# ANALYSIS OF THE PROFITABILITY OF MIXED TREE INTERCROPPING AND RELAY CROPPING AGROFORESTRY TECHNOLOGIES: A CASE OF ZOMBA DISTRICT

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## DECLARATION

I hereby declare that the work in the thesis is my own work and effort and that it has not been submitted anywhere else for another academic award. Where other sources of information have been used, they have been acknowledged.

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## CERTIFICATE OF APPROVAL

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

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# DEDICATION

To my dear family, Owen my husband, you have been a source of inspiration to me. Wongani my daughter, this is for you. My parents, Milward and Lincy Selemani, you have always been my motivation.

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# ABSTRACT

This study was conducted in Zomba District of Southern Malawi to evaluate the profitability of mixed tree intercropping and relay cropping agroforestry technologies. Thondwe, Malosa and Dzaone Extension Planning Areas of the district agriculture office were selected for the study. A total of 286 farmers was targeted, 74 relay cropping *Tephrosia vogelli/candida* with maize (RA), 101 practicing mixed tree intercropping of *Gliricidia sepium* with maize (MA) and 119 non-adopters. The study used primary data which was analyzed using descriptive statistics, Gross Margins (GMs), Benefit-Cost Ratio (BCR), Net Present Value (NPV) and the Expected Variance (E-V) model.

Both MA and RA farmers had positive NPV estimated over a period of twenty years at MK 52,418.53 (US$374.42) and MK 10,573.69 (US$75.53) respectively. Non-adopters had negative NPV of MK -7,283.84 (US$52.03). GMs per hectare for MA farmers were the highest. The BCR for the two agroforestry technologies were greater than 1 at 1.6 for MA and 1.12 for RA, implying that it is worth investing in the technologies.

The results of the optimization of MA and RA using the E-V programming model showed that if risk is not considered in the optimization of farm resources, farmers can optimize the use of their resources with the production of maize under the two agroforestry technologies only. At the optimal level, the farmers cultivated 1.27 hectares of MA and 1.1 hectares of RA only. When risk was introduced into the optimization, farmers started withdrawing land from maize in agroforestry to maize produced without agroforestry, which reduced their expected income. The results also showed that farmers considered MA to be more risky compared to RA technology.

# CHAPTER ONE

## 1. INTRODUCTION

### 1.1 Geography of Malawi

Malawi is a small, highly populated, land locked country in Southern Africa. It has an estimated land area of 11.8 million hectares with 2.4 million hectares covered by water. Estimates indicate that 5.3 million hectares of the total land area for Malawi is cultivatable (Food and Agricultural Organization (FAO), 2006). Malawi shares its boundaries with Tanzania to the north, Zambia to the west and Mozambique to the east and south (Figure 1).

The total population for Malawi is estimated to be 11.5 million with an annual growth rate of 2% per annum. The country has an average population density of 105 persons per $km^2$ with some parts of the southern region having a population density of 307 persons per $km^2$ (National Statistical Office, 2007).

### 1.2 Agriculture in Malawi

The Malawi economy is dominated by agriculture, which accounts for 38.6% of the country's Gross Domestic Product (GDP) and forms the main source of livelihood for the rural poor. The sector contributes about 63.7% of total income for the rural population (GeographyIQ, 2006) and absorbs over 80% of the labor force (Department of State, 2006). Agriculture accounts for 70% of the total export earnings (National Statistical Office (NSO), 2004).


Source: Atlas of Malawi, National Statistical Office

**Figure 1: Malawi's administrative districts and international boundaries**

The country's agricultural sector is composed of two main sub-sectors, the smallholder and the estate sub-sectors. The estate sub-sector produces about 15% of the country's agricultural produce for the local food staple demand, but accounts for 70% of all agricultural exports. Maize is the main food crop for Malawi produced by both sub-sectors. Tobacco is the major cash crop grown by the estates. It is grown on almost 60% of the estate land area. Tobacco provides 63% of the country's total export earnings. Tea and sugar are next, grown on 20% and 18% of estate land, respectively. Tea and sugar provide 8% and 7% of the total export earnings for the country, respectively. There are also other cash crops grown on a smaller scale by the estates including coffee, tung oil and macadamia (FAO, 2006).

The smallholder sub-sector on the other hand produces 85% of the country's agricultural produce for the local food staples demand and export (Ministry of Information, October, 2006). The major food crops grown by the smallholder farmers are maize, groundnuts, cassava, sorghum, millet, beans and sweet potatoes. The smallholder farmers also produce tobacco, tea, sugar, coffee and cotton on smaller scale for cash.

There are approximately 2 million farm families under smallholder farming who cultivate about 4.5 million hectares of land (FAO, 2006). Most of the smallholder farmers have small land holdings and produce for subsistence use. Estimates indicate that approximately 25% of smallholder farmers cultivate on less than 0.5 hectares of land on average with 55% of the farmers cultivating on less than 1 hectare and 31% on land holdings of between 1 hectare and 2 hectares. Only 14% of the smallholder farmers have land holdings of more than 2 hectares (FAO, 2006). This puts land as one of the challenges that smallholder farmers in Malawi are facing. Malawi's high population growth rate, which is exerting pressure on natural resource base, has been attributed to the land problem faced by smallholder farmers. Increasing population has meant an increased demand on maize, which is the country's main staple. To meet the increasing demand for food, farmers have increased their production by cultivating on marginal land areas with inadequate soil and water conservation measures. This has perpetuated the problem of soil erosion, declining soil fertility and high water and soil run-off.

### 1.2.1 Malawi's agriculture sector policy

Malawi's agriculture sector policy is to promote and facilitate agricultural productivity in order to ensure food security, increased incomes and creation of employment through the 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). Agriculture is an important part in the growth and development strategy for the country. It is one of the tools that are meant to achieve equity in household food security, income and employment, and sustainable utilization of natural resources. Despite the importance of agriculture in the economy, the sector is characterized by low and stagnant yields, which have led to many years of food and income insecurity at both household and national levels (Malawi Government, 2006). The Malawi Government has put in place strategies that are aimed at increasing agricultural productivity. The key strategies put in place include encouraging the expansion and intensification of staple food production by smallholder farmers, and promoting soil and water conservation and farming techniques. This is to be achieved through increased access to land, credit and farm inputs by smallholder farmers, improvement in agricultural technology, prevention of land degradation and deforestation, improving agricultural marketing and trading systems, promotion of agricultural diversification, improvement of extension and farming, and development of irrigation systems (Malawi Government, 2006).

### 1.2.2 Maize production in Malawi

Maize is the most important food crop for Malawi. Its production occupies 80% of the cultivated land with more than 1.2 million hectares planted annually. The production is mostly by smallholder farmers and usually done under continuous cultivation with little and sometimes no external inputs like fertilizer. Unlike in the central and northern regions of Malawi where population pressure is lower, maize production in the southern region of the country is done in mixed cropping with other crops such as cassava, pigeon peas, sorghum, beans and cowpeas on small pieces of land (Malawi Government, 2006).

Estimates indicate that for the past 15 years maize production by smallholder farmers who are the main producers of maize for the country and the main focus in the study has been between 1.3 and 1.8 million metric tones despite the population growing at a faster rate. Maize production is estimated to be growing at less than 1% as the population is growing at a higher rate of 2.1% per annum (Malawi Government, 2006). Table 1.1 shows that annual maize production for the season 1999/00 was 2,245,824 metric tones compared to 1,733,125 metric tones in 2003/04. Production of other cereals that are alternatives to maize has also dwindled during the period. For example, from the table, rice production during the 1999/00 season was 92,859 metric tones while in the 2003/04 season it dropped to 49,722 metric tones. The table also shows that sorghum, millet and pulse production also went down. This has meant a fall in per capita food supply for the country. Malawi's per capita cereal production is estimated to be at 159 kg compared to the per capita requirement of 232 kg (FAO, 2006).

