerators and Questionnaire Pretesting

Data was collected by the researcher with the help of four enumerators. The enumerators were trained for a day in order to master the research and the data collection tools in order to minimize enumerator errors. Questionnaires were pretested for one day to ensure that wording and coding matched field situation. The tested questionnaires were used for corrections and production of final questionnaires which were used to collect household data.

3.3 Model Specifications

3.3.1 Stochastic Frontier Production Models

The study employed the stochastic frontier production model of parametric approach specified by Battese and Coelli (1995) to evaluate TE of mixed and relay cropping agroforestry technologies and identify factors that determine the TE of the farmers. The stochastic frontier production function takes the following form;

$y_i = f(x_i, \beta) + \varepsilon_i \quad i = 1, 2, \ldots\ldots, n.$ where; ε_i is a composite error term with two elements ($\varepsilon_i = v_i - u_i$). This specification means that the model can be presented as:

$$y_i = \beta x_i + (v_i - u_i), i = 1, 2, \ldots\ldots, n \qquad (1)$$

where; y_i is output obtained by farm i,

β is a vector of parameters estimated, and

x_i is vector of inputs used on farm i like land size (ha), and cost of production (MK).

The error component v_i represents the symmetric disturbance that captures the random variations in production due to factors such as chance and errors in observation and measuring data. v_i was assumed to be identically and independently distributed meaning that N(0, δ_v^2). The error component u_i is an asymmetric term that captures technical inefficiency and was assumed to be distributed independently of v_i. It was also expected to be non-negative and have N(0, δ_u^2) (Battese and Coelli, 1995).

The technical efficiency of an individual farm is defined as;

$$TE_i = \frac{y_i}{y_i *} = \frac{f(x_i, \beta)\exp(v_i - u_i)}{f(x_i \beta)\exp v_i} = \exp(-u_i)$$

where (y_i) is actual output and (y_i^*) is the corresponding frontier output given the available technology. In this study, the actual and frontier output was maize in kgs.

TE has values between 0 and 1. A farm is technically efficient when TE = 1. The exp ($-u_i$) implies that when u_i is large the farmer has less technical efficiency.

The inefficiency model (u_i) is defined as follows:

$$u_i = f(z_i, \alpha) + \varepsilon_i \qquad (2)$$

Where: z_i is a vector of variables responsible for technical inefficiencies,

α is a vector of parameters to be estimated, and ε_i is an error term.

The fitted models were analyzed using frontier software which is based on STATA statistical computer software. Frontier fits stochastic production frontier models and is compatible with cross sectional data that was used in this study. It provides estimators for the parameters of a linear model with a disturbance. The disturbance is assumed to have two components of which one has strictly nonnegative distribution and the other one has a symmetric distribution. The nonnegative component of the error term is referred to as a measure of inefficiency (StataCorp., 2003).

3.3.2 Operational Definitions of Variables in Equations 1 and 2

Maize yield

Maize yield is regarded as the main output from agroforestry in Malawi. In this study, maize (shelled) output was measured in kgs. Technical efficiency of MI and RC agroforestry technologies was determined by comparing the actual or observed maize output against the frontier maximum output.

Land holding size

Land holding size affects farmers' decisions to allocate enterprises and adopt technologies. Agroforestry trees compete with crops for land. Most smallholder farmers report their land holding sizes in acres. In this research, land holding size was presented in hectares using conversion rate of 1 hectare = 2.47 acres.

Labour

Labour is an important variable in any production. Household labour was measured using conversion rates (Table 2) employed in estimating contribution to family labour of household members by availability of household member, gender and age category developed by Ministry of Agriculture.

Table 2: Conversion rates employed in estimating contribution to family labour of household members by availability of household member, gender and age category

Availability of member	Gender	Conversion rates by age category[a]		
		< 15	15 – 59	≥ 60
		------------- man-equivalents -------------------		
Permanent resident	Male	0.2	1.0	0.6
	Female	0.2	0.8	0.4
Permanent resident in local employment	Male	-[b]	0.2	-
	Female	-	0.2	-
Permanent resident in full-time education	Male	0.1	0.5	---[c]
	Female	0.1	0.4	----
Polygamist spending part of time in other households	Male	-	0.5	0.5
Resident hired labour	Male	0.5	1.0	0.7
	Female	0.5	1.0	0.7

Source: Ministry of Agriculture Headquarters, Lilongwe, 1985

a. Age category in years
b. Nil
c. Not applicable

Inorganic fertilizer

Inorganic fertilizer is also applied to maize under agroforestry for optimal production. In this study, the amount of inorganic fertilizer applied in mixed intercropping, relay cropping and non-adopters of agroforestry was measures in kilograms (Kgs). This variable was also used in the estimation of the stochastic frontier model.

Maize seed

Maize seed is critical in maize production. In this study, the amount which was planted in 2006/07 cropping season was measured in kilograms (Kgs).

Age of household head

Age of household head is one of the factors that affect production decisions and the efficiency of carrying out farm activities. In this study, only age of the household head was considered assuming that the head is responsible for household farm decisions.

Education status of household head

Education status of household head also affects farm decisions such as adoption of agricultural technologies. This study considered both formal and informal education.

Formal education was categorized into primary, secondary school and high school. The informal education considered was from adult literacy classes, home craft and farmer training. The education was measured by the number of years spent in schools.

Gender of household head

Gender of household head was applied to measure women's and men's contribution to agroforestry technologies in terms of their time and family labour supply. The variable was used to determine gender differentials among agroforestry adopters and non-adopters. Household head was categorized into male and female (male=1, female =0).

Size of household

Size of household in Malawi is one of the factors affecting farm activities. In this study, household size was measured in numbers and was used in the assessment of technical efficiency of agroforestry technologies.

Extension access

Extension access is important in agroforestry adoption and efficiency. In this study, extension access was a dummy measured by 0: no extension access and 1: extension access. The extension services were provided by government and ICRAF.

3.3.3 Two Stage Least Squares (2SLS) Model

To assess the impact of agroforestry technical efficiency on maize production, 2SLS was applied. In this model, technical efficiency was one of the explanatory variables regressed on maize in the system of equations. The equations took the following form.

$$y_i^{**} = f(TE_i, x_i^{**}) + \varepsilon^{**} \qquad (3)$$

where; y_i** is maize in kgs,

TE_i** is technical efficiency, and ε^{**} is error term.

Three systems of equations were employed in the assessment. In the first and second systems, data from MI and RC agroforestry technology was used with technical efficiency as one of the independent variables. The third system used data from non-adopters of agroforestry and technical efficiency was not one of the independent variables. Definitions and measurements of variables used in this objective were as described in the section of operational definitions and measurements of variables contained in equations 1 and 2.

3.4 Analytical Approach

The study used STATA, Statistical Package for Social Scientists (SPSS) and Microsoft Excel computer software packages for data analysis. Both qualitative and quantitative analytical approaches were applied to avoid inappropriately narrow conclusions. Quantitative analysis alone would have given incomplete results.

3.5 Limitations of the Methodology

The study considered only maize yield excluding fuelwood, and environmental and income benefits as output from agroforestry. However, the assessment of the technical efficiency basing on maize still gave good results as maize is a major agroforestry output. The study also only considered relay cropping and mixed intercropping agroforestry technologies. It would have been better to include other technologies like alley and improved fallow. However, the exclusion of these technologies did not compromise the quality of this study.

CHAPTER FOUR

4.0 SOCIO-ECONOMIC CHARACTERISTICS OF HOUSEHOLDS

4.1 Introduction

This chapter gives a comparison of mixed intercropping, relay cropping and agroforestry non-adopters by looking at the household socio-economic characteristics. The household characteristics discussed are household size, age of household head, land size, household labour availability, maize yield, maize seed, inorganic fertilizer application, period of practice, period of prunning agroforestry trees, education, sex of household head, contact with extension and agroforestry training.

4.2 Socio-Economic Characteristics

4.2.1 Household Size

The average household size of farmers practicing mixed intercropping was 5.6 persons compared to 5.3 persons of those practicing relay cropping agroforestry technology. Non-adopters of agroforestry had the lowest household size of 4.7 persons (Table 3). However, t-test showed that the means of household sizes of MI and RC were not significantly ($p \geq 0.01$) different but mean of MI was significantly ($p \leq 0.01$) different from mean of NA. Means of RC and NA were also significantly ($p \leq 0.05$) different. The lowest average household size of 4.7 among non-adopters of agroforestry partly justifies the failure to practice agroforestry because it is labour demanding while the highest average household size of MI technology partly justifies the practice of the technology. Household size has a bearing on the availability of household labour. Number of people who contribute to farm work determines agroforestry adoption (Thangata and Alavalapati, 2003).

4.2.2 Age of Household Head

Non adopters of agroforestry had the least average age of household head (40.4 years) while farmers practicing MI had the highest average age of 50.7 years. Households practicing RC had an average age of 43.0 years (Table 3). The mean ages of household heads practicing MI was significantly ($p \leq 0.01$) different from those of RC and NA. However, there were no significant ($p \geq 0.1$) differences between mean ages of household heads of RC and NA. The results mean that as opposed to RC and NA, MI is mainly practiced by households headed by older people.

4.2.3 Inorganic Fertilizer

The results showed that farmers practicing MI, RC and NA applied an average of 118.3, 92 and 131.8 kgs of inorganic fertilizers, respectively (Table 3). However, the amounts of inorganic fertilizer applied in MI and NA, and MI and RC were not significantly different ($p \geq 0.05$). Only amounts of inorganic fertilizer applied in RC and NA were significantly ($p \leq 0.05$) different. The higher amount of inorganic fertilizer applied by NA of agroforestry is probably because of the absence of organic fertilizer realized from agroforestry trees in RC and MI technologies. On average, the three categories of farmers applied 116 kgs of inorganic fertilizers.

4.2.4 Maize Seed

Maize seed is important in determining output and technical efficiency. The study assumed no differences in maize varieties among the farmer categories. The results of the study showed that farmers practicing mixed intercropping planted the lowest amount of maize seed of 9.5 kgs. The farmers practicing relay cropping and non-adopters of agroforestry planted an average maize seed of 11.2 and 13.8 kgs, respectively (Table 3). The amounts of maize seed planted by farmers practicing MI and RC, and RC and non-adopters of agroforestry were not significantly ($p \geq 0.05$) different. The three categories planted an average of 11.5 kgs of maize seed. The probable reason for the low amount of maize seed in MI is that *Gliricidia sepium* occupies more space in the fields of farmers practicing MI than the space occupied by *Tephrosia vogelii/candida* in RC.

4.2.5 Land Size

It is assumed that land size affects farm decisions and efficiency of an enterprise. The average land sizes of mixed intercropping, relay cropping and non-adopters of agroforestry were 1.78 ha, 1.3 ha and 0.99 ha, respectively (Table 3). There were no significant ($p \geq 0.05$) differences between average land sizes of farmers practicing mixed intercropping and relay cropping agroforestry technologies. However, both average land sizes of relay cropping and mixed intercropping were significantly ($p \leq 0.01$) different from land size of non adopters of agroforestry. Average agroforestry portions of mixed intercropping and relay cropping agroforestry technologies were 0.49 ha and 0.47 ha, respectively. However, average land portions under the two agroforestry technologies were not significantly ($p \geq 0.1$) different.

Table 3: Socio-economic characteristics of farmers practicing MI and relay cropping and non adopters of agroforestry

Characteristic	**MI**	**RC**	**NA**
Number of households (hh)	101	74	119
Average hh size	5.6[a]	5.3[b]	4.7[c]
	(0.22)	(0.23)	(0.19)
Average age of hh head (years)	50.7[d]	43.0[e]	40.4[f]
	(1.31)	(1.67)	(1.30)
Inorganic fertilizer (kg)	118.3	92.0[g]	131.8[h]
	(13.00)	(9.30)	(8.40)
Maize seed (kg)	9.6[i]	11.2	13.8[j]
	(0.78)	(1.02)	(0.97)
Average land size (ha)	1.78[k]	1.3[l]	0.99[m]
	(0.3)	(0.3)	(0.1)
Average agroforestry portion (ha)	0.49	0.47	-
	(0.36)	(0.40)	
Average maize yield from whole cultivated field (kg/ha)	2097	890	835
	(1.45)	(1.60)	(1.62)
Average maize yield from agroforestry portion (kg/ha)	1440[n]	1010[o]	-
	(1.38)	(1.76)	

Note: (1) Figures in parentheses are standard errors

(2) *a* and *c*, and *b* and *c* are significantly different at 1 percent.

(3) *g* and *h*, *i* and *j*, and *n* and *o* are significantly different at 5 percent.

(4) *d* and *e*, *d* and *f*, *k* and *m*, and *l* and *m* are sig. different at 10 % .

The results showed that household land size has a bearing on the practice of agroforestry. Farmers with more land practice mixed intercropping and relay cropping technologies as evidenced by their bigger household land sizes. However, the allocation of land to the two technologies does not differ among the agroforestry adopters.