**Table 1.1: Smallholder crop production from 1999 to 2005 in metric tones**

| Crop | 1999/00 | 2000/01 | 2001/02 | 2002/03 | 2003/04 |
|---|---|---|---|---|---|
| Maize | 2,245,824 | 2,211,859 | 1,899,185 | 1,983,440 | 1,733,125 |
| Paddy Rice | 92,859 | 67,084 | 93,200 | 88,184 | 49,722 |
| G/nuts | 124,604 | 116,363 | 155,200 | 190,112 | 161,162 |
| Tobacco | 84,555 | 98,675 | 82,500 | 94,312 | 106,186 |
| Cotton | 50,589 | 34,907 | 37,600 | 40,446 | 53,581 |
| Sorghum | 41,401 | 36,799 | 36,900 | 45,438 | 40,905 |
| Millet | 20,224 | 19,508 | 20,400 | 24,515 | 17,349 |
| Pulses | 233,811 | 248,243 | 303,800 | 323,488 | 247,242 |
| Cassava | 895,420 | 2,757,186 | 3,362,400 | 1,735,065 | 2,559,319 |
| Sweet Potatoes | 1,680,313 | 1,634,268 | 2,586,900 | 1,535,137 | 1,784,749 |

Source: Government of Malawi, the National Fertilizer Strategy (Government of Malawi, Economic Reports, 2004)

A number of constraints have been attributed to the low levels of smallholder maize production. These constraints include limited resources to investment in crop production, over dependence on rain fed agriculture, limited irrigation, soil fertility loss, drought, and inadequate access to external inputs such as fertilizer and extension services (Malawi Government, 2006). These are what the Malawi Agriculture Sector Policy is hoping to address.

### 1.2.3 Soil fertility status on smallholder farms

Most of the smallholder farmers' fields have poor soils due to continuous cultivation without replenishment of the soil. The soil mining on smallholder farmers' fields is leaving the poor farmers vulnerable to low maize productivity and consequently food insecurity. Poor soils are considered the main contributor to the low grain yield that has led to previous chronic food shortages Malawi faced (World Agroforestry Centre, 2006).

Application of inorganic fertilizers is regarded as a remedy to the soil fertility loss. However, the high costs of such fertilizers coupled with low grain prices have made smallholder farmers apply less fertilizer than the recommended amounts and sometimes none at all. The prices of fertilizers have increased 10 fold from an average of MK316 per 50kg bag in 1995/96 season to around MK3200 in the 2005/06 season, representing a 1012.66% increase. This has led to a low fertilizer consumption rate per hectare. In Malawi, fertilizer use per hectare is estimated to be at 43 kg compared to the recommended average of 160 kg per hectare for all crops and fertilizer types (Malawi Government, 2006).

The government of Malawi has been implementing different programmes that are aimed at increasing the use of inorganic fertilizer by smallholder farmers in the country since the removal of agricultural input subsidy in 1981. The Starter Pack Scheme (SPS) was the first to be implemented where smallholder farmers were provided with a package of free agricultural inputs like seed and fertilizer. The programme started during the 1998/99 agricultural season with the aim of increasing access to fertilizer and other inputs to smallholder farmers who are resource constrained. The program was then changed to

Targeted Input Program (TIP) after 2 years, which then phased out in the 2004/05 agricultural season. The maim problem with TIP was long term sustainability. The government has also implemented the Agricultural Productivity Investment Programme (APIP) since 1997/98 season, which distributes agricultural inputs on credit to credit worthy farmers. The government has in the 2005/06 season launched the Input Subsidy Program (ISP) which was abandoned since the government signed up for the economic structural adjustment programs (SAPs) supported by the World Bank, the International Monetary Fund (IMF) and other donors in 1981 (GeographyIQ, 2006). One of the conditions of the SAPs was the removal of subsidy on agricultural inputs, fertilizer inclusive since they proved to be unsustainable. This meant a gradual removal of subsidy on agricultural inputs and an increase in the price of inorganic fertilizers with the exception of the 2005/06 cropping season when the government of Malawi implemented a targeted agricultural input subsidy program for smallholder producers. Despite all the programs on fertilizer and other agricultural inputs, the use of fertilizer by smallholder farmers is still low and the need for more sustainable means of replenishment of soil fertility still remains.

### 1.2.4 Organic soil fertility technologies

Organic soil fertility enhancement technologies have been promoted to complement the inorganic fertilizers, which have proved to be expensive and unsustainable for smallholder farmers. There are a number of organic soil fertility enhancement technologies that have offered an alternative to inorganic fertilizers. Agroforestry is one of the organic soil fertility enhancement technologies that have been advocated for smallholder farmers.

#### 1.2.4.1 Agroforestry practices in Malawi

Agroforestry is defined as a dynamic, ecological based, natural resource management system involving the integration of trees and/or shrubs on farms and in the agricultural landscape in order to diversify and sustain production for increased economic and environmental benefits of land users at all levels (World Agroforestry Centre, 2006). In agroforestry systems trees and/or shrubs are grown in association with crop plants and sometimes livestock in a spatial arrangement or rotation or both (Nyirenda, 2002). Agroforestry is one of the organic soil fertility enhancement technologies that can increase organic matter and nitrogen content of the soil through the fixation of nitrogen by nitrogen fixing tree species. Nitrogen fixing tree species take up nitrogen from the air and pass it on to other plants for growth through the cycling of organic matter. When these trees are integrated with agricultural crops on a farm, they are a good source of nitrogen fertilizer that can supplement inorganic fertilizers.

Agroforestry in Malawi was introduced to increase agricultural productivity. Department of Agricultural Research and World Agroforestry Centre (WAC) carried out agroforestry research both on-farm and on-station. Since then, there are a number of organizations that have been actively involved in disseminating agroforestry technologies in Malawi including Land Resource Conservation Department (LRCD), which had two projects, Malawi Agroforestry Extension Project (MAFE) and Promotion of Soil Conservation and

Rural Production (PROSCARP) who worked with a number of partners on the ground. Malawi Government through its extension department is also encouraging farmers to practice agroforestry as one of the long-term measures to replenish soil fertility. Agroforestry practices that have been adopted by farmers in Malawi include dispersed systematic tree interplanting, regeneration of natural soil improving trees, annual undersowing, mixed tree intercropping, alley cropping, improved fallow and relay cropping (Bunderson *et al.,* 2002).

Dispersed systematic tree interplanting requires planting of trees at wide spacing of 10 meters by 5 meters with annual crops to enhance soil fertility, improve crop yields, and supply fuelwood, building materials, fodder and poles for home use or sale. Regeneration of natural soil improving trees involves encouraging farmers to protect naturally regenerating trees in their fields with the aim of improving soil fertility. In relay cropping, agroforestry species are under-sown in a maize field with the aim of soil fertility improvement. In alley cropping, crop plants are planted between hedgerows of soil improving trees and shrubs that are planted 4-5 meters apart with 45-90 centimeters between plants within the row and coppiced annually (Bunderson *et al.,* 2002).

Annual undersowing is an agroforestry technology in which maize is intercropped with shrubs annually when the rains start. The trees/shrubs are harvested just before land preparation at the beginning of the following season (Bunderson *et al.,* 2002). The aim of annual undersowing is to restore productivity by improving the chemical, physical and biological properties of the soil. *Tephrosia vogelli/candida* is one of the recommended species for annual undersowing since it is easy to establish and its management is similar to that of pigeon peas, which farmers are used to growing in the southern region of Malawi (Ministry of Agriculture and Food Security, 2005).