4.2.6 Maize Yield

Results showed that farmers practicing mixed intercropping produced the highest average maize yield (2097 kg/ha) than those practicing relay cropping (890 kg/ha) and non-adopters of agroforestry (835 kg/ha). There were significant ($p \leq 0.05$) differences between the average maize yields of farmers practicing MI and RC, and MI and NA. The average maize yields from agroforestry portions of mixed intercropping and relay cropping were 1440 kg/ha and 1010 kg/ha, respectively. The two average maize yields were significantly ($p \leq 0.01$) different (Table 3). The probable reason is that *Gliricidia sepium* in MI produce more biomass and release more nutrients than *Tephrosia vogelii/candida* in RC.

4.2.7 Cost of Production

High cost of establishment and maintenance is one of the constraints farmers face when investing in soil conservation methods like agroforestry. On-site benefits alone without considering the cost-effectiveness of technologies do not justify the investment (Lapar and Pandey, 1999). High production costs affect farm profitability. Appropriate intensification technologies, like agroforestry, in tropical agriculture need to be profitable to enhance their use by farmer (Bamire and Manyong, 2003). Cost of production also affects efficiency of a technology.

The results showed that mixed intercropping had the highest total variable cost (TVC) per hectare while non-adopters had the lowest TVC per hectare (Table 4). There were no significant differences between the average TVC per ha for mixed intercropping and relay cropping ($p \geq 0.05$), and relay cropping and non-adopters ($p \geq 0.05$). However, there were significant ($p \leq 0.05$) differences between TVC of mixed intercropping and non-adopters of agroforestry.

Table 4: Cost of production of farmers practicing mixed intercropping and relay cropping and non adopters of agroforestry

Characteristic	MI	RC	NA
Average TVC per ha (Mk)	22,276.43[a]	17,350.79	15,808.89[b]
Range of household TVC per ha (Mk)	1550 - 87516	3264 - 55400	387 – 33,670

Note: *a* and *b* are significantly different at 5 percent

4.2.8 Household Labour Availability

Agroforestry is a labour demanding technology and as such, labour availability is critical in agroforestry adoption. Agroforestry technologies do not rapidly spread from farmer to farmer due to lack of appreciation of farmers' labour constraints (Carr, 2004). In this study, the average household labour availability of farmers practicing MI, RC and non adopters of agroforestry were 4492.07 labour hours per annum, 4314.58 labour hours per annum and 3906.79 labour hours per annum, respectively. The average households annual labour availability of MI and RC ($p \geq 0.05$), and RC and NA ($p \geq 0.05$) were not significantly different. However, the average annual household labour availability of MI and NA ($p \leq 0.05$) were significantly different. The low average labour availability of non-adopters of agroforestry partly explains why they do not adopt agroforestry technologies.

4.2.9 Gender of Household Head

Gender of household head has a bearing on farm decisions. Results showed that 72.1% and 27.9% of the household heads were male and female, respectively (Table 5). Non-adopters had more males (74.8%) while those practicing RC had the lowest proportion of male headed households (69.2%). Farmers practicing RC had the highest proportion of female heads while non-adopters of agroforestry had the lowest proportion of the female heads. However, chi-square test showed that there were no significant ($p \geq 0.05$) gender differences among the farmer categories.

Table 5: Gender of household head of farmers practicing mixed intercropping, relay cropping and non adopters of agroforestry

Gender of hh head	MI (%)	RC (%)	AA (%)	NA (%)	Total(%)	P-Value

Male	71.3	69.2	70.2	74.8	72.1	0.09
Female	28.7	30.8	29.8	25.2	27.9	0.21
Total	100.0	100.0	100	100.0	100.0	

Note: (1) p-value is for adopters and non-adopters of agroforestry
(2) AA is combined MI and RC adopters of agroforestry

4.2.10 Marital Status of Household Head

The results of the study indicated that there were more married household heads (73.5%) than single (3.7%), widowed (13.4) and divorced (9.4%) household heads among the interviewed farmers (Table 6). Chi-square test showed that there were no significant ($p \geq 0.05$) differences on marital status of the household heads. In all the three categories of farmers, there were more married heads, followed by widowed, divorced and single household heads. Mkandawire *et al*., (2004) showed that married farmers in Zomba district were willing to invest in agroforestry technologies compared to other categories of household heads.

Table 6: Marital status of household head of farmers practicing mixed intercropping, relay cropping and non adopters of agroforestry

Marital status of hh head	MI (%)	RC (%)	AA (%)	NA (%)	Total(%)	P - Value
Single	4.0	1.3	2.65	5.0	3.7	0.00
Married	72.2	70.5	71.35	76.5	73.5	0.46
Widowed	12.9	15.4	14.15	12.6	13.4	0.12

Divorced	10.9	12.8	11.85	5.9	9.4	0.00
Total	100.0	100.0	100.0	100.0	100.0	

Note: p-value is for adopters and non-adopters of agroforestry

4.2.11 Education of Household Head

Literacy level has a bearing on technology adoption and efficiency. In this study, 74.8% of the farmers could read and write while 25.2 % could not read and write (Table 7). In the three categories of farmers 24.8%, 20.5% and 28.6% of mixed intercropping, relay cropping and non-adopters could not read and write. Chi-square test showed that literacy level of the three categories was not significantly ($p \geq 0.05$) different. The results showed that the average educational level of farmers practicing MI, RC and non-adopters of agroforestry were standard seven, standard six and standard five, respectively. This means that the average education level among the three categories was primary school. There is, therefore, high probability that the farmers practicing MI and RC do not effectively implement the technologies because of the low education level.

Table 7: Literacy level of farmers practicing mixed intercropping, relay cropping and non adopters of agroforestry

Literacy	MI (%)	RC (%)	AA (%)	NA (%)	Total(%)	P -Value
Able to read and write	75.2	79.5	77.4	71.4	74.8	0.34
Unable to read and write	24.8	20.5	22.6	28.6	25.2	0.08
Total	100.0	100.0	100	100.0	100	

Note: p-value is for adopters and non-adopters of agroforestry

The results also show that 67.6% of all the household heads in the study area reached primary level while 59.4%, 70.5% and 59.7% of the household heads in mixed intercropping, relay cropping and non-adopter categories reached the primary level (Table 8). Education helps farmers to easily understand and adopt agroforestry technologies (Kwesiga *et al*., 2003).

Table 8: Education level of farmers practicing mixed intercropping, relay cropping and non adopters of agroforestry

Education level	MI (%)	RC (%)	AA (%)	NA (%)	Total(%)	P-Value
Primary	59.4	70.5	64.9	59.7	67.6	0.46
Secondary	6.9	7.7	7.3	11.8	15.6	0.00
Adult learning	7.9	1.3	4.6	0.0	2.0	0.00
Home craft	1.0	0.0	0.5	0.0	0.3	0.00
No education at all	24.8	20.5	22.7	28.6	13.5	0.00
Total	100.0	100.0	100.0	100.0	100.0	

Note: p-value is for adopters and non-adopters of agroforestry

4.2.12 Access to Extension Services

Extension has an impact on agroforestry efficiency. Strong extension support system is important for agroforestry success (Bunderson *et al*., 2004, Ayuk and Jera, 2004, Thangata and Alavalapati, 2003, Degrande, 2001 and Kwesiga *et al*., 2003). In this study, 76.2% and 78.2% of farmers practicing mixed intercropping and relay cropping agroforestry had access to agroforestry extension (Table 9). Chi-square test showed that there were significant ($p \leq 0.05$) differences in accessing extension among MI and NA, and RC and NA of agroforestry. However, there were no significant ($p \geq 0.05$) differences in extension access among MI and RC. The extension accessed by agroforestry adopters was mainly in the areas of nursery management and agroforestry field and tree management.

Table 9: Extension access of farmers practicing mixed intercropping, relay cropping agroforestry farmers and non adopters of agroforestry

Nature of access	MI (%)	RC (%)	AA (%)	NA (%)	Total(%)	P -Value
Access	76.2	78.2	77.2	63.9	71.8	0.38
No access	23.8	21.8	22.8	36.1	28.2	0.01
Total	100.0	100.0	100.0	100.0	100.0	

Note: p-value is for adopters and non-adopters of agroforestry

4.2.13 Agroforestry Training

Training imparts new knowledge which is important for technology improvement and efficiency. Agroforestry training is vital for its adoption and scaling up (Kwesiga *et al.*, 2003). Results showed that 56.4% of the farmers attended agroforestry training (Table 10). The majority of the farmers who are trained practice MI. The probable reason is that MI was introduced earlier than RC by ICRAF which is the main institution supporting the trainings.

Table 10: Agroforestry training of farmers practicing mixed intercropping and relay cropping

Agroforestry training attendance	MI (%)	RC (%)	Total (%)	P - Value
Training attendance	56.4	23.1	56.4	0.05
No training attendance	43.6	76.9	43.6	0.00
Total	100.0	100.0	100.0	

4.2.14 Year of Agroforestry Adoption

Number of years of technology practice is important for quality improvement since farmers accumulate experience. Mistakes are minimized and lessons incorporated in production with time. On average, farmers practicing mixed intercropping and relay cropping adopted the technologies in 1999 and 2000 respectively (Table 11). It means that, on average, mixed intercropping has been practiced for 7 years while relay cropping has been practiced for an average of 6 years. However, t-statistic showed that there were no significant ($p \geq 0.05$) differences in the number of years of practice between the two agroforestry technologies.

Table 11: Year of adoption and period of farming experience of the farmers

Characteristic	MI	RC	NA
Number of households (hh)	101	74	119
Average year of adoption	1990	2000	-
Average period of practice (years)	7.0 (0.30)	6.0 (0.50)	-

Average period of farming (years)	32.7) (1.3)	25.0 (1.7)	22.4 (1.3)

Note: Figures in parentheses are standard errors

4.2.15 Period of Farming

Period of farming is critical in any agriculture. This increases farming experience to the farmers and minimizes inefficiencies. In this study, farmers practicing mixed intercropping had the highest (32.7 years) number of farming period while non-adopters of agroforestry had the lowest period (22.4 years) of farming (Table 11). The results showed that there were significant ($p \leq 0.05$) differences in the period of farming between farmers practicing MI and RC and, MI and NA. However, there were no significant differences ($p \geq 0.05$) between period of farming of farmers practicing RC and NA.

4.2.16 Land Fragmentation

Zomba is one of the districts in the southern region with high population resulting in increased pressure on land. Generally, high pressure on farming land results in land fragmentation which is the proportion of number of field to total household field area. When land is fragmented, farmers spend more time shifting from one field to another as the fields are normally widely spaced. This reduces efficiency as efforts and resources are spread to the different fields. In this study, farmers practicing relay cropping had the highest land fragmentation level followed by non-adopters of agroforestry (Table 12). The results showed that there were significant ($p\leq 0.05$) differences in land fragmentation between MI and RC and, MI and NA. However, there were no significant ($p \geq 0.05$) differences in land fragmentation between farmers practicing RC and NA.

Table 12: Land fragmentation of farmers practicing mixed intercropping, relay cropping and non-adopters of agroforestry

Characteristic	MI	RC	NA
Land fragmentation	1.33$^{\mathbf{a}}$	1.80$^{\mathbf{b}}$	1.76$^{\mathbf{c}}$
	(0.13)	(0.24)	(0.22)

Note: *a* and *b* and, *a* and *c* are significantly different at 5 % and Figures in parentheses are standard errors

4.2.17 Club Membership

Club membership is critical for effective implementation of any agricultural technologies. In agroforestry, farmers share experiences on tree management, act as an entry point for trainings, selling of seedlings and sourcing of credit through the clubs. Farmers practicing RC had the highest proportion of club membership (50%) while non-adopters of agroforestry had the lowest proportion of club membership (30.2%). The results showed that there were significant ($p \leq 0.05$) differences of club membership in all the three categories of farmers. In general, 41.5 % of the farmers belong to clubs in the study area (Table 13).

Table 13: Club membership of farmers practicing mixed intercropping and relay cropping and, non-adopters of agroforestry

Membership	MI (%)	RC (%)	AA (%)	NA (%)	Total(%)	P – Value
Club membership	45.5	50.0	47.8	30.2	41.5	0.07
No club membership	54.5	50.0	52.2	69.8	58.5	0.00
Total	100.0	100.0	100.0	100.0	100.0	

Note: p-value is for adopters and non-adopters of agroforestry

4.3 Concluding Remarks

The purpose of this chapter was to assess the socio-economic household characteristics of farmers practicing MI, RC and NA of agroforestry. The results showed that NA of agroforestry had the lowest household size, average age of household head, land size, average annual labour availability and applied the highest amounts of inorganic fertilizer compared to farmers practicing MI and RC. The results also showed that farmers practicing MI produce more maize than those practicing RC and non-adopters of agroforestry.

The average education level of farmers practicing MI, RC and NA was primary school implying that the farmers do not implement the technologies effectively. The results also showed that a bigger proportion of farmers practicing MI and RC access extension services of agroforestry than NA farmers. It was also shown that farmers practicing mixed intercropping had the highest number of farming period, land fragmentation level and proportion of club membership than the farmers practicing MI and NA.

CHAPTER FIVE

5.0 MODELS RESULTS AND DISCUSSIONS

5.1 Introduction

The previous chapter presented an analysis of household socio-economic characteristics of mixed intercropping (MI), relay cropping (RC) and non-adopters (NA). This chapter presents an analysis of technical efficiency (TE) of the three categories of farmers. It also presents factors responsible for the respective levels of technical efficiency of the farmers. It further examines the effect of technical efficiency of the three categories of farmers on household maize production and concludes by presenting a summary of the results.

5.2 Stochastic Frontier Models Results

The analyses involved three separate estimations of mixed intercropping and relay cropping agroforestry technologies, and non-adopters of agroforestry stochastic frontier production functions (SFPF). SFPF allows simultaneous prediction of technical efficiency and technical inefficiency component (μ) of the individual farms. Maize output was a dependent variable in the three stochastic frontier production functions. The estimation involved the transformation of dependent variable and all the explanatory variables were transformed into logs. Fan (1999) and Edriss and Simtowe (2003), estimated technological change in Egyptian rice and technical efficiency of groundnuts in Malawi, respectively, using the same translog function.

Maximum log likelihood (ML) estimates of the parameters of MI, RC and NA were generated using STATA computer software. STATA has frontier command which is ideal for stochastic production frontier models analysis. The stochastic frontier (SF) estimates for mixed intercropping, relay cropping and non-adopters of agroforestry are presented in Tables 12, 13 and 14, respectively.

5.2.1 Technical Efficiency of Mixed Intercropping

The log likelihood estimate of -65.321 showed the overall significance of the estimated SFPF of mixed intercropping. The chi-square test showed that the estimated SFPF was significant ($p = 0.000$). The significance ($p \leq 0.05$) of gamma ($\gamma = 0.929$) shows that the frontier is stochastic. The significance of gamma also shows that there is almost 93% variation in maize output among the farmers due to the presence of technical inefficiencies. Variance Inflation Factor (1.527) and Durbin-Watson (1.912) tests showed that there was no multicollinearity and autocorrelation, respectively, in the model. The results showed that labour, inorganic fertilizer, maize seed and land were significant ($p \leq 0.05$) in the estimated function (Table 14).

The significance of labour in determining maize output is in line with the general principle that mixed intercropping is labour intensive. Labour is mainly needed for prunning trees and incorporating biomass into the soil. The significance and positive relationship of labour with maize output showed that maize output increases with an increase in labour. This means that farmers practicing MI and with more labour produce more maize compared to farmers with less labour. Shanmugam (2003) in his application of the SFPF also found out that labour was significant in determining rice and groundnuts outputs in Tamil Nadu in India.

Table 14: Maximum log-likelihood parameter estimates for mixed intercropping

Variable	**Coefficient**	**Standard error**	**P>z**
Intercept	7.661**	0.00E-07	0.000
log (land, ha)	0.999**	0.00E-07	0.000
log (labour, labour units)	0.006**	0.00E-07	0.000
log (fertilizer, kg)	0.00E-07**	0.00E-07	0.000
log (seed, kg)	0.008**	0.00E-07	0.000
Log likelihood	-65.321		
Prob> Chi-square	0.000**		
Lambda (λ)	3.620**		
Gamma (γ) = $\lambda^2/(1+\lambda^2)$	0.929**		
Variance Inflation Factor	1.527		
Durban-Watson	1.912		
Number of observations	101		

Likelihood-ratio test of sigma u = 0	Chibar2(01) = 58.33** Prob>=chibar2 = 0.000

Note: ** = Significant at 5 percent.

The significance of inorganic fertilizer in determining maize output and its positive relationship with maize output mean that there is potential to increase maize output in MI through increased inorganic fertilizer application. This means that MI practicing farmers who apply more inorganic fertilizer produce more maize compared with farmers who apply less inorganic fertilizer. Combinations of *Gliricidia* prunnings and inorganic fertilizer in mixed intercropping increases maize output over prunnings alone (Makumba *et al*. (2006). Similar findings were also found by Iraizoz *et al.* (2003) in the application of the SFPM in Navarra, Spain in the assessment of TE of tomato and *Asparagus.*

The results also showed maize seed was significant and positively related to maize output. This means that farmers practicing MI can produce more maize by increasing the amount of seed planted in the agroforestry fields. Currently, the farmers practicing MI plant the lowest amounts of maize seed compared to farmers practicing relay cropping and non-adopters of agroforestry as shown in chapter four.

The results further showed that land size is significant and also affects maize output positively in MI. This means that farmers who allocate bigger field portions to MI agroforestry technology produce more maize than farmers who allocate less field portions to the technology. Ogundari and Ojo (2005) also found out that land size affects crop production in Nigeria.

The inefficiency component of the disturbance term (u), of the estimated MI frontier was significantly different from zero indicating the presence of significant inefficiencies in the technology (Table 14). It means that maize production in MI is below the frontier. This implies that farmers practicing MI do not produce the maximum possible maize output because of technical ineffective use of resources. The null hypothesis that the farmers practicing mixed intercropping agroforestry technology are technically inefficient was rejected by the likelihood-ratio test (p= 0.00).

5.2.2 Technical Efficiency of Relay Cropping

In relay cropping agroforestry technology, the log likelihood estimate showing the overall significance of the estimated SFPF was -85.218. The chi-square test of the estimated SFPF was also significant (p=0.000) as in mixed intercropping agroforestry technology. The significance ($p \leq 0.05$) of gamma ($\gamma = 0.676$) shows that the frontier is stochastic as in MI. The significance of gamma also shows that there is almost 68% variation in maize output among the farmers due to the presence of technical inefficiencies. The Variance Inflation Factor (1.220) and Durbin-Watson (1.838) tests also showed that there was no multicollinearity and autocorrelation, respectively, in the model. The results showed that only inorganic fertilizer was significant ($p \leq 0.05$) in determining maize output under relay cropping agroforestry technology (Table 15).

The significance and positive effect of inorganic fertilizer on maize output mean that farmers practicing RC and apply more inorganic fertilizer produce more maize output than those who apply less inorganic fertilizer. The results imply that there is potential of increasing maize output by increasing the amount of inorganic fertilizer applied to maize in RC. The finding was consistent with previous studies which also showed that inorganic fertilizer increases output of rice and mixed-crop food production in India and Nigeria, respectively (Shanmugam, 2003; Ogundari and Ojo, 2005).

Table 15: Maximum log-likelihood parameter estimates for relay cropping

Variable	Coefficient	Standard error	P>z
Number of observations	73		
Intercept	3.790**	0.539	0.000
log (maize seed, kg)	0.032	0.129	0.806
log (land, ha)	0.531	0.150	0.604
log (fertilizer, kg)	0.649**	0.135	0.000
log (labour, labour units)	0.055	0.204	0.789
Log likelihood	-85.218		
Prob> Chi-square	0.000**		
Lambda (λ)	1.445**		
Gamma (γ) = $\lambda^2/(1+\lambda^2)$	0.676**		
Variance Inflation Factor	1.220		
Durban-Watson	1.838		
Number of observations	73		
Likelihood-ratio test of sigma u = 0	Chibar2(01) = 2.39** Prob>=chibar2 = 0.061		

Note: ** = Significant at 5 percent.

Despite the positive relationship of maize output and labour, the variable was not significant in determining maize output in RC. This is probably because biomass is normally applied once in RC unlike in MI where biomass is applied 2 to 3 times per year. Relatively, this reduces labour demand for *Tephrosia vogelii/candida* pruning and biomass incorporation into the soil in RC.

The disturbance error term component of RC was significantly ($p = 0.061$) different from zero. The results mean that farmers practicing relay cropping agroforestry technology are technically inefficient implying that maize is produced below the frontier. This means that RC agroforestry farmers do not effectively utilize the resources to produce the maximum possible maize output. As in MI, the null hypothesis that farmers practicing RC are technical inefficient was rejected by the likelihood-ratio test of sigma (Table 15).

5.2.3 Technical Efficiency of Non-adopters

The log likelihood estimate of non-adopters of agroforestry was -114.82. This showed the overall significance of the estimated SFPF of NA. The chi-square test of the estimated SFPF was also significant ($p = 0.096$) as in mixed intercropping and relay cropping agroforestry technologies. The significance ($p \leq 0.05$) of gamma ($\gamma = 0.964$) shows that the frontier is stochastic as in MI and RC. The significance of gamma also shows that there is almost 96% variation in maize output among the farmers due to the presence of technical inefficiencies. The Variance Inflation Factor (1.149) and Durbin-Watson

(1.680) tests also showed that there was no multicollinearity and autocorrelation, respectively, in the model. The results also showed that land and inorganic fertilizer were significant ($p \leq 0.05$) in determining maize output of non-adopters of agroforestry (Table 16).

Table 16: Maximum log-likelihood parameter estimates for non-adopters of agroforestry

Variable	**Coefficient**	**Standard error**	**P>z**
Intercept	5.460**	1.027	0.000
log(land, ha)	0.793**	0.407	0.051
log(fertilizer, kg)	0.859**	0.45	0.048
log(seed, kg)	0.095	0.082	0.249
log(labour, labour units)	0.088	0.121	0.466
log likelihood	-114.82		
Lambda (λ)	5.197**		
Gamma (γ) = $\lambda^2/(1+\lambda^2)$	0.964**		
Variance Inflation Factor	1.149		
Durbin-Watson	1.680		
Number of observations	104		
Likelihood-ratio test of sigma u = 0	Chibar2(01) = 11.55** Prob>=chibar2 = 0.000		

Note: ** = Significant at 5 percent.

The significance and positive effect of inorganic fertilizer mean that non-adopters of agroforestry who apply more inorganic fertilizer produce more maize compared to those who apply less inorganic fertilizer. There is therefore, potential to increase maize output given the available resources by increasing inorganic fertilizer application among non-adopters of agroforestry. This is in line with the Government strategy of increasing accessibility and use of inorganic fertilizers among smallholder farmers to increase maize production (Malawi Government, 2006).

The results further showed that land has a positive effect on maize output of non-adopters of agroforestry. This means that farmers who have more land produce more maize compared to farmers with less land. The results mean that there is potential to increase maize output by increasing land allocated to maize production among non-adopters of agroforestry. Iraizoz *et al.* (2003) also found similar results in Navarra, Spain in the application of the same SFPF in the assessment of tomato production.

As in agroforestry adopters, the inefficiency component of the disturbance term (u), was also significantly different from zero indicating the presence of significant inefficiencies among non-adopters. The presence of inefficiencies is responsible for the production of maize below the frontier among non-adopters of agroforestry. The study also rejected the null hypothesis that non-adopters of agroforestry are technically inefficient (p= 0.000).

5.3 Comparison of Technical Efficiencies

The results of the Stochastic Frontier Models showed that mean TE of MI, RC and NA were 0.62, 0.57 and 0.46, respectively (Table 15). This means that farmers practicing MI are 62% efficient in maize production. Similarly, farmers practicing RC and non-adopters of agroforestry are 57% and 46% technically efficient, respectively. The results mean that the farmers in all the categories produce maize below their respective frontier levels with non-adopters of agroforestry producing below half of the frontier. The results further indicated that 51%, 33% and 38% of farmers practicing MI, RC and NA, respectively produce maize below the mean TE indicating considerable levels of technical inefficiencies among the farmers. This was calculated from the generated individual technical efficiency levels of the farmers practicing MI.

Table 17: Technical efficiency of farmers practicing mixed intercropping, relay cropping and non-adopters of agroforestry

Element	Mixed intercropping	Relay cropping	Non-adopters
Population	101	72	104
Mean technical efficiency	0.62^{a} (0.030)	0.50^{b} (0.022)	0.46^{c} (0.023)

Note: (1) Figures in parentheses are standard errors.
(2) *a* and *b*, and *a* and *c* are significantly different at 1 percent.

One-way analysis of variance showed that the TE means of MI and RC (p= 0.004), and MI and NA (p= 0.000) were significantly different. However, there were no significant differences between TE means of RC and NA (Table 15). This means that there are differences in maize output in MI and RC, and MI and NA relative to their respective frontier levels. Similarly, there are no significant differences in maize output between RC and non-adopters of agroforestry.

The ranges of the technical efficiency levels of the three technologies are presented in the forthcoming boxplots (Figure 3). The respective maximum and minimum attained TE levels which are not outliers are depicted by the horizontal upper and lower lines of the plots, respectively. The top and lower sides of the shaded boxes represent the upper (75th percentile) and lower (25th percentile) quartiles, respectively. The line inside the box represents the median of the respective technical efficiencies. The median shows the central tendencies of the technical efficiencies in the three categories of farmers.