Mixed tree intercropping entails planting rows of soil improving trees and shrubs 1.8 m apart with rows of agricultural crops in between and the interplant spacing of the agroforestry tree is 0.9 m. The hedge rows are pruned two or three times during the year to minimize shading and competition with the crop plant, and to provide leaf biomass for improving soil fertility, suppress weeds and conserve soil (Bunderson *et al.,* 2002). The pruned branches may also be used for fuelwood and poles.

### 1.3 Problem Statement and Justification

Mining of soil nutrients threatens sustainable livelihood means for the majority of the rural poor and leaves them vulnerable to food insecurity and poverty since agriculture is the main source of food and income. Soil fertility loss, characterizes food-oriented small-scale farms and has led to low labor and land returns. Sole-cropped, unfertilized or little fertilized maize cropping systems dominate the crop production of smallholder farmers in Malawi (Snapp *et al.,* 2002). These cropping practices have accelerated soil fertility loss due to soil erosion and nutrient leaching. As a result, soils in Malawi are deficient of major nutrients like nitrogen, phosphorus and sulphur. The decline in soil fertility associated with falling levels of organic matter and soil nutrients threatens the sustainability of smallholder maize-based systems.

The Government of Malawi and other stakeholders have prescribed both organic and inorganic soil fertility enhancing technologies in order to boost smallholder farmers' crop yields. Organic fertilizers are naturally occurring and are derived from either plant or animal sources containing one or more elements that are essential for plant growth. Inorganic fertilizers on the other hand are chemically synthesized nutrient sources. Due to the exorbitant cost of inorganic fertilizers, organic fertilizers have offered a cheaper alternative fertilizer source to smallholder farmers.

Apart from the price problem, the supply of inorganic fertilizer on the market has also not been stable, thereby affecting its accessibility. The supply problem has largely been attributed to inadequate foreign exchange and agro dealer network among other factors. The agro dealer network comprises different suppliers of agricultural inputs from either the producers or wholesalers to the smallholder farmers. The degree of demand for inorganic fertilizer has been affected by inadequate access to credit by smallholder farmers, low produce prices, poor farmer organization, and limited fertilizer application technologies (Malawi Government, 2006).

With the constraints on supply and access to inorganic fertilizers, there has been need for a more sustainable means for replenishing soil fertility and organic fertilizers are being advocated as a more sustainable and cheaper means to replenish soil fertility.

Agroforestry is one of the organic soil fertility enhancement technologies, which plays a significant role in improving soil fertility, and offers a range of other benefits like fuelwood, poles, fodder, shelter, medicines and income from the sale of tree products. For farmers to adopt any technology, they consider its costs and benefits. Agroforestry like any agricultural technology is no exception. A thorough understanding of the profitability of agroforestry will therefore be necessary to assist policy makers in the promotion of the technology.

Studies on the profitability of agroforestry in Malawi are scarce. Available studies used deterministic models, which ignored risk. Risk is important in the analysis of any agricultural system since agriculture is prone to risk due to the biological nature of the agricultural produce interacting with variable weather conditions. Nyirenda (2002) used the enterprise budget, Net Present Value and Benefit Cost ratio to assess the performance of improved fallow based maize production in Malawi. Kamanga *et al.* (2000) used gross margins to assess the profitability of tree based maize production systems. However, agroforestry like any agricultural production system is prone to risk and its output is stochastic. Risks are situation that can affect agricultural production but are outside the control of a farmer. In agriculture, the biological nature of crops and livestock interacting with variable weather and environmental conditions, pests and diseases, changing demand and unpredictable government policies that may affect yields and consequently prices makes agriculture prone to risk (Boisvert *et al.* 1992). This is specifically important to smallholder farmers since they are land constrained. Risk results in variable returns from crop and animal production. Risk is therefore important during the decision making process on the farm. Therefore models that are used in the economic analysis of any agricultural production should include risk. If risk is ignored in any agricultural model, the model assumes that a fixed input level will result in some predictable level of output (Pimentel *et al.*, 1998).

Agroforestry like any agricultural production is prone to risk. Apart from the natural causes of risk in agriculture, agroforestry is also considered risky by the smallholder farmers because of the loss of land for maize production to agroforestry trees. By disregarding risk in the analysis of agroforestry systems, it is assumed that the output from an agroforestry field can be predicted with certainty which is not the case for any agricultural system. In this study, the profitability of mixed tree intercropping of *Gliricidia sepium* and maize, and relay cropping of *Tephrosia vogelli/candida* and maize agroforestry technologies are estimated using the Expected-Variance (E-V) model. This model was chosen for the study because unlike other models used in the analysis of profitability, it is a risk programming model, which includes the assumption of risk in the analysis of profitability through the incorporation of mean and variance. The study was carried out in Zomba District of the Southern Region of Malawi. The area was chosen because it is one of the districts in Malawi where maize production levels had been dwindling over the years. The area was also chosen because of the high prevalence of farmers practicing agroforestry. The two agroforestry technologies were chosen because they are the most prevalent technologies in the Southern region of Malawi.

## 1.4 Objectives

The underlying objective of the study was to evaluate the profitability of mixed intercropping and relay cropping agroforestry technologies to smallholder farmers in Zomba District of the Southern Malawi. The specific objectives of the study were:

1. To evaluate the profitability of mixed tree intercropping and relay cropping agroforestry technologies to smallholder farmers.
2. To assess farm production plans for mixed tree intercropping and relay cropping agroforestry technologies.

## 1.5 Hypotheses

The hypotheses of the study were:

1. Mixed tree intercropping and relay cropping agroforestry technologies are not profitable to smallholder farmers.
2. Farm production plans have no effect on the successful implementation of relay cropping and mixed tree intercropping agroforestry technologies.

### 1.6 Summary and Thesis Organization

Chapter 1 has given background information on the study. The chapter has firstly described the geography of Malawi. This has been followed by a description of agriculture in Malawi and the agriculture sector policy. Maize production in Malawi and the soil fertility status on smallholder farms has also been focused in the chapter. The chapter has further described the organic soil fertility technologies practiced in Malawi including agroforestry. The chapter has ended by presenting the problem statement and justification, and outlining the objectives and hypotheses for the study.

Chapter two reviews selected literature on studies that have been done on agroforestry and related topics. The chapter begins with considering the soil fertility problem. Other issues focused on in the chapter include soil fertility improvement strategies in Malawi, maize productivity and agroforestry and economic analysis of agroforestry.

Chapter 3 focuses on the methodology for the study. The chapter presents the description of the study area, sampling method used in the study and concludes with discussion of the analytical framework for the study. In chapter 4, the results on socio-economic characteristics of the farmers involved in the study are discussed.

Chapter five focuses on the analysis of profitability of mixed tree-intercropping and relay cropping agroforestry technologies. Results on gross margin analysis, net present value, cost benefit ratios and sensitivity analysis are presented and discussed in the chapter. In chapter six, there are results of the Expected Variance (E-V) programming model that was used in the study to optimize relay cropping and mixed tree intercropping agroforestry technologies. The results of the model have also been used to generate management plans for the two technologies in the chapter. Chapter seven concludes the study with policy recommendations.

# CHAPTER TWO

## 2. LITERATURE REVIEW

### 2.1 Introduction

This chapter presents an overview of selected literature on soil fertility and agroforestry. Special emphasis is placed on economic analysis of agricultural and agroforestry systems. The chapter has the following sections; soil fertility loss, soil fertility improvement strategies in Malawi, maize productivity and agroforestry, and economic analyses of agroforestry systems.