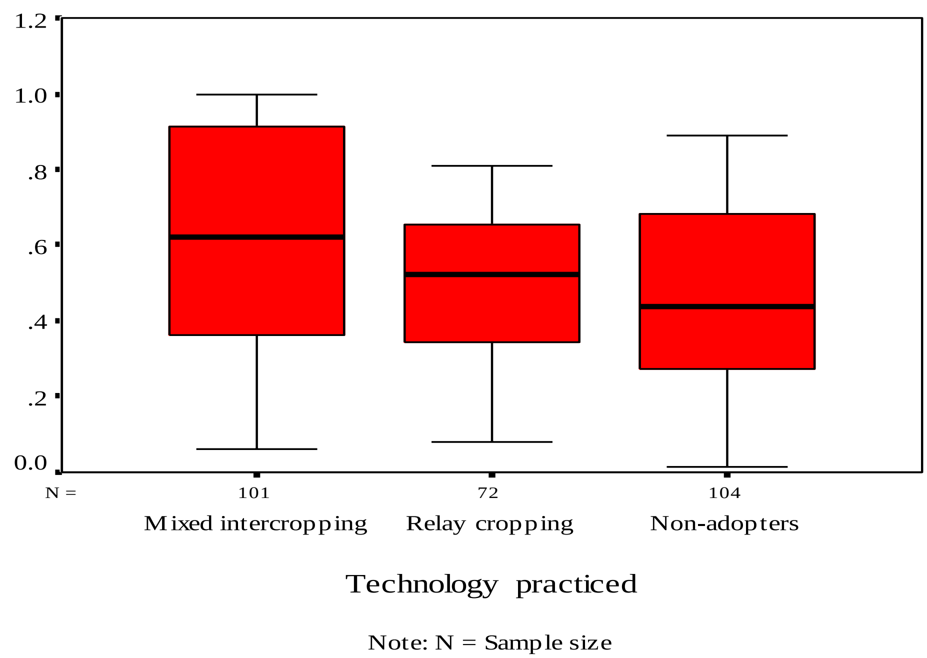


Figure 3: Technical efficiency of mixed intercropping, relay cropping and non adopters of agroforestry

Individual mixed intercropping farmers technical efficiency ranged from 0.06 to 0.99 with median of 0.62. The TE of relay cropping farmers ranged from 0.08 to 0.81 with median of 0.52 while TE of non-adopters ranged from 0.01 to 0.88 with median of 0.43. The results also show that MI has more farmers with TE between the 75th and 25th percentiles compared to RC and NA. The study also revealed that 5% of MI farmers produced on the frontier. The main challenge in MI, therefore, is the wide range of TE with the lowest level of 0.06. The wide variation in TE among the individual farmers in the three categories implies that the farmers widely differ in maize production relative to their respective frontiers (potential maize output levels) though they use similar resources in their respective categories.

5.3.1 Technical Efficiencies of Adopters and Non-Adopters of Agroforestry Technologies

The study also assessed technical efficiencies of adopters and non-adopters of agroforestry. This was done in order to assess if there are technical efficiency differences between the two categories. It involved comparison of aggregate estimated technical efficiencies of mixed intercropping and relay cropping with those of non-adopters of agroforestry.

Overall mean technical efficiencies of agroforestry adopters and non-adopters of agroforestry were 0.57 and 0.46, respectively. The assessment also showed significant (p= 0.000) differences in technical efficiencies of agroforestry adopters and non-adopters (Figure 4). This means that agroforestry adopters produce maize closer to the frontier relative to non-adopters of agroforestry with mean TE below half of the frontier. The results imply that maize production among non-adopters of agroforestry has more technical inefficiencies compared to adopters of agroforestry.

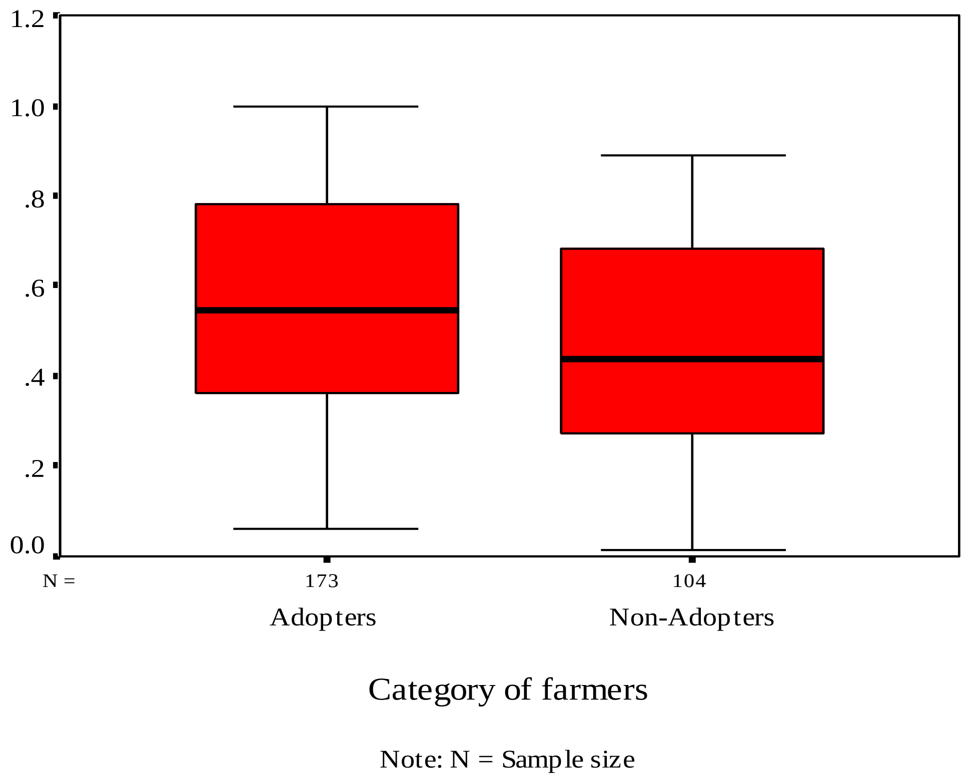


Figure 4: Distribution of technical efficiency of agroforestry adopters and non adopters

5.3.2 Technical Efficiency Analysis per Extension Planning Area

The study further assessed the technical efficiency levels of the three categories of farmers per Extension Planning Area (EPA). This involved the comparison of technical efficiency of the three categories of farmers in Thondwe, Dzaone and Malosa EPAs. This was done in order to show the distribution of TE of the three categories of farmers in the three EPAs. The results showed that mean technical efficiencies of RC in Thondwe and

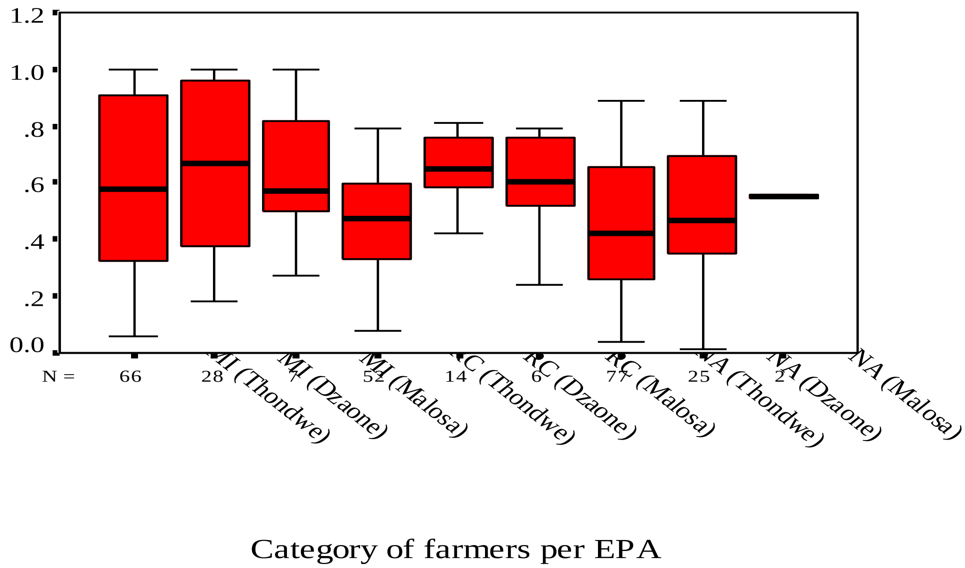
Dzaone EPAs (p = 0.00), and Thondwe and Malosa EPAs (p = 0.92) were significantly different (Table 18).

Table 18: Technical efficiency of farmers practicing mixed intercropping, relay cropping and non-adopters of agroforestry per extension planning area

EPA	**Mean TE of mixed intercropping**	**Mean TE of relay cropping**	**Mean TE of non-adopters**
Thondwe	0.60	0.455[a]	0.445
	(0.039)	(0.026)	(0.028)
Dzaone	0.662	0.653[b]	0.497
	(0.055)	(0.031)	(0.048)
Malosa	0.64	0.587[c]	0.551
	(0.100)	(0.083)	(0.007)
Total	0.62	0.50	0.46
	(0.030)	(0.022)	(0.023)

Note: (1) Figures in parentheses are standard errors.
(2) *a* and *b*, and *a* and *c* are significantly different at 1 percent.

The results also showed that mean TE of MI and NA in Thondwe and Dzaone, and Thondwe and Malosa EPAs were not significantly different (Table 18). This implies that MI and NA maize productions in Thondwe and Dzaone, and Thondwe and Malosa EPAs are not different compared to their respective maximum possible maize output levels. The results further showed that the highest technical efficiency level was attained by MI farmers (0.99) in Thondwe, Dzaone and Malosa EPAs while the lowest TE level (0.01) was attained by NA in Dzaone EPA. The following boxplots show the TE ranges of the three categories of the farmers in the three EPAs (Figure 5).



Note: (1) MI=Mixed intercropping, RC=Relay cropping, NA=Non-adopters

(2) N= Sample size

Figure 5: Distribution of technical efficiency of mixed intercropping, relay cropping and non-adopters of agroforestry per Extension Planning Area.

5.4 Determinants of Technical Inefficiency

After establishing the existence of technical inefficiencies in mixed intercropping and relay cropping agroforestry technologies, and non-adopters of agroforestry, the study further assessed the sources of the inefficiencies. The technical inefficiency components (μ), were simultaneously estimated with the technical efficiencies of the technologies derived in the stochastic frontier models. The respective technical inefficiency components were used as dependent variables in separate models of mixed intercropping, relay cropping and non-adopters of agroforestry. The factors responsible for technical inefficiencies were separately regressed on the technical inefficiency components of the three categories of farmers.

The study assessed age of household head, education of household head, household size, club membership, extension contact, land fragmentation, gender of household head, agroforestry training, period of farming, number of fields owned and number of pruning agroforestry trees in all the three models. However, due to the insignificance of some of the factors, backward elimination method was applied to identify the significant factors per technology. The study identified different factors responsible for the technical inefficiencies in each technology. This was mainly because of the differences in the nature of the agroforestry technologies.

In the determinants of technical inefficiency analysis, a negative sign of a coefficient shows that an increase in the parameter improves the technical efficiency of the respective technology (Battese and Coelli, 1995). Results of the MI, RC and NA models are presented in Tables 17, 18 and 19, respectively.

5.4.1 Determinants of Technical Inefficiency in Mixed Intercropping

The log likelihood (-97.583) of the technical inefficiency model of MI measured by chi-square statistic was significant. This showed the overall significance of the estimated model. The Variance Inflation Factor (1.513) and Durbin-Watson (2.032) tests also showed that there was no multicollinearity and autocorrelation, respectively, in the model. The results also showed that age and education of household head were significant ($p \leq 0.05$) in determining technical inefficiency (Table 19). This led to the rejection of the hypothesis that there are no factors responsible for technical inefficiencies in MI agroforestry technology.

Table 19: Determinants of technical inefficiency of mixed intercropping

Variable	Coefficient	Standard error	p>z
Constant	1.289**	0.485	0.008
Age of household head (years)	-0.092**	0.032	0.004
Education (years of schooling)	-0.026**	0.015	0.076
Land fragmentation (number of fields to total household field area)	0.034	0.029	0.248
Household size (numbers)	-0.040	0.032	0.134
Log likelihood	-97.583		
Variance Inflation Factor	1.513		
Durbin-Watson	2.032		

Note: ** = Significant at 5 percent.

The results showed that age of household head has a negative relationship with technical inefficiency in MI. The significance of age of household head means that an increase in age of household head reduces technical inefficiency of mixed intercropping. This means that households with older heads are technically efficient in MI. This is probably because the farmers gain experience with age. They understand the technology and technically utilize the resources better as they grow older. This enables them to produce maize closer to the frontier. Ogundari and Ojo (2005) also found out that age of household head reduces technical inefficiency of mixed-crop food production in Nigeria.