### 2.2 Soil Fertility Loss

Soil fertility is lost due to plant use of soil nutrients without replenishment, soil erosion, nutrient leaching and some other chemical processes in the soil. Briggs and Twomlow (2002) noted that soil nutrient loss from the steeply sloping hillsides of the tropics and subtropics is not only caused by soil erosion, but also by the net transfer of annual crop residues to more profitable parts of the farming system. The paper further reported that a lot of studies on soil nutrient balances across Africa have found that there is a lot of mining of the soil resource within the smallholder farming sector, since in annually cropped hillside fields the organic matter and nutrient source are not replenished.

Deforestation caused by shifting and expanding cultivation and charcoal production has led to land degradation in central and southern Africa (Chidumayo and Kwibisa, 2003). In Malawi, soil degradation is threatening sustainable agricultural production. Blackie (1994) reported that the decline in soil fertility associated with falling levels of organic matter and soil nutrients is negatively affecting the sustainability of smallholder maize based systems. The soil nutrient loss has been attributed to continuous cultivation of the soil by smallholder farmers with limited and sometimes without the use of external soil fertility improvement inputs.

Population and land pressure are some of the major challenges to the smallholder. In Malawi rapid population growth has increased demand for food and natural resources. Makumba (2003) reported that due to population pressure and high food demand in some areas of the country, there is no land to spare for fallowing which was one of the ways for replenishing soil fertility in the past. Smallholder farmers have expanded their staple food production to marginal areas, including river banks and hillsides as well as steep slopes thereby aggravating the problem of soil fertility loss.

Cultivated land is expanding as the demand for fuelwood and other tree products is also increasing. Bamire and Manyong (2003) noted that sustaining productivity of the land resource under the existing land use system and increasing population pressure requires the use of appropriate technology. However, the smallholder sub-sector in Malawi is characterized by use of unimproved crop varieties and limited use of nutrient replenishing technologies under marginal conditions. For example, Makumba (2003) found that although smallholder farmers are aware of the importance of fertilizer, they only apply 20 to 30% of the recommended mineral fertilizer rate and no organic fertilizers at all due to the prohibitive cost of inorganic fertilizer. In other areas of the world, chemical fertilizers have been mostly used to maintain and increase soil fertility (Blackie, 1994).

Crop production under the reduced fertilizer systems can only be productive if the reduction in the use of inorganic fertilizers is matched with adoption of integrated soil fertility management that incorporates organic soil fertility improvement technologies. A combination of small rates of inorganic fertilizer and organic fertilizer produces the best levels of yields. There are a number of organic soil fertility improvement technologies such as agroforestry, compost manure, animal manure and burying of crop residues that have been advocated to smallholder farmers in Malawi (Ministry of Agriculture, 2005).

## 2.3 Soil Fertility Improvement Strategies in Malawi

Soil fertility improvement is one of the most important objectives of the Malawi Government's policy on increasing agriculture production. Inorganic fertilizers have been advocated to farmers as one of the ways to replenish soil fertility but due to the high cost of inorganic fertilizers, cheaper alternative organic soil fertility improvement strategies have been advocated for resource poor smallholder farmers in Malawi. These technologies include compost manure, animal manure, use of legumes and agroforestry.

In a study that evaluated legume intensification as a means to improve maize-based systems in Malawi under on farm conditions, Snapp *et al.* (2002) found that legume-intensified systems produced residues that contained approximately 50 kg N/ha per year, two-fold higher than sole-cropped maize residues. The study evaluated grain/legume intercrops of long-duration pigeon pea (*Cajanus cajan*) and groundnut (*Arachis hypogaea*) rotated with maize (*Zea mays*) and a relay green manure system of maize with a tree crop, *Tephrosia vogeli*.

On farms, trees have also been used as a productivity enhancement technology by smallholder farmers in Malawi. Trees influence both the supply and availability of nutrients in the soil by increasing the release of nutrients from soil organic matter (SOM) and recycled organic residues, and improving the release of nutrients within the rooting zone of crops (Buresh and Tian, 1997). Trees input nitrogen by biological nitrogen fixation, retrieve nutrients from below the rooting zone of crops since roots of trees regularly extend beyond the rooting depth of crops and reduce nutrient losses from processes such as leaching and erosion. Lost soil fauna which are important for soil organic matter and plant residue decomposition can also be brought back by trees (Buresh and Tian, 1997).

Agroforestry which uses leguminous trees is seen as a low cost alternative to maintain or improve soil fertility in the absence of inorganic fertilizers under low input farming systems. Agroforestry may offer a quantifiable value in short term sustainability, and might meet recent economic definition of long term sustainable development embodied in conservation of natural and human capital (Price, 1995).

## 2.4 Maize Productivity and Agroforestry

The majority of smallholder farmers fail to meet subsistence maize requirement due to declining soil fertility accompanied by application of little or no fertilizer. This is worsened by the use of inappropriate farming methods, by the smallholder farmers who do not practice soil conservation measures. In Malawi, farmers can reduce dependence on inorganic fertilizers and maintain desirable crop yields from limited land through the use of organic soil fertility enhancement technologies.

Kamanga *et al.* (2000) reported that, adopting a tree legume-based system of the organic fertility enhancing technologies, with or without half of the recommended 96 kg N per hectare, gives a yield level which can bring food insecure households to a level of food self sufficiency. The report further observed that production under tree legume-based cropping system gives higher yields than the traditional cropping system of using maize stovers manure. Chirwa *et al.* (2003) noted that agroforestry may be used to increase the input of organic fertilizer and reduce the need for expensive inorganic fertilizer in Malawi.

In a study that was aimed at determining the productivity of relay cropping maize and *Sesbania sesban* in three landscape positions in Malawi, Phiri *et al.* (1999) found that relay cropping of *Sesbania sesban* with maize increased maize grain yield, as compared to sole maize in two of the three project years. David and Raussen (2003) demonstrated that on upper terrace in Uganda, cumulative maize yield after fallowing increased significantly compared to a continuous cropping system. Rao *et al. (*2000) also demonstrated that, maize yields increased by 17% and 19%, respectively when maize-cowpea sequential and pigeon pea/maize intercropping system followed a sole maize crop.

In a three year study conducted in Zomba, Malawi, to assess agroforestry-based soil management technologies on smallholder farmers' fields, Kamanga *et al.* (2000) found that resource poor farmers can obtain higher maize yields when organic inputs are combined with inorganic fertilizers in lower landscape. The study further established that uplands required different approaches to land resource improvement.

Banzi *et al.* (2002) reported that tree species such as *Leuceana leucocephala* and *Acacia polyacantha* are best suited for rotational woodlots to improve soil fertility and subsequent crop yields as a secondary goal to serving the function of wood production. Chilimba *et al.* (2002) also noted that both intercropping of maize between hedgerows of trees and use of foliar biomass of shrub trees as organic manure gave significantly higher yields than unfertilized maize control plots in several sites in Malawi. In a synthesis of improved fallow for soil fertility improvement in Tanzania, Gama *et al.* (2002) showed that short duration planted fallow has great potential for improving soil fertility and subsequent crop yields for the benefit of resource poor farmers.

Makumba *et al.* (2006) noted that application of *Gliricidia sepium* prunings increased maize yields three times those of sole maize cropping with or without inorganic nitrogen fertilizer. Application of agroforestry prunings increased maize yields by 29%. The aim of the study was to assess the yields of *Gliricidia sepium* prunings under intensive pruning management and the effects of continuous application of *Gliricidia* prunings and fertilizer on maize yield and soil properties in Malawi.

In western Kenya, Buresh *et al.*, (1997), showed that fast-growing trees that have high nitrogen, (N), demand took up subsoil nitrate that had accumulated below the rooting depth of annual crops. The study used *Calliandra calothyrsus*, *Sesbania sesban* and

*Eucalyptus grandis* tree species. From the result of the study, it was noted that trees have the potential to increase inorganic soil N, N mineralization and amount of N in light fraction soil organic matter. The study further noted that some agroforestry trees can provide enough N for moderate crop yields. The study also reported that there is normally insufficient phosphorus, (P) cycling from organic materials required for crops and that sustained crop production under agroforestry systems on P-deficient soils requires external P inputs.