The significance of education of household head in determining technical inefficiency means that educated household heads are technically efficient compared to uneducated household heads. It means that technical inefficiency reduces with increase in education level. This shows that educated household heads implement mixed intercropping technology better and produce closer to the frontier than the household heads with low education status. This is because the educated household heads understand the technology and technically use the resources better than uneducated household heads. Battese and Coelli (1995) also found out that education reduces technical inefficiency of rice farmers in Aurepalle, India.

5.4.2 Determinants of Technical Inefficiency in Relay Cropping

The log-likelihood estimate (-57.101) showing the overall significance of the model as measured by chi-square statistic was significant. The Variance Inflation Factor (1.270) and Durbin-Watson (1.290) tests also showed that there was no multicollinearity and autocorrelation, respectively, in the model. The results also showed that age of household head and land fragmentation were significant ($p \leq 0.05$) in determining technical inefficiency (Table 20). This led to the rejection of the hypothesis that there are no factors responsible for technical inefficiencies in RC agroforestry technology.

The results mean that an increase in age of household head reduces technical inefficiency in relay cropping agroforestry technology. As in mixed intercropping, age of household head has a bearing on farming experience. It means that older household heads have more experience of relay cropping technology than younger household heads. This results in maize production closer to the frontier among households with older heads. The result was consistent with previous finding in Nigeria that age reduces technical inefficiency of mixed-crop food production (Ogundari and Ojo, 2005).

Table 20: Determinants of technical inefficiency of relay cropping

Variable	Coefficient	Standard error	p>z
Constraint	1.050**	0.458	0.022
Club membership (1= member, 0 =otherwise)	-0.171	0.121	0.155
Age of household head (years)	-0.060**	0.025	0.018
Extension contact (hours)	-0.018	0.148	0.899
Land fragmentation (number of fields to total household field area)	0.080**	0.035	0.023
Log likelihood	-57.101		
Variance Inflation Factor	1.270		
Durbin-Watson	1.290		

Note: ** = Significant at 5 percent

The results show that farmers with more fragmented plots are more technically inefficient than farmers with less fragmented fields. The probable reason is that farmers with no fragmented plots concentrate their efforts on one plot thereby becoming technically efficient. The farmers with less fragmented fields utilize their resources effectively and utilize their time effectively.

5.4.3 Determinants of Technical Inefficiency of Non-adopters

The estimated log likelihood of the model of non-adopters of agroforestry technical inefficiency model was -106.749. Chi-square statistics showed that the estimated model was also significant. The Variance Inflation Factor (1.155) and Durbin-Watson (1.646) tests also showed that there were no multicollinearity and autocorrelation, respectively, in the model (Table 21).

Table 21: Determinants of technical inefficiency of non-adopters of agroforestry

Variable	Coefficient	Standard errors	p>z
Constraint	1.830**	0.594	0.002
Period of farming (years)	-0.008**	0.004	0.092
Education (years of schooling)	-0.005	0.019	0.791
Land fragmentation (number of fields to total household field area)	0.160**	0.049	0.001
Log likelihood	-106.749		
Variance Inflation Factor	1.155		
Durbin-Watson	1.646		

Note: ** = Significant at 5 percent

The results showed that period of practice and fragmentation were significant ($p \leq 0.05$) factors responsible for technical inefficiencies in NA. This led to the rejection of the hypothesis that there are no factors responsible for technical inefficiencies among non-adopters of agroforestry.

In relative terms, the significance and negative sign of the coefficient of period of farming shows that farmers who have been farming for more years are technically efficient. This is mainly because of the farming experience accumulated with increase in years of farming. The farmers utilize resources effectively as they increase the number of years of farming. Ogundari and Ojo (2005) also found out that farming experience reduces technical inefficiency of mixed-crop food production in Nigeria.

As in relay cropping, the results also showed that land fragmentation increases technical inefficiency of non-adopters of agroforestry. This is because non-adopters of agroforestry with less fragmented plots concentrate on localized plots thereby producing maize closer to the frontier.

5.5 Technical Efficiency and Maize Production

After assessing technical efficiency levels and identifying factors responsible for the technical inefficiencies, the study further assessed the impact of TE on maize production. Previous studies of technical efficiency did not extend the analyses to assess the impact of TE on crop output. This assessment applied Two Stage Least Squares (2SLS) where technical efficiency was an explanatory variable regressed on maize in the system of equations. The 2SLS was ideal because technical efficiency was generated within the system (endogenous variable) and the equations were over identified. This analysis helped to get consistent parameter estimates by avoiding correlation of error terms. Application of OLS would have led to simultaneous equations bias. Separate 2SLS were run for the three categories of farmers.

Table 22: Summary of two stage least squares of mixed intercropping, relay cropping and agroforestry non-adopters

Estimate	Technology		
	Mixed intercropping	**Relay cropping**	**Non-adopters**
Technical efficiency coefficient	2.05	3.68	2.64
	(0.07)	(0.26)	(0.18)
z-statistic of technical efficiency	30.77***	14.00***	14.35***
P>z of TE	0.000	0.000	0.000
Adjusted R-Squared	0.95	0.81	0.89
F-Statistic	531.67***	77.19***	170.37***
Prob>F	0.000	0.000	0.000

Note: (1) Figures in parenthesis are standard errors

(2) *** = significant at 1 percent

The adequacy of the three regressions was guaranteed by the adjusted R- Squared values of 0.95, 0.81 and 0.89 of MI, RC and NA, respectively. These mean that TE explain 95%, 81% and 89% of maize output in MI, RC and NA. In all the three categories of farmers, TE and F-statistic were highly significant ($p \leq 0.01$) showing the overall significance of the variables in MI, RC and NA. Technical efficiency was significant ($p \leq 0.01$) in determining maize output in all the three categories of farmers. This led to the rejection that technical efficiency does not affect maize production in all the three categories of farmers. Table 22 gives a summary of the results of the regressions.

The results showed that there is positive relationship between technical efficiency and maize output in MI. This means that an increase in technical efficiency in MI increases maize output. The results mean that farmers practicing MI agroforestry technology and technically efficient, produce more maize compared to farmers practicing MI and technically inefficient.

Similar results were also found for relay cropping agroforestry technology and non-adopters of agroforestry. The results show that farmers practicing relay cropping agroforestry technology has potential of increasing their maize output by addressing the factors responsible for the technical inefficiency. Similarly, non-adopters of agroforestry can increase their maize output by increasing their technical efficiency.

5.6 Concluding Remarks

The purpose of this chapter was to assess the technical efficiency of MI, RC and NA; to identify the factors responsible for technical efficiency, and to assess the impact of TE on maize production. Three SFPF were estimated to assess TE of MI, RC and NA. In the process of estimating the models, TE and inefficiency components of the error terms were generated simultaneously. The generated error components of the error terms were used to determine factors responsible for TE in all the three categories of farmers. The generated TE levels were later regressed on maize in three 2SLS models for the respective categories of farmers.

The results showed that all the three categories of farmers have technical inefficiencies with NA having the least TE level below 50% of the frontier. The results also showed that age and education of household head in MI, age of household head and land fragmentation in RC and period of farming, age of household and land fragmentation in NA determine technical inefficiency. The analysis ended by establishing that technical efficiency affects maize output in MI, RC and NA. This showed that technically efficient farmers produce more maize than technically inefficient farmers in all the three categories.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The study was conducted in order to (i) evaluate TE of MI and RC technologies on smallholder farms, (ii) identify factors that determine TE of agroforestry farmers, (iii) determine the effect of TE of MI and RC agroforestry technologies on maize production among smallholder farmers and (iv) assess the socio-economic characteristics of farmers practicing MI and RC agroforestry technologies. This was achieved through the use of a SFPF fitted to MI, RC and NA farmers. The key conclusions of the study are summarized in the following sections.

6.1.1 Socio-economic Characteristics of Farmers

The results showed that farmers in NA category had the lowest household size, average age of household head and average annual labour availability than farmers practicing MI and RC. The farmers in NA category also applied the highest amounts of inorganic fertilizer compared to MI and RC farmers. Finally, the farmers practicing MI had the highest number of farming years and proportion of club membership than those in RC and NA categories. The study concludes that because of farming experience and club membership, farmers practicing MI produce more maize than those in RC and NA categories.

6.1.2 Technical Efficiency

The mean technical efficiencies of MI, RC and NA were 0.62, 0.57 and 0.46, respectively. It was further shown that 51%, 33% and 38% of MI, RC and NA, respectively produce maize below the mean technical efficiency levels indicating considerable levels of technical inefficiencies. The study therefore, concludes that a larger proportion of the farmers practicing MI, and RC agroforestry technologies and NA produce maize below their respective frontier levels. The farmers in all the three categories therefore, do not realize the maximum possible maize output. This illustrates that the farmers do not effectively use their resources in maize production.

In addition to the presence of technical inefficiencies, there are wide variations in technical efficiency levels in the three categories of farmers. Individual MI and RC agroforestry practicing farmers' technical efficiency levels ranged from 0.06 to 0.99 and 0.08 to 0.81, respectively. Similarly, technical efficiency of non-adopters of agroforestry ranged from 0.01 to 0.88. The study therefore, concludes that despite using similar resources, there are huge variations in resource use in all the three categories of farmers.

6.1.3 Factors Determining Technical Efficiencies

The study showed that age and education of household head determine technical inefficiency of MI. The study therefore, establishes that younger household heads in MI agroforestry technology are technically inefficient. Similarly, uneducated household heads in MI are technically inefficient.

The study further revealed that age of household head and land fragmentation are determinants of technical inefficiency of RC agroforestry technology. The study concludes that RC practicing farmers gain farming experience with age and thereby reducing their technical inefficiency. The study also concludes that RC practicing farmers with fragmented land are technically inefficient because they spread their efforts on different fields.

The study further concludes that land fragmentation increases technical inefficiency of NA of agroforestry. Similarly, NA of agroforestry technologies who have practiced farming for few years are technically inefficient.

6.1.4 The Effect of Technical Efficiency

The study shows that technical efficiency positively affects maize production in MI, RC and NA. The results show that an increase in technical efficiencies increases maize output to the farmers. Thus, farmers with low technical efficiencies produce lower quantities of maize.

6.2 Recommendations

On the basis of the study results, the following recommendations are made:

1. There is need to reduce the technical inefficiencies in MI through formal and informal education of the farmers.
2. In order to reduce the variations in technical efficiencies, both government and ICRAF extension staff should intensify extension contact with farmers practicing RC.

3. There is need for further studies on technical efficiencies of other agroforestry technologies such as alley cropping and improved fallow practiced in Zomba district. This will help fill the economic research gap in agroforestry.

4. The current study only focused on technical efficiency of MI, RC and NA. The corresponding studies should consider assessing allocative efficiencies of MI, RC, alley cropping and improved fallow agroforestry technologies. This will be important for the establishment of allocative efficiencies of the five technologies.

5. Organic manure was not included in the estimation of the stochastic frontier production models. This was because of the inability to obtain biomass quantities from the agroforestry portions. Future studies should consider obtaining the biomass in order to include the organic fertilizer component in the models.

7.0 REFERENCES

Ayuk, E.T. and Jera, R. (2004). Scaling up Improved Fallows in Zimbabwe: A Comparative Analysis with other Organic Sources of Soil Fertility Improvement Practices. In: M.R. Rao and F.R. Kwesinga (Eds). *Proceedings of the Regional Agroforestry Conference on Agroforestry Impacts on Livelihoods in Southern Africa: Putting Research in Practice.* South Africa, pp 285-290.

Babu, S. C., Ehui, S., and Ng'ong'ola, D. H. (1993). *Agroforestry Ecosystem, Technological Change and Optimal Use of Green Manures- Policy Implications for Designing Research Strategies.* Lilongwe, Malawi.

Bakengesa, S.S., Ottsyina, R. and Ok'ting'ati. (2004). Influence Of National Policies on Tree Planting and Conservation: The Case of Agroforestry Technologies in Shinyanga, Tanzania. In: M.R. Rao and F.R. Kwesinga (Eds). *Proceedings of the Regional Agroforestry Conference on Agroforestry Impacts on Livelihoods in Southern Africa: Putting Research in Practice.* South Africa, pp 301-306.

Bamire, A.S., and Manyongo, V.M. (2003). Profitability of Intensification Technology among Smallholder Farmers in the Forest-Savanna Transition Zone of Nigeria. *Agriculture, Ecosystems and Environment,* 100(2/3): 111-118.

Battese, G. E., and Coelli, T. J. (1995). A model for technical inefficiency effect in stochastic frontier production for panel data. *Empirical Economics,* 20: 325-332.

Bello, W.B. (1990). The Past, Present and Future of Agroforestry Activities in Malawi. In A.R. Saka, W.T. Bunderson and J.A.Mughembe (Eds). *Proceedings of the First National Agroforestry Symposium on Agroforestry Research and Development.* Limbe, Malawi, pp 118 – 121.

Bunderson, W.T., Hayes, I.M., Jere, Z.D., and Phombeya, H.S.K. (2004). Malawi Agroforestry Extension Project: A Partnership Model to Expand Outreach Efforts for Technology Adoption by Farmers in Malawi. In: M.R. Rao and F.R. Kwesinga (Eds). *Proceedings of the Regional Agroforestry Conference on Agroforestry Impacts on Livelihoods in Southern Africa: Putting Research in Practice.* South Africa, pp 307-317.

Carr, S.J. (2004). Osmosis or Project Activity? The Spread of Agroforestry in Malawi. In: M.R. Rao and F.R. Kwesinga (Eds). *Proceedings of the Regional Agroforestry Conference on Agroforestry Impacts on Livelihoods in Southern Africa: Putting Research in Practice.* South Africa, pp 269-273.

Chikowo, R., Mapfumo, P., Nyamugafata, P., Nyamadzawo, G., and Giller, K.E. (2003). Nitrate-N Dynamics following Improved Fallows and Maize Root Development in a Zimbabwean Sandy Clay Loam. *Agroforestry Systems*, 59(3): 187-195.

Chilimba, A. D.C., Phombeya, H. S. K., Saka, A.R., and Kabambe, V. H. (2004). Promising Agroforestry Technologies for Small-Scale Farmers in Malawi. In: M.R. Rao And F.R. Kwesinga (Eds). *Proceedings of the Regional Agroforestry Conference on Agroforestry Impacts on Livelihoods in Southern Africa: Putting Research in Practice.* South Africa, pp 125-130.

Chirwa, E.W. (2005). *Access to Land, Growth and Poverty Reduction in Malawi*. Zomba, Malawi, pp 3-8.

David, S. and Raussen, T. (2003). The Agronomic and Economic Potential of Tree Fallows on Scoured Terrace Benches in the Humid Highlands of Southwestern Uganda. In: O. Lyasse, N. Sanginga, B. Vanlauwe, J. Diels and R. Merckx (Eds). *Journal of Agriculture, Ecosystems and Environment*. 95 (1): 359 – 369.

Degrande, A. (2001). Farmer Assessment and Economic Evaluation Shrub Fallows in the Humid Lowlands of Cameroon. *Agroforestry Systems,* 53(1):11-19.

Edriss, A., and Simtowe, F. (2003). Technical Efficiency in Groundnut Production in Malawi: An Application of a Frontier Production Function. In: A. Edriss (Ed). *The Dynamics of Food Production Systems and Adoption of Technologies in a Village Economy.* Las Vegas: International Puplishers Press, pp 34-74.

European Union. (2006). *EU Relations with Malawi*. Lilongwe, Malawi, pp 1-8.

Fan, S. (1999). Technological Change, Technical and Allocative Efficiency in Chinese Agriculture: The Case of Rice Production in Jiangsu. *American Journal of Economics.* EPTD Discussion Paper Number 39, pp 1-26.

Farmers World. *Personal Communication*. March 14, 2007.

Franzel, S., Coe, R., Cooper, P., Place, F., and Scherr, S.J. (2001). Assessing the Adoption Potential of Agroforestry Practices in Sub-Saharan Africa. *Agricultural Systems*, 69 (1/2): 37-62.

Gromwell, E., and Kyegombe, N. (2005). *Food Security Options in Malawi.* Lilongwe, Malawi.

International Centre for Research in Agroforestry. (1993). *International Centre for Research in Agroforestry: Annual Report*. Nairobi, Kenya.

International Centre for Research in Agroforestry. (September, 2003). Research and Development Foci. *ICRAF-SA Publication Series No.1.*

International Monitory Fund. (2000). *Malawi: The Food Crises and Strategic Grain Reserve*. Lilongwe, Malawi.

Iraizoz, B., Rapun, M., and Zabaleta, I. (2003). Assessing the Technical Efficiency of Horticultural Production in Navarra, Spain. *Agriultural Systems Journal*, 78 (3): 387-403.

Jordan, C.F. (2004). Organic Farming and Agroforestry: Alley cropping for Mulch Production for Organic Farms of Southern United States, *Agroforestry Systems*, 61/62: 79-90.

Kabambe, V.H., Drennan, D.H.S., Chilimba, A.D.C. and Nambuzi, S.C. (2004). Influence of Leucaena Leaves and Urea Fertilizer on Striga Infestation and Maize Yield in Malawi. In: M.R. Rao and F.R. Kwesinga (Eds). *Proceedings of the Regional Agroforestry Conference on Agroforestry Impacts on Livelihoods in Southern Africa: Putting Research in Practice.* South Africa, pp 239-244.

Kabwe, G., Katanga, R., Mafongoya, P.L, Grundy, I.M., Phiri, D., and Kwesiga, F. (2004). Dissemination Pathways for Scaling up Agroforestry Options in Eastern Zambia. In: M.R. Rao and F.R. Kwesinga (Eds). *Proceedings of the Regional Agroforestry Conference on Agroforestry Impacts on Livelihoods in Southern Africa: Putting Research in Practice.* South Africa, pp 275-284.

Kamanga, B., Kanyama, P.G., Minae, S. (1999). Intercropping Perennial Legumes for Green Manure Additions to Maize in Southern Malawi. *African Crop Science Journal*, 9.7(4): 355-363.

Kuntashula, E., and Mafongoya, P.L. (2005). Farmer Participatory Evaluation of Agroforestry Trees in Eastern Zambia. *Agroforestry Systems,* 84: 39-53.

Kwesiga, E., 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.

Lapar, M.L.A., and Pandey, S. (1999). Adoption of Soil Conservation: The Case of the Philippine Uplands. *Agricultural Economics,* 9.21(3): 241-256.

Makumba, M., Janssen, B,. Oenema, O., and Akinnifesi, F.K. (2006). Influence of Time of Application of the Performance of *Gliricidia* Prunnings as a Source of Nitrogen for Maize. *Experimental Agiculture*, 42: 51-63.

Makumba, W. (2003). *Nitrogen use efficiency and Carbon Sequestration in Legume Tree-Based agroforestry Systems: A Case Study of Malawi*. Published PhD Thesis, University of Pretoria, South Africa.

Malawi Government. (2000). *National Land Resources Management Strategy*. Lilongwe, Malawi.

Malawi Government. (2000). *The State of Malawi's Poor: Agriculture and Making a Living from the Land*. Lilongwe, Malawi.

Malawi Government. (2002). *Malawi: An Atlas of Social Statistics*. Zomba, Malawi.

Malawi Government. (2005). *Guide to Agricultural Production and Natural Resources Management Handbook.* Lilongwe, Malawi.

Malawi Government. (2005). *Second Integrated Household Survey.* Zomba, Malawi, pp 1-3.

Malawi Government. (2005). *The Governance Dimensions of Food Security in Malawi.* Lilongwe, Malawi.

Malawi Government. (2006). *Policy Logical Frameworks for the Establishment of the Malawi Agriculture Policy Framework.* Lilongwe, Malawi, pp 92-125.

Malawi Government. (2006). *The National Fertilizer Strategy*. Lilongwe, Malawi.

Mangisoni, J.H. (1999). *Land Degradation, Profitability and Diffusion of Erosion Control Technologies in Malawi.* Published PhD Thesis, University of Manissota, USA.

Mkandawire, E., Ngwira, N. and Kambewa, P. (2004). Smallholder Farmers' Willingness to Invest in Agroforestry Technologies in Zomba District, Malawi. In: M.R. Rao and F.R. Kwesinga (Eds). *Proceedings of the Regional Agroforestry Conference on Agroforestry Impacts on Livelihoods in Southern Africa: Putting Research in Practice.* South Africa, pp 11-18.

Mwakalagho, R.J. (1990). Agroforestry Development Activities in the Agricultural Development Divisions: Prospects and Problems. In: A.R. Saka, W.T. Bunderson and J.A.Mughembe (Eds). *Proceedings of the First National Agroforestry Symposium on Agroforestry Research and Development.* Limbe, Malawi, pp 42 – 47.

Mythill, G., and Shanmugam, K. R. (2000). Technical Efficiency of Rice Growers in Tamil Nadu: A Study based on Panel Data. *Indian Journal of Agricultural Economics,* 55 (1): 15-25.

National Statistical Office. (2004). *Demographic and Health Survey*. Zomba Malawi.

National Statistical Office. (2005). *Analytical Report*. Zomba Malawi.

Neupane, R.P., and Thapa, G.B. (2001). Impact of Agroforestry Intervention on Soil Fertility and Farm Income under the Subsistence Farming System of the middle Hills, Nepal. *Journal of Agriculture, Ecosystems and Environment,* 84(2): 157-167.

Noragric. (2006). *Decentralisation in the Agricultural Sector in Malawi, Policies, Processes and Community Linkages*. Norwegian University of Life Sciences, Norway, pp 12-20.

Nyakanda, C., Maringa, Murwira, H. K., Nyamugafata, P., and Salifu, D. (2004). The Status of Existing Set aside Fallows in Smallholder Farming. In: M.R. Rao and F.R. Kwesinga (Eds). *Proceedings of the Regional Agroforestry Conference on Agroforestry Impacts on Livelihoods in Southern Africa: Putting Research in Practice.* South Africa, pp 1-10.

Nyathi, P., Hikwa, D., and Hove, L. (2004). Scaling up the Impact of Agroforestry Technologies in Zimbabwe: The Current Thrust, Strengths and Potential Pitfalls. In: M.R. Rao and F.R. Kwesinga (Eds). *Proceedings of the Regional Agroforestry Conference on Agroforestry Impacts on Livelihoods in Southern Africa: Putting Research in Practice.* South Africa, pp 319-328.

Nyirenda, M. (2002). *A Socio Economic Assessment of the Performance of the Improved Fallow Agroforestry Technology in Central Malawi.* Published MSc Thesis, University of Malawi.

Ogundari, K., and Ojo, S.O. (2005). The Determinants of Technical Efficiency in Mixed-Crop Food Production in Nigeria: A Stochastic Parametric Approach. *East African Journal of Rural Development*, 21(1): 41-51.

PASAD. (2005). *Policy Analysis and Sustainable Agricultural Development in Central, Eastern Europe and Southern Africa Final Report*. Bonn, Germany, pp.4-12.

Phiri, D., Franzel, S., Mafongoya, P., Jere, I., Katanga, R., and Phiri, S. (2004). Who is Using the New Technology? The Association of Wealth Status and Gender with the Planting of Improved Tree Fallows in Eastern Province, Zambia. *Agricultural Systems.* 79 (2): 131-144.

Reinhard, S., Lowell, C. A. K., and Thijssen, G. (1999). Econometric Estimation of Technical and Environmental Efficiency: An Application to Dutch Daily farms. *American Journal of Agricultural Economics,* (1): 44-60.

Saka, A. R., and Bunderson W.T. (1990). Basic Concepts and the Potential of Agroforestry in Smallholder Crop production Systems. In: A.R. Saka, W.T. Bunderson and J.A.Mughembe (Eds). *Proceedings of the First National Agroforestry Symposium on Agroforestry Research and Development.* Limbe Malawi, pp 14 – 21.

Sanchez, P.A. (1999). Improved Fallows come of Age in the Tropics. *Agroforestry Systems,* 9.47 (1/3): 3-12.

Sarker, S. C., Abedin, J., and Islam, S.M.F. (1999). Performance of Commercial Poultry Farms: A profitability and Efficiency Analysis. *Bangladesh Journal of Agricultural Economics,* 22 (1): 63-75.

Scherr, S.J., and Muller, A. (1991). *Evaluating Agroforestry Interventions in Extension Projects.* Nairobi, Kenya.

Selenje, M. B., and Mwakalagho, R.J. (1990). Agroforestry in Lilongwe Agricultural Development Division. In: A.R. Saka, W.T. Bunderson and J.A.Mughembe (Eds). *Proceedings of the First National Agroforestry Symposium on Agroforestry Research and Development.* Limbe, Malawi, pp 14 – 21.

Shanmugam, K. R. (2003). Technical Efficiency of Rice, Groundnut and Cotton Farms in Tamil Nadu. *Indian Journal of Agricultural Economics*, 58 (1): 101-104.

Smallholder Fertilizer Revolving Fund of Malawi. *Personal Communication*. March 14, 2007.

Snapp, S and Silim, S. (2002). Farmer Preferences and Legumes Intensification for low Nutrient Environments. *Plant and Soil.* 245(1). 181-192.

Snapp, S., Kanyama. P.G., Kamanga, B., Gilbert, R., and Wellard, K. (2002). Farmers and Researcher Partnerships in Malawi: Developing Soil Fertility Technologies for the Near-Term and Fer-Term. *Experimental Agriculture*, 38: 411-431.