## 2.5 Economic Analyses of Agroforestry

Economic analysis of any technology is necessary to assist farmers in the adoption decision process. There are different methods that can be used for the analysis of the profitability of agroforestry including cost-benefit analysis, net present value, gross margin analysis, capital budgeting and linear programming. Some of these methods and their applications are discussed in the sections below.

### 2.5.1 Cost-Benefit analysis

Economic returns play a very important role in farmers' decision to adopt any new technology and consequently influences their resource management decisions (Bamire *et al.,* 2003). Agroforestry has benefits and costs that are incurred by the farmer during implementation. These are considered by the smallholder farmers before the adoption of the agroforestry technology. Cost-benefit analysis is a financial appraisal of an activity that compares all cost and benefits that go into the production process. It is one of the methods that are used to assess the profitability of a system. The method has been used in the study of profitability in agriculture.

In agroforestry adoption, farmers compare the benefits of trees in weed suppression and anticipated cash earnings, to the costs of seed, problems of seed access, labor requirements and problems of grain market access and price (Snapp *et al.*, 2002).

David *et al.* (2003) demonstrated that in Uganda, apart from improving crop yields, some agroforestry species like S*esbania sesban, Calliandra calothyrsus* and *Alnus acuminata*, also provided fuelwood. In a study to evaluate the benefits of agroforestry and farm forestry projects in Central America and the Caribbean, Current and Scherr (1995) found that tree planting provided financial benefits to farmers, as well as social, economic and environmental benefits.

Snapp *et al.* (2002) reported that the probability of adoption of legume-intensified systems remains uncertain despite having a higher yield potential than continuous sole maize. This was attributed to constraints and trade-offs that are associated with technology choice. The study also noted that such kind of information is not usually considered when conducting on-farm trials for different technologies. The paper further reported that despite the legumes being highly productive, marginal loss of maize production is of concern to smallholder farmers.

Nyirenda *et al.* (2002) used enterprise budget, Net Present Value and Benefit-Cost ratios to compare the economic performance of improved fallow based maize production against three other production options available to farmers in central Malawi. The study was meant to assess the costs and benefits of the short term improved fallow agroforestry.

The results showed that maize produced after *Sesbania sesban* fallow had the highest benefit cost ratio of 2.55 compared to the other cropping systems. The study further noted that short-term improved fallow is not only economically beneficial to farmers but also has other benefits like fuelwood and poles. As such Nyirenda (2002) concluded that farmers can increase their maize production while reducing investment through reduction in mineral fertilizer inputs.

Mumba *et al.* (2002) used Net Present Value (NPV) to examine the profitability of rotational woodlot technology under two management conditions in Tanzania. The NPV were subjected to sensitivity analysis to examine the financial returns under several assumptions regarding quantities and costs of inputs and outputs. The results showed that at the end of 5 years woodlots gave substantially greater returns than continuous maize cropping despite the high labor and cash requirements in the first year.

Nelson *et al.* (1998) did a cost-benefit analysis to compare economic returns from traditional open-field maize farming with returns from intercropping maize between leguminous shrub hedgerows, natural vegetation strips and grass strips in Philippines. The results revealed that natural vegetation grass strips were more attractive to farmers due to their lower establishment costs and they provided intermediate steps to adoption.

Pimentel *et al.* (1998) used the cost-benefit analysis in Central America to assess the benefits of maize production in an agroforestry system. The report highlighted the need for sensitivity analysis to quantify the proneness of a particular agroforestry system to risk. The results of the study showed that in a maize field with legume trees there was low input cost and low rate of soil erosion compared with a low inorganic fertilizer input field. The study further indicated that the field with legumes was more sustainable and produced 80% more food than the field with low inorganic fertilizer input.

In a study to assess the impact of an agroforestry intervention project on soil fertility and farm income based on a sample of subsistence farm households in Nepal, Neupane *et al.* (2001) used the cost-benefit analysis to assess the profitability of agroforestry. The results demonstrated that agricultural systems with agroforestry were more profitable than conventional systems.

Although cost-benefit analysis is an effective tool for analysis of the profitability of a technology, the tool has a number of weaknesses. Cost-benefit analysis is usually done on financial costs and benefits. In the case where intangible cost and benefits are included in the analysis, there is need for estimation of the value of these. This may introduce subjectivity in the analysis of the costs and benefits.

### 2.5.2 Gross Margin Analysis

A gross margin of an enterprise is its financial output minus its variable costs (Firth, 2002). Gross margins are used to evaluate the production and economic efficiency of an enterprise, which can be essential when comparing enterprises. Gross margins are however only used to compare enterprises with similar characteristics and production systems (Firth, 2002). They are widely used in agriculture for farm planning and comparing different farms with similar characteristics or different enterprises on the same farm.

In a study that evaluated the financial and environmental aspects of sustainability of organic farming systems (OFS) and conventional farming systems (CFS) at farm level and on more detailed spatial scales, Pacini *et al.* (2003), compared the gross margins of three case study farms in Tuscany (Italy). The farms were covering different farming systems (FSs) and different spatial scales. The results of the study indicated that the gross margins of steady-state OFS were higher than the gross margins of CFS.

Sparkes *et al.* (1998) used gross margins to compare the economic efficiency of two farms along side grain production levels. The two farms had contrasting rotations. At one of the farms at Broom's Barn, Suffolk, UK there was a five course rotation consisting of sugar beet and four cereals, while at Bunny Park, Nottinghamshire, UK, there was oilseed rape as the break crop, which was followed by three cereals. The results of the study showed that the headland set-aside produced a larger gross margin and had the greatest impact on grain production. The headland set aside also showed an additional benefit in its potential to improve the environment through increased habitat diversity and the provision of 'buffer zones' to prevent agrochemicals from drifting into hedges and watercourses.

Talukder *et al.* (1993) used residual income measures such as gross margins, net farm income and management income to evaluate the relative economic performance of alternative farming systems in Kazir Shimla village of Mymensingh district in Bangladesh. During the study, whole farm business was analyzed and measures of performance of individual subsystems within each farming system were derived. Gross margins for different enterprises in the study varied sufficiently as well as components within and between farming systems. Vegetables and fruits gave higher gross margins in the crop component. None of the farming systems earned any positive return to management apart from the crop-cattle-poultry-fish system.

Gross margins have been widely used in the analysis of the profitability of agricultural enterprises. However, gross margins have a limitation in that they can only be compared between and among enterprises that have similar fixed costs. Comparison of enterprises that have different fixed cost structures can be misleading especially when conventional variable costs have been substituted by fixed costs.

### 2.5.3 Mathematical Programming

Mathematical programming is an optimization tool that is used to tackle problems in which the optimizer faces inequality constraints. It is a unique optimizing tool since it liberalizes the constraint requirements of the optimizer by having inequality constraints (Chiang, 1984). There are different mathematical programming techniques including linear programming, non-linear programming, and chance-constrained programming. This section focuses on mathematical programming model application.

In a study that optimized water allocation and cropping patterns taking into consideration variations in expected incomes from agricultural production and rising water prices for the Jordan Valley, Doppler *et al.* (2002) used linear programming models for determining solutions that maximize gross margins and minimize potential variations in these gross margins. The results indicated that optimizing cropping patterns and the allocation of irrigation water still had a substantial potential to increase the financial return from agriculture. Optimal solutions that consider risk from varying gross margins react quite elastically in terms of demand for irrigation water to rising water prices.