Snapp, S., Mafongoya, P., and Waddington, S. (1998). Organic Matter Technologies for Intergrated Nutrient Management in Smallholder Cropping System of Southern Africa. *Agriculture, Ecosystems and Environment.* 71 (1/3).185-200.

Snapp, S., Rohrbach, D.D., Simtowe, F., and Freeman, H. A. (2002). Sustainable Soil Management Options for Malawi: Can Smallholder Farmers grow more Legumes? *Agriculture, Ecosystems and Environment.* 91 (1/3).159-174.

Southern African Regional Poverty Network. (2003). *Hunger and Food Security*. Lilongwe, Malawi, pp 1-5.

StataCorp. (2003). *Stata Statistical Software: Release 8.0.* College Station, TX: Stata Corporation, pp 413-427.

Thangata, P.H., and Alavalapati, J.R.R. (2003). Agroforestry Adoption in Southern Malawi: The Case of Mixed Intercropping of *Gliricidia Sepium* and Maize. *Agricultural Systems*, 78(1): 57-71.

Appendix 1

University of Malawi

BUNDA COLLEGE OF AGRICULTURE

ECONOMICS OF MIXED INTERCROPPING AND RELAY CROPPING AGROFORESTRY TECHNOLOGIES: A Case of Zomba District in Malawi.

Mixed intercropping and Relay Cropping Agroforestry Technologies Questionnaire

August 2006

Enumerator: Follow instructions before asking any question. Do not give your own views but record information from the interviewee. Circle the appropriate code and fill the blank spaces where necessary. Refer to 2005/2006 cropping season only.

Introduction to every interviewee

We are from Bunda College and working in partnership with ICRAF and the Ministry of Agriculture. We are conducting a survey on Agroforestry. You were chosen to participate in the exercise. Your information will be kept with confidentiality and you will not be singled out in the results. You will be briefed on the results of the study.

Enumerator's name:________________________ Date of interview:____________

Category of farmer: A = Mixed B = Relay *(Circle accordingly)*

Name of household:_________________________ HH Code: __________________

Name of EPA:_____________________________ Section_____________________

T.A.______________________________________ Village: ____________________

Checked by:_______________________________ Date:_______________________

A. BACKGROUND INFORMATION AND HOUSEHOLD HEAD CHARACTERISTICS

1. Household composition

   (Filled cells are not applicable)

Person No.*(HH should be number 1)*	**Age (in years)**	**Marital status of HH* *(Use codes below)***	**Gender.** *1: Male* *2: Female*	**Relationship to household head**	**Availability**** *(Use codes below)*
1					
2					
3					
4					
5					

6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

Codes for HH Marital Status*

1 Single

2 Married

3 Polygamist

4 Widowed

5 Divorced

6 Other *(Specify)*……………..

Codes for Availability**

1 Permanent resident

2 Permanent resident in local employment

3 Permanent resident in full education

4 Polygamist spending time in other households

5 Resident hired labour

6 Other *(Specify)* …………………

Codes for Relationship to household head

1 = Spouse, 2 = Child, 3 = Parent, 4 = Grandchild, 6 = Other Specify________________________

2. Do you read and write Chichewa? Code: Yes = 1 No = 2

3. If **yes**, how far did you go with your education?

   (Circle depending on where the education was obtained)

a) Formal Education:

Code:

1 None

2 Primary school *(actual class)*______________

3 Secondary School *(actual class)*____________

4 High school and above *(actual level)*_________

b) Informal education:

Code:

1 None

2 Adult literacy

3 Home craft

4 Farmer training

5 Other *(specify)*______________________ 5 Other *(specify)*________

B HOUSEHOLD INCOME

4. What are your main sources of income?

Code 1 Sales of livestock

2 Sales of crops

3 Labor sales

4 Remittances

5 Other (*Specify*)____

5. What was your income the previous year?

	Source	**Amount**
1	Sales of livestock	
2	Sales of crops	
3	Selling labor	
4	Remittances	
5	Other (Specify)	

6. How much of this income did you allocate to agricultural activities? **MK _____________**

C LAND HOLDING AND AGROFORESTRY TECHNOLOGY

7. How many fields do you have?

Code 1 One

2 Two

3 Three

4 Four

5 Five

6 More than five (*Specify*)_____________________________________

8. Are all these gardens owned by you?

Code 1=Yes 2=No

9. If **no**, how many are not owned by you? ***(If yes, go to question 11)***

Code 1= 1 garden, 2= 2 gardens, 3= more than 2 gardens

10. How did you get the garden(s) you do not own?

Code 1=Rent 2=Borrowed for free 3= Other *(Specify)*____________

11. How did you acquire the garden(s) you own?

Code 1 Allocated by village headman

2 Bought

3 Family inheritance

4 Through marriage

5 Other *(specify)* ………….

12. Do you practice agroforestry in all your fields?

Code 1 Yes 2 = No (if yes, go to 14)

13. If no, why not?

Code 1 Labour demanding

2 Land limitations

3 Some fields are already fertile

4 Has access to inorganic fertilizer

5 Other (Specify) ____

14. If yes, in how many gardens?

Code: 1= 1 garden 2= 2 gardens 3=3 gardens 4= gardens 5 = all gardens

15. Agroforestry and maize field allocation

Garden number	Garden size (whole garden, ha/acres)	Garden portion with agroforestry trees (ha/acres)	Agroforestry species* (use codes below)	Maize variety grown with the species** (use codes below)
1				
2				
3				
4				
5				
6				

*Codes for Agroforestry Species	**Codes for maize variety
1 = *Gliricidia sepium* (Gliricidia)	1 = Local
2 = *Tephrosia vogelli* (Mthuthu / Mtetezga)	2 = Hybrid
3 = *Sesbania sesban* (Jelejele / Binu)	3 = Composite / OPV
4 = *Leucaena diversifolia* (Lukina)	
5 = *Senna spectabilis* (Keshya wa maluwa)	
6 = *Senna siamea* (Keshya wa milimo)	
7 = *Tephrosia candida*	
8 = Other (*Specify*)______________________________	

16. For how long have you been practicing the technology? ______________ years.

17. What made you start practicing mixed/relay cropping agroforestry technology?. ***(Circle all reasons given)***

Code 1 To reduce soil infertility problem
2 To reduce soil erosion problem
3 To get fodder for livestock
4 To get fuelwood
5 High prices of inorganic fertilizer
6 To obtain poles for sales and infrastructure construction.
7 To get medicine
8 To conserve moisture
9 Others (Specify)____

18. Who introduced the technology to you?

Code 1 ICRAF
2 Government extension staff
3 NGO
4 Fellow farmer
5 Other *(Specify)*________________

19. How many times did you prune the agroforestry trees this farming year? ________times.

20. Which month(s) did you prune the agroforestry trees? *(Tick the appropriate months)*

Code 1 Before October 2005
2 October 2005

3 November 2005

4 December 2005

5 January 2006

6 February 2006

7 After February 2006

21. What challenges do you encounter during the implementation of agroforestry technologies? ***(Circle all answers given)***

Code 1 High labor demands

2 Land limitations

3 Lack of seed

4 Lack of technical knowledge

5 Lack of time

6 Limited extension support

7 Other (*Specify*)____

22. What other crops and crop combinations do you plant apart from agroforestry and maize?

Code 1 Maize without agroforestry trees

2 Tobacco

3 Groundnuts

4 Cotton

5 Other (Specify)____

23. How much land was allocated to these crops?

	Crops and crop combinations	**Land Size (ha/acre)**
1	Maize	
2	Tobacco	
3	Groundnuts	
4	Cotton	
5	Other (Specify)	
6		

D COST AND BENEFITS OF AGROFORESTRY

24. What was the total amount of maize harvested from all gardens this year? *(record in units given)*______________________(Ngolo/Dengu/wheelbarrow/50 Kg bags)

______________________(Other specify)

25. Benefits from agroforestry garden

Crop Type	Description of Benefits	Units of measure	Amount Harvested	Price per unit	Total Revenue
Agriculture crop	Maize yields	Kilograms			
Agroforestry crop	Seed sales	Kilograms			
	Fuel wood	Bundles			
	Poles	Numbers			
	Fodder	Oxcarts			
Other benefits (Specify)					

26. Farm inputs used this year on relay/mixed cropping gardens only.

Activity	Cost Item	Unit of measurement	Amount Used	Total Cost	Source of input
Land Preparation	Hired labor	Labor days			
	Family labor	Labor days			
Planting					
Planting of Agroforestry trees	Seed for agroforestry trees	Kilograms			
	Labor	Labor days			
	Polythene tubes				
	Labor for Nursery management	Labor/ days			

Planting of agricultural crop	Seed for agricultural crop	Kilograms			
	Labor	Labor days			
Pruning and Biomass management					
1st Pruning	Labor	Labor days			
2nd Pruning	Labor	Labor days			
Fertilizer application					
Basal-dressing	Fertilizer	Kilograms			
	Hired labor	Labor days			
	Family labor	Labor days			
Top-dressing	Fertilizer	Kilograms			
	Hired labor	Labor days			
	Family labor	Labor days			
Weeding	Hired labor	Labor days			
	Family labor	Labor days			
Harvesting	Hired labor	Labor days			
	Family labor	Labor days			
Marketing	Hired labor	Labor days			
	Family labor	Labor days			
Other Cost (Specify)					
Herbicides/pesticides					
Transporting inputs/produce					

27. Did you experience problems in accessing these inputs? Code: 1= Yes 2= No

28. If **yes**, what was the most difficult input to access?

Code 1 Tree seeds/seedlings
2 Maize seed
3 Inorganic fertilizer
4 Chemicals
5 Labour
6 Other *(specify)*.

29. What was the main reason behind the inaccessibility?

Code 1 Scarcity

2 Lack of money

3 Distance to where they were found

4 Other *(Specify)* _______________

30. How did that affect your input use?

Code 1 Did not affect

2 Reduced their use

3 Delayed their use

31. If it **delayed**, by how many days? _________ days.

32. If it **reduced** use, by how much? *(Specify input and number of days accordingly)*.

1. ________________ by ________ days

2. ________________ by ________ days

3. ________________ by ________ days

E EXTENSION SERVICES

33. Do you have access to agroforestry extension services? Code: 1= Yes 2= No

(If no, go to question 39)

34. If **yes**, on which main area?

Code 1 Nursery management

2 Land preparation

3 Tree planting and spacing

4 Disease and pest control

5 Tree pruning

6 Other *(Specify)*____

35. What is the main source of the extension services?

Code 1 ICRAF

2 Government extension staff

3 NGOs

4 Fellow farmers

5 Others *(Specify)*____

36. How many times per month are you visited by extension services provider (s)?

Code 1 More than four times

2 Four times

3 Three times

4 Two times

5 Once

6 Not at all

7 Other (Specify)____

37. Do you participate in field days? Code: 1 = Yes 2 = No

38. Do you have any demonstration plots in this EPA? Code: 1 = Yes 2 = No

F SUSTAINABILITY

39. Who owns the agroforestry trees in your garden?

Code 1 ICRAF

2 Myself

3 Government

4 Other *(Specify)* ____

40. Do you belong to any agroforestry club or association? Code: 1 = Yes 2 = No

41. If **no**, what is the main reason?

Code: 1 Absence of clubs association

2 No incentive/benefit

3. Lack of organisation in the club

4. Clubs are not organised

5. Poor supervision by ICRAF/extension workers

6 Other *(specify)*____

42. If **yes**, what was the main reason of joining the club/association?

Code 1 ICRAF/government staff directive/demand

2 To learn and share experiences with fellow farmers

3 To easily obtain inputs

4 To sell produce as a group

5 Others *(specify)*____

43. Does the club/association have a constitution? Code: 1=Yes 2=No

44. Do you keep farm records of agroforestry activities? Code: Yes=1 No=2

45. If **Yes**, what is the main reason?

Code 1 To keep track of agroforestry activities

2 We are instructed to do so by ICRAF/extension staff

3 For future reference

4 Other *(Specify)*____

46. How frequent do you record agroforestry activities?

Code 1 Daily

2 Weekly

3 Monthly

4 Quarterly

5 More than 3 months

47. Do you write reports? Code: Yes=1 No=2

48. If **yes**, where do you send the reports?

Code 1 ICRAF

2 Nowhere, they are for my/our records

3 To other organisations/people who demand them

4 Other *(Specify)* ____

49. How frequent do you write the reports?

Code 1 Weekly

2 Monthly

3 Quarterly

4 Every six months

5 Annually

50. Are you involved in any ICRAF or government planning, monitoring and evaluation activities? Code: 1=Yes 2=No

51. If **no**, what is the main reason?

Code 1 Not invited

2 Activities don't occur

3 No reason for participating in those activities

4 Only local or club leaders are involved

5 Other *(Specify)* ___________________________________

52. Have you ever attended any training or workshop on agroforestry? Code: 1=Yes 2=No

53. If **yes**, who organised it?

Code 1 ICRAF

2 Government staff

3 NGOs

4 Other *(Specify)*____________________________________

54. Did you benefit from the training/workshop? Code 1=Yes 2=No

55. If **yes**, what do you benefit?

Code 1 Agroforestry types

2 Agroforestry tree management

3 Field management

4 M & E

5 Other (*specify*)____________________________________

56. Did you receive any free fertilizer or buy subsidized fertilizer? Code: 1=Yes 2=No

57. If **yes**, how much? _________________Kg

58. Assuming that you will continue receiving the free or buying the subsidized fertilizer for the **next five years**, will you continue planting or managing agroforestry trees for soil improvement reasons? Code: 1=Yes 2=No