El Awar *et al.* (2001) also used the linear programming mathematical model to determine optimum water allocation for irrigation of several crops in Lebanon. The optimization model was used to choose the optimal cropping pattern that satisfied the existing climatic, agronomic, economic, land and water availability constraints in the area of study. The results of the study revealed that neither the existent cropping patterns nor the planned distribution scheme was optimal.

Alwang *et al.* (1999) used the linear programming model of representative smallholder households to investigate the sources of relative scarcity of labor and land in Malawi. The study indicated that multiple constraints, including lack of finance and concerns for food security, lead to sub-optimal allocations of household resources. The findings of the paper provided a clear signal to policymakers and research and extension institutions that the constraints are linked and therefore needed to be addressed together.

Tyynela *et al.* (2003) used the linear programming model to study the effect of three alternative land-use scenarios and costs and benefits of each land-use type in Indonesia. The three alternative land use scenarios were based on the current land-use, the integrated tree plantation system with incentives and government regulations, and a financially optimal land-use distribution. The results of the study showed that incorporation of land-use regulations prevented further deforestation but also decreased households' economic returns.

Kaya *et al.* (2000) used a linear programming based model to examine the potential for the adoption of improved fallow on different household groups to improve soil fertility and crop productivity. The model revealed that improved fallow would be an option only if fodder from the fallow had a market value and maize yields were higher than the traditional maize systems. The study further showed that improved fallow is not financially attractive to farmers if it does not produce benefits other than soil fertility improvement.

Mudhara *et al.* (2003) used a five year linear programming model sensitive to diversity within households with improved fallows of *Sesbanian sesban* in Zimbabwe. The model simulated the livelihood system of households and determined their potential for adoption of fallows. The results of the study indicated that there was potential for the technology to be adopted by 80% of the farmers.

The linear programming model is an effective tool for optimization. It can be applied on different activities including agriculture. There is though a limitation to its use in agriculture since agricultural production happens in a risky environment due to the biological nature of crop and livestock production. This requires the use of linear programming in agriculture to incorporate risk. Expected variance (E-V) programming is an extension of the linear programming tool that incorporates risk in its analysis (Boisvert *et al.,* 1992). The E-V programming was used in this study to assess the profitability of agroforestry.

# CHAPTER THREE

## 3. METHODOLOGY

### 3.1 Introduction

Chapter three presents the methodology used in the study. The first section of the chapter describes the study area. The section is followed by sampling method, data collection process and the analytical framework for the study. The analytical framework is presented per objective to give an indication of how each objective of the study was achieved.

### 3.2 The Study Area

The study was conducted in Zomba District of the Southern Region of Malawi. The district was chosen due to the dwindling maize production levels for the district and the high prevalence of smallholder farmers practicing agroforestry. The district has a total land area of 2,580 square kilometers with 78.69% of this land under cultivation. The main crops grown in the area are maize, rice, tobacco, cotton, soya, sunflower, paprika, chilli, cassava, sweet potatoes, groundnuts, beans and pigeon peas. Maize is the staple food, grown on 85% of the arable land. There are both estate and smallholder farmers in the area. The estates cover approximately 9% of the total arable land. Smallholder farming in the district covers an area of 111,007 hectares. The extension worker to farmer ratio in Zomba stands at 1:2,013, which is above the recommended ratio by United Nation Development Program (UNDP) of 1:750 (Zomba District Assembly, 2000).

The topography of the area ranges from mountainous and hilly regions to broad flat plain. Due to the varying topography, the area has diverse climate. The climate is generally tropical with wet and dry seasons. The soils are well drained, yellow-brown to reddish, medium to fine texture, slight to medium acidity and are very deep. The area has one farming season and receives an average of 600 mm to 1500 mm of rainfall annually with February being the wettest month (Zomba District Assembly, 2000).

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Zomba District has a total population of 540,428. The population density for the area is 209 persons per square kilometer which higher than the national population density of 105 persons per square kilometer. The average annual population growth rate of 1.8 percent for the district is slightly lower than the national level at 2%. The average land holding size per smallholder farming household is pegged at 0.5 hectare (Zomba District Assembly, 1998).

Environmental degradation is one of the major problems in Zomba District. This problem has been aggravated by the encroachment into protected forests for agricultural production, increasing demand for fuelwood and higher timber requirement. The loss of forest cover has led to a high rate of soil erosion, which threatens sustainable agricultural production. Crop yields have dwindled due to the soil fertility loss (Zomba District Assembly, 1998).

Zomba District Agriculture Office has seven Extension Planning Areas (EPAs)[1]: Thondwe, Dzaone, Malosa, Msondole, Chingale, Mpokwa and Ngwelero EPAs. According to a reconnaissance survey carried out in Zomba District before the main survey, Thondwe, Dzaone and Malosa EPAs had most of the mixed tree intercropping and relay cropping agroforestry farmers. The three EPAs were therefore focused on in the study.

### 3.3 Sampling of Smallholder Farmers

Purposeful sampling was used to select the three EPAs out of the seven EPAs under Zomba District Agriculture Office because they had the most agroforestry farmers practicing mixed tree intercropping and relay cropping agroforestry technologies which were the focus of the study. In purposeful sampling, elements that posses the characteristic of interest of the study are purposefully sampled. From the selected EPAs the population of agroforestry farmers practicing the agroforestry technologies under the study was interviewed. Simple random sampling was used to draw the sample of non-adopters in the three EPAs.

A total population of 175 mixed tree inter-cropping and relay cropping agroforestry farmers in the three EPAs was targeted during the study. 175 agroforestry farmers were targeted during the study because this was the population of agroforestry farmers in the study area. Out of the population, there were 74 farmers practicing relay cropping of

[1] An EPA is fourth in the hierarchy of the Ministry of Agriculture and Food Security of Malawi. Ministry headquarters is on top of the hierarchy followed by Agriculture Development Divisions (ADDs) for ease of administration. The ADDs are divided into District Agriculture Offices (DAOs) which are subdivided into Extension Planning Areas (EPAs). The EPAs are divided into sections that are managed by an Extension Officer who works with the farmers on the ground. A section comprises several villages, which in turn embrace a number of households.

*Tephrosia vogelli/candida,* and maize, 101 practicing mixed tree intercropping of *Gliricidia sepium* with maize. A total of 119 non-adopters were also targeted as a control for the study.

## 3.4 Collected Data

The study used primary data collected through interviews with farmers practicing agroforestry using a structured questionnaire, and key informant interviews. The structured questionnaires collected primary data on detailed costs that go into crop production under agroforestry and the benefits from both the agricultural crop and the tree crop. Other data that were collected included output prices, crop and tree yields, labor hours, amount of land allocated to each technology and amount of land available to the farmer (See Appendix 1 and 2).

## 3.5 Model Description

### 3.5.1 Conceptual Framework

In Malawi, agroforestry has been promoted by government and non-governmental organizations as one of the soil fertility enhancement technologies. The technology has been advocated to farmers but the adoption rate is still low (Nyirenda, 2002). This is despite that farmers know that declining soil fertility is a problem on their farms. A thorough understanding of why most farmers are not adopting the technology despite its advocacy is therefore important. A study on the profitability of agroforestry is thus a milestone in the promotion of the technology since profit maximization is one of the main objectives of a farmer. Farmers always consider the profitability of any technology before its adoption. This means that the profits that are realized from agroforestry have to be higher than the existent technologies for farmers to adopt.

Smallholder farmers in Malawi are faced with a choice problem. They have a number of activities at their disposal as a result they usually mix production of different crops and crop combinations on their farms. Farmers need to make choices that will give them optimum profits. The options that farmers have include agroforestry. They have to make a decision on whether to adopt the technology or not. The main assumption in this study therefore is that farmers' current practices are not maximizing profits and that the existing enterprise combinations are not optimal. Thus the Expected Variance (E-V) model was used to maximize profits of the farmers. The E-V model was used to evaluate optimal enterprise combinations on the farm that will give a farmer maximum profits in the presence of risk.

Smallholder farmers' have limited resources at their disposal for the production of different crops. They optimize production of different enterprise combinations faced with a number of challenges. In the model, the other assumption is that farmers want to maximize net returns subject to labor, land, capital and food security. This study therefore optimized net returns for the smallholder relay cropping and mixed tree intercropping farmers subject to land, labor, capital and food security constraints.

The availability of capital may influence the farmer decision making process as regard to the purchase of inputs like seed, fertilizer and the participation of the farmer in different farm and off-farm activities. It will also determine how much the farmer invests in agroforestry. In this study capital is regarded as a constraint because costs on the farm during the whole season must not exceed available funds.

Most organic soil fertility enhancing technologies take up a lot of land hence farm size may affect the decision making of the farmers as to how much land to invest in agroforestry. Some agroforestry technologies are labor intensive. This may also influence decision making of the farmer on the extent of agroforestry. Food security status of a household determines how much the household will participate in both farm and off-farm activities. It determines how much energy the household has for agroforestry activities.

Like any agricultural system, agroforestry is characterized with risk. Smallholder agroforestry farmers operate under a risky environment. The major sources of risk are yields and farm prices. The risks are due to the biological nature of crops and agroforestry trees, which interact with uncertain climatic conditions that control agricultural production. Thus through comparison of agroforestry technologies using risk programming, expected variance (E-V) programming model uncertainty was taken care of.

### 3.5.2 Approach to Empirical Analysis

The analysis was conducted using descriptive statistics, gross margins, net present value, benefit cost ratios and Expected Variance model. Descriptive statistics were done on socio-economic characteristics of farmers. The statistics included means, cross tabulations and frequencies of relevant variables.

### 3.5.2.1 Evaluation of profitability of mixed tree intercropping and relay cropping agroforestry technologies

To evaluate profitability, gross margins, net present value, cost benefit ratios and the E-V programming model were used.

#### 3.5.2.1.1 Gross Margin Analysis

A gross margin is the difference between gross income and variable costs (Kay *et al.* 2004). It provides a measure of profitability of an enterprise. To evaluate the profitability of agroforestry technologies in the study, gross margins for each technology were calculated as well as those for non-adopters. The gross margins were compared using the t-test to assess if they were significantly different from each other.

The gross margins were calculated using farm-gate prices for both produce price and input price. To calculate the gross margins the following formula was used:

$$GM = GI - VC \qquad (1)$$

where GM is the gross margin per hectare;

GI is the gross income which was calculated as the product of price per unit of output at farm gate and the amount of units harvested per hectare; and

VC is the variable costs directly linked to production.

#### 3.5.2.1.2 Net Present Value

Net present value is the difference between total discounted benefits and total discounted costs. Enterprises that have positive net benefits are considered profitable. Enterprises with greater net benefits are more justifiable means of investment (Watkins, 2006).

In this study Net Present Value (NPV) were the objective function coefficients for the E-V programming. Data on all cost that go into the production process, all the benefits and the interest rate were required to estimate the NPVs. The NPV provided a measure of the future financial worth of an enterprise and was used instead of nominal gross margins since trees used in agroforestry take a number of years to show benefits. This requires the analysis of costs and returns projected in the future production years to be discounted.

NPV was calculated by summing up all the costs and subtracting them from the benefits of an enterprise projected over a period of twenty years at a discount rate as follows:

$$NPV = \sum_{t=0}^{19} \frac{B_t - C_t}{(1+i)^t} \qquad (2)$$

Where $B_t$ are benefits in each year (MK/ha)

$C_t$ are Costs in each year (MK/ha)

$i$ is discount rate

$t$ is time period in years

#### 3.5.2.1.3 Benefit-Cost Ratio (BCR)

Benefit-cost ratios (BCR) is the ratio of total discounted benefits to total discounted costs. If an enterprise has a BCR of greater than one it is considered to have greater benefits than costs and positive net benefits. A higher ratio entails greater benefits relative to costs. Benefit-cost ratios were estimated for mixed tree intercropping farmers, relay cropping farmers and non-adopters to check the viability of investing in agroforestry. A BCR of greater than one meant it was viable to invest in agroforestry since the returns were greater than the costs.

To estimate the BCR, first the costs and benefits of mixed tree intercropping farmers, relay cropping farmers and non-adopters in a period of twenty years were discounted. The discounted benefits and costs were calculated as follows:

$$\text{Discounted benefits} = \frac{B_i}{(1+d)^i} \tag{3}$$

$$\text{Discounted costs} = \frac{C_i}{(1+d)^i} \tag{4}$$

where $B_i$ are benefits per hectare in each year (MK)

$C_i$ are costs per hectare in each year (MK)

$i$ is time in years

$d$ is the discount rate

To obtain the BCR, the sum of discounted benefits was divided by the sum of the discounted costs as follows:

$$BCR = \frac{\sum_{i=0}^{i=19} \frac{B_i}{(1+d)^i}}{\sum_{i=0}^{i=19} \frac{C_i}{(1+d)^i}} \tag{5}$$

#### 3.5.2.1.4 Sensitivity analysis

In order to evaluate how changes in key variables will affect the profitability of agroforestry, the gross margins, net present value and the cost benefit ratios were subjected to a sensitivity analysis. Sensitivity analysis was necessary since it is one of the ways that enables the analysis of the profitability of enterprises to incorporate time factor. The sensitivity analysis was conducted by changing the value of the following variables: cost of fertilizer, cost of maize seed, price of maize grain, price of agroforestry seeds and discount rate.

#### 3.5.2.1.5 The E-V programming model

The E-V programming model was used as the main tool to achieve the main objective of the study, which was to assess the profitability of mixed tree intercropping and relay cropping agroforestry technologies. Since farmers are faced with a challenge to allocate land among competitive enterprises especially in places where land is scarce, it is necessary for farmers to assess the optimal land allocation to maintain long-term land productivity (Mangisoni, 1999). The E-V programming model that was used in the study optimized net present value for the farmers practicing the two technologies under the study. The initial stage of the model was to run a general linear programming (LP) model. The LP maximized Net Present Value (NPV) subject to land, labor, capital and food security constraints.

Following Boisvert and McCarl (1992), the general Linear Programming problem was formulated as follows:

Find $x_j \geq 0$ $(j = 1,\ldots\ldots\ldots\ldots,n)$ which

$$\text{Max } \sum_{j=1}^{n} b_j x_j = w \tag{6}$$

$$\text{Subject to } \sum_{j=1}^{n} e_{ij} x_j \leq k_i \quad (i=1,\ldots\ldots\ldots\ldots, m) \tag{7}$$

Where $x_j$'s are decision variables (amount of land allocated to each crop in ha)

$b_j$*'s* are the objective function coefficients (the NPV per hectare)

$w$ is the total farm profit in Malawi Kwacha (MK)

$k_i$ is the total amount of resource $i$, available on the farm

$e_{ij}$ is the resource $i$, requirement per hectare of activity $j$

Risk was then introduced into the LP model through the incorporation of mean returns and variance. Mean and variance were introduced into the model because the E-V programming model has its basis on the proposition that for any distributions that have equal means, a risk averter will prefer the distribution with the smallest variance (Boisvert and McCarl, 1992). This means that the E-V programming entails a trade-off between expected returns and risk. In the programming, the efficient actions are those that maximize the expected returns for a given variance level or minimize variance for a given level of expected returns.