59. If **no**, what will be the main reason?

Code 1 Agroforestry trees will not be useful

2 The trees will be left for fuelwood, folder and poles only

3 Other *(Specify)*__________________________________

60. Will you continue planting/managing agroforestry trees after soil fertility restoration? Code 1=Yes 2=No

61. If **no,** what will be the main reason?

Code 1 Will uproot/cut/unmanage the trees

2 Will shift to tobacco industry

3 There will be no need of agroforestry trees

4 Other *(specify)*____

62. If ICRAF or government can stop supporting agroforestry activities in this area, will you continue planting/managing trees? Code 1=Yes 2=No

63. If **no**, what can be the main reason?

Code 1 I will have no inputs

2 The program/trees will have no owner

3 There will be nobody to encourage and direct me

4 Other (*specify*)____

64. Have you reduced the size of your agroforestry field from the time you started?

Code 1 = Yes 2 = No

65. If yes what happened to the trees?

Code 1 Uprooted

2 Cut down

3 Other (*specify*)____

66. What was the main reason for reducing the agroforestry field?

Code 1 Planted tobacco in the garden

2 Soil is now fertile

3 ICRAF no longer visited the farm

4 Received free inorganic fertilizer

5 Bought subsidized fertilizer

6 Trees were attacked by diseases or pests

7 Owner of land took it back

8 No labor to manage the trees

9 Lack of cultivating land

10 Other (*specify*) ___________________________________

67. How many agroforestry trees do you have? __________________ (*Write actual number*).

68. How many trees were planted after practicing the technology for five years of adoption?__ ______________(*Write the actual no.*)

69. What was the original area with agroforestry tree?

Code 1 <0.5 ha

2 0.5 to less than 1 ha

3 1 to less than 1.5 ha

4 1.5 to less than 2 ha

5 2 to less than 2.5 ha

6 greater than 2.5 ha

70. Has there been any change in use and management of the trees with reference to previous years? Code: 1 = Yes 2 = No

71. If yes, what is the main change in use and management of the trees?

Code 1 No longer prune the trees

2 No longer apply biomass to the soil now

3 Applying less biomass to the soil now

4 Other *(Specify)* ________________

72. What is the main reason behind the change in use and management?

Code 1 Planted tobacco in the garden

2 Soil is now fertile

3 ICRAF no longer visited the farm

4 Received free inorganic fertilizer

5 Bought subsidized fertilizer

6 Trees were attacked by diseases or pests

7 Owner of land took it back

8 Had no labour to manage the trees

9 Lack of cultivating land

10 Other, *(specify)* _______________

G FOOD SECURITY ISSUES

73. What month did the maize harvested last season (2004/05) cropping season last?

____

74. How did you supplement the shortfall? ***(Only ask if it applies to the household)***

Code 1 Buying maize

2 Winter maize harvest

3 Sold labor for food

4 Given by other

5 Ate other foods (*Specify*)__________________________

6 Other (*specify*)____

ENUMERATOR: Ask the interviewee if there are any questions.

CONCLUDING REMARKS

I thank you for your time and corporation. Once again, the information you have given me will be confidential and you will not be taken to task for anything. The results of the study will be made available to you

HAND OVER THE QUESTIONNAIRE FOR CHECKING

Appendix 2

University of Malawi

BUNDA COLLEGE OF AGRICULTURE

ECONOMICS OF MIXED INTERCROPPING AND RELAY CROPPING AGROFORESTRY TECHNOLOGIES: A Case of Zomba District in Malawi.

Non-adopters Questionnaire

August 2006

Enumerator: Follow instructions before asking any question. Do not give your own views but use information from the interviewee. Circle the appropriate code and fill the blank spaces where necessary.

Introduction to every interviewee

We are from Bunda College and working in partnership with ICRAF and the Ministry of Agriculture. We are conducting a survey on agriculture. You were chosen to participate in the exercise. Your information will be kept with confidentiality and you will not be singled out in the results. You will up briefed on the results of the study.

`

Enumerator's name:______________________ Date of interview:____________

Name of household:________________________ HH Code: ________________

Name of EPA:___________________________ Section_____________________

T.A.__________________________________ Village: ____________________

Checked by:______________________________Date:______________________

A. BACKGROUND INFORMATION AND HOUSEHOLD HEAD CHARACTERISTICS

75. Household composition

(Filled cells are not applicable)

Person No. ***(HH should be number 1)***	**Age (in years)**	**Marital status of HH*** ***(Use codes below)***	**Gender.** ***1: Male*** ***2: Female***	**Relationship to household head**	**Availability**** ***(Use codes below)***
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

Codes for HH Marital Status*

1 Single

Codes for Availability**

1 Permanent resident

2	Married	2	Permanent resident in local employment
3	Polygamist	3	Permanent resident in full education
4	Widowed	4	Polygamist spending time in other households
5	Divorced	5	Resident hired labour
6	Other *(Specify)*……………..	6	Other *(Specify)* …………………

Codes for Relationship to household head

1 = Spouse, 2 = Child, 3 = Parent, 4 = Grandchild, 6 = Other Specify_________________

76. Do you read and write Chichewa? Code: Yes = 1 No = 2
77. If **yes**, how far did you go with your education?

    (Circle depending on where the education was obtained)

a) Formal Education:

Code:

1 None

2 Primary school *(actual class)*______________

3 Secondary School *(actual class)*____________

4 High school and above *(actual level)*_________

5 Other *(specify)*_______________________

b) Informal education:

Code:

1 None

2 Adult literacy

3 Home craft

4 Farmer training

5 Other *(specify)*________

B HOUSEHOLD INCOME

78. What are your main sources of income?

    Code 1 Sales of livestock

    2 Sales of crops

    3 Labor sales

    4 Remittances

    5 Other (*Specify*)____

79. What was your income the previous year?

	Source	Amount
1	Sales of livestock	
2	Sales of crops	
3	Selling labor	
4	Remittances	
5	Other (Specify)	

80. How much of this income did you allocate to agricultural activities? MK _______________

C LAND HOLDING AND AGROFORESTRY TECHNOLOGY

81. How many fields do you have?

Code 1 One

2 Two

3 Three

4 Four

5 Five

6 More than five (*Specify*)_________________________________

82. Are all these gardens owned by you?

Code 1=Yes 2=No

83. If **no**, how many are not owned by you? ***(If yes, go to question 11)***

Code 1= 1 garden, 2= 2 gardens, 3= more than 2 gardens

84. How did you get the garden(s) you do not own?

Code 1=Rent 2=Borrowed for free 3= Other *(Specify)*_____

85. How did you acquire the garden(s) you own?

Code 1 Allocated by village headman

2 Bought

3 Family inheritance

4 Through marriage

5 Other *(specify)* ....

86. What crops and crop combinations do you plant?

Code 1 Maize without agroforestry trees

2 Tobacco

3 Groundnuts

4 Cotton

5 Other (Specify)____

87. On how much land do you have these crops?

	Crops and crop combinations	**Land Size (ha/acre)**
1	Maize	
2	Tobacco	
3	Groundnuts	
4	Cotton	
5	Other (Specify)	
6		

D FARM COSTS AND BENEFITS

88. Benefits

Crop Type	**Description of Benefits**	**Units of measure**	**Amount Harvested**	**Price per unit**	**Total Revenue**
Agriculture crops	Maize yields	Kilograms			
	Tobacco	Kgs			
	Groundnuts	Kgs			
	Cotton	Kgs			
Other benefits (Specify)					

89. Farm inputs used this year.

(Indicate if it was free or subsidized under comment column)

Activity	Cost Item	Unit of measurement	Amount Used	Total Cost	Source of input
Land Preparation	Hired labor				
	Family labor	Labor days			
Planting maize					
	Seed for maize	Kilograms			
	Labor	Labor days			
Fertilizer application					
Basal-dressing	Fertilizer	Kilograms			
	Hired labor	Labor days			
	Family labor	Labor days			
Top-dressing	Fertilizer	Kilograms			
	Hired labor	Labor days			
	Family labor	Labor days			
Weeding	Hired labor	Labor days			
	Family labor	Labor days			
Harvesting	Hired labor	Labor days			
	Family labor	Labor days			
Marketing	Hired labor	Labor days			
	Family labor	Labor days			
Other Cost (Specify)					
Herbicides/pesticides					
Transporting inputs/produce					

90. Did you experience problems in accessing these inputs? Code: 1= Yes 2= No

91. If **yes**, what was the most difficult input to access?

Code 1 Tree seeds/seedlings

2 Maize seed

3 Inorganic fertilizer

4 Chemicals

5 Labour

6 Other *(specify)*.

92. What was the main reason behind the inaccessibility?

Code 1 Scarcity

2 Lack of money

3 Distance to where they were found

4 Other *(Specify)* _______________

93. How did that affect your input use?

Code 1 Did not affect

2 Reduced their use

3 Delayed their use

94. If it **delayed**, by how many days? _________ days.

95. If it **reduced** use, by how much? *(Specify input and number of days accordingly)*.

1. ________________ by ________ days

2. ________________ by ________ days

3. ________________ by ________ days

E EXTENSION SERVICES

96. Do you have access to extension services? Code: 1= Yes 2= No ***(If no, go to question 28)***

97. If **yes**, on which main area?

Code 1 Agroforestry

2 Land preparation

3 Planting and spacing

4 Disease and pest control

5 Other crops

6 Other *(Specify)*____

98. What is the main source of the extension services?

Code 1 ICRAF

2 Government extension staff

3 NGOs

4 Fellow farmers

5 Others *(Specify)*____

99. How many times per month are you visited by extension services provider (s)?

Code 1 More than four times

2 Four times

3 Three times

4 Two times

5 Once

6 Not at all

7 Other (Specify)____

100. Do you participate in field days? Code: 1 = Yes 2 = No

101. Do you have any demonstration plots in this EPA? Code: 1 = Yes 2 = No

102. Do you belong to any club or association? Code: 1 = Yes = No

103. If **no**, what is the main reason?

Code: 1 Absence of clubs association

2 No incentive/benefit

3. Lack of organisation in the club

4. Clubs are not organised

5. Poor supervision by extension workers

6 Other *(specify)*____

104. If **yes**, what was the main reason of joining the club/association?

Code 1 Government staff directive/demand

2 To learn and share experiences with fellow farmers

3 To easily obtain inputs

4 To sell produce as a group

5 Others *(specify)*____

105. Do you keep farm records? Code: Yes=1 No=2

106. If **Yes**, what is the main reason?

Code 1 To keep track of farm activities

2 We are instructed to do so by extension staff

3 For future reference

4 Other *(Specify)*____

107. How frequent do you record your agricultural activities?

Code 1 Daily

2 Weekly

3 Monthly

4 Quarterly

5 More than 3 months

108. Do you write reports? Code: Yes=1 No=2

109. If **yes**, where do you send the reports?

Code 1 Nowhere, they are for my/our records

2 To other organisations/people who demand them

3 Other *(Specify)* ____

110. How frequent do you write the reports?

Code 1 Weekly

2 Monthly

3 Quarterly

4 Every six months

5 Annually

5 Other (*specify*)_____________________________________

111. Did you receive any free fertilizer or buy subsidized fertilizer? Code: 1=Yes 2=No

112. If **yes**, how much? ________________Kg

F FOOD SECURITY ISSUES

113. What month did the maize harvested last season (2004/05) cropping season last?

____

114. How did you supplement the shortfall if there was any?

Code 1 Buying maize

2 Winter maize harvest

3 Sold labor for food

4 Given by other

5 Ate other foods (*Specify*)_________________________________

6 Other (*specify*)____

41 Do you practice any organic soil fertility enhancement technology?

1 = Yes 2 = No

42 If yes, which ones?

1 = Compost manure 2 = Legumes 3 = burying of crop residues 4 = Animal manure 5 = Other (*Specify*)_______________________________

43 Why do you not opt for agroforestry?

1 = Land constraint

2 = Labor constraint

3 = No interest

4 = Can’t find seed

5 = Has never heard about agroforestry

6 = Other (*Specify*)___________________________

ENUMERATOR: Ask the interviewee if there are any questions.

CONCLUDING REMARKS

I thank you for your time and corporation. Once again, the information you have given me will be confidential and you will not be taken to task for anything. The results of the study will be made available to you

HAND OVER THE QUESTIONNAIRE FOR CHECKING