If the NPVs are assumed to have means $\bar{b}_j$ and covariance $\sigma_{ij}$ $(\sigma_{ii} = \sigma_i^2)$, then the mean and variance of the objective function are given by:

$$\overline{w} = \sum_{j=1}^{n} \overline{b}_j x_j \qquad (8)$$

and

$$\sigma w^2 = \sum_{j=1}^{n} \sum_{i=1}^{m} \sigma_{ij} x_i x_j \qquad (9)$$

Using the relationships above, the general formulation of the E-V problem according to Boisvert and McCarl (1992) is:

$$\text{Max } \overline{w} - \Phi \sigma w^2 = \sum_{j=1}^{n} \overline{b}_j x_j - \Phi \sum_{j=1}^{n} \sum_{k=1}^{m} \sigma_{kj} x_k x_j \qquad (10)$$

Subject to $\sum_{j=1}^{n} a_{ij} x_j \le L$ *(i=1…………m)* Labor Constraint (11)

$\sum_{j=1}^{n} m_{ij} x_j \le Q$ *(i=1…………m)* Land Constraint (12)

$\sum_{j=1}^{n} p_{ij} x_j \le K$ *(i=1…………m)* Capital Constraint (13)

$\sum_{j=1}^{n} f_{ij} x_j \ge F$ (*i = 1…………m)* Food security constraint (14)

$x_j \ge 0$ *(j=1, 2…………n)* Non-negativity requirement (15)

Where $\overline{w}$ is the expected total profit measured as Net Present Value in MK

$\Phi$ is the risk aversion coefficient

$\sigma w^2$ is the variance of the objective function in a general linear programming model

$\bar{b}_j$ is the mean NPV per hectare for crop $j$,

$x_j$ is the amount of land allocated to activity $j$ measured in hectares

$\sigma_{kj}$ is the covariance of the NPVs between activity $k$ and $j$

$x_k$ is the amount of land allocated to activity $k$ measured in hectares

$a_{ij}$ is the labor requirement per hectare of activity j measured in labor hours

$L$ is the total labor hours available on the farm

$m_{ij}$ is the amount of land required per hectare for activity $j$

$Q$ is the total amount of land on the farm measured in hectares

$p_{ij}$ is the amount of capital required per hectare of activity $j$

$K$ is the total amount of capital available on the farm measured in MK

$f_{ij}$ is the amount of food produced per hectare of activity $j$

$F$ is the minimum food requirement for the household

In the E-V model, the main element of risk was Net Present Value per hectare for individual agroforestry technologies. The objective function maximized expected total profits less a risk aversion coefficient times the variance of total profit subject to some constraints. Expected annual costs and returns during the life of the tree crop were projected for twenty years because agroforestry is a long-term activity that takes a number of years to start showing benefits.

#### 3.5.2.1.5.1 Estimation of Constraints

In the study the constraints were capital, farm size, labor supply and food security.

**Capital**

Smallholder farmers operate under limited resources, capital inclusive. Capital becomes a very important variable during the decision making process on the farm since it determines the enterprise choices that a farmer makes. Some enterprises are capital intensive hence they require a lot of initial investment. This brings capital at the centre as farmers optimize the use of limited farm resources. In the study, capital was measured by total farm and off-farm income that is directed towards agricultural activities. It also included borrowed funds for investing in agriculture. Capital requirement per hectare of activity was calculated basing on the calculations by Nothale (1980).

**Labor Supply**

Some agricultural activities are labor intensive hence a farmer will always consider the amount of labor available in the household before making an enterprise choice. Labor was included as one of the constraints to farmers decision making in the optimization problem.

Labor included both family and hired labor available on the farm. Since different technologies and activities have different labor requirements, labor was measured in labor hours per technology and activity on the farm. In order to estimate the labor supply per household, members in each household were categorized according to gender, age and availability. Based on the Ministry of Agriculture (1985) availability of household members was categorized into permanent resident, permanent resident in local employment, permanent resident in full-time education, polygamist spending time in other households and resident hired labor (see table 3.1). Labor was given in man-equivalents per household, which were converted into annual man-hours. The average working day was pegged at 6.3 hours for adult men, 7.9 hours for adult female and 3.0 hours for children with 25 working days in a month. Labor requirements per activity were derived from Nothale (1980) and Mangisoni, (2006) and they formed the technical coefficients for the labor constraint in the model.

**Table 3.1: Conversion rates for household labor availability**

| **Availability of member** | **Gender** | **Conversion rates by age category (years)** | | |
|---|---|---|---|---|
| | | **<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 | - | 0.2 | - |
| | Female | - | 0.2 | - |
| Permanent resident in full-time education | Male | 0.1 | 0.5 | NA |
| | Female | 0.1 | 0.4 | NA |
| Polygamist spending part of time in other households | Male | - | 0.5 | 0.5 |
| Resident hired labor | Male | 0.5 | 1.0 | 0.7 |
| | Female | 0.5 | 1.0 | 0.7 |

**Source: Ministry of Agriculture, 1985.**

Note: NA is not applicable

**Food Security**

In this study, food supply was measured by the quantities of different foods produced domestically available to the household and food purchases that were possible to supplement own production. The nutrition content of the food was estimated using tables on nutrient content of selected foods by Latham (1997). The tables gave nutrients available in 100g edible portion of food. Subsistence food requirements were taken from average individual energy requirements and safe levels of intake for protein and iron tables (Latham, 1997). In each household, each individual's daily requirements were estimated using the tables and was converted to annual requirements by multiplying with 365 days.

**Farm size**

Some technologies take up a lot of land hence a farmer will always have to make a decision on enterprises and enterprise combinations on the farm depending on the available land. In the study land was measured in hectares per activity on the farm.

#### 3.5.2.2 Farm plans for mixed intercropping and alley cropping agroforestry technologies' adopters

Using the results obtained from the E-V programming, the study developed farm production plans for the implementation of mixed intercropping and relay cropping agroforestry technologies. The plans included optimal enterprise combinations for mixed tree intercropping and relay cropping agroforestry technologies on adopter field. Mixed tree intercropping farmers combined the production of maize in agroforestry with maize produced without agroforestry. Relay cropping farmers' enterprises were also maize in agroforestry and maize without agroforestry.

# CHAPTER FOUR

# 4. SOCIO-ECONOMIC CHARACTERISTCS OF SAMPLE HOUSEHOLDS

## 4.1 Introduction

This chapter compares the socioeconomic characteristics of the sampled households of Thondwe, Dzaone and Malosa EPAs of the Zomba District Agriculture Office. The socioeconomic characteristics of farmers in the study were intended to assist in the understanding of the differences that may exist between the three categories. The t-test and the chi-square were used to test the significant difference between the socioeconomic characteristics of mixed-tree intercropping farmers, relay cropping farmers and non-adopters.

## 4.2 Age of Household Head

The overall average age of household heads for the sampled farmers in Thondwe, Dzaone and Malosa EPAs was 44.57 years. The average age of farmers practicing mixed tree intercropping was 50.73 years while those of relay cropping and non-adopters were 42.95 years and 40.41 years, respectively. There were highly significant differences in average age of farmers practicing mixed tree intercropping and those practicing relay cropping ($p<0.01$). There was a high significant difference in the average age of mixed tree intercropping farmers and non-adopters ($p<0.01$). There was however no significant difference between the average age of farmers practicing relay cropping and non-adopters (Table 4.1).

**Table 4.1: Socio-economic characteristics of sampled households by technology**

| Characteristic | Mixed Intercropping | Relay | Non-adopter | Total |
|---|---|---|---|---|
| Number of households | 101 | 78 | 119 | 298 |
| Average age of household | 50.7*** | 43.0 | 40.4 | 44.6 |
| head (years) | (1.3) | (1.7) | (1.3) | (0.9) |
| Average household size | 5.6 | 5.3 | 4.7*** | 5.2 |
| | (0.2) | (0.2) | (0.2) | (0.1) |
| Average available labor | 4,508.2 | 4,314.6 | 3,718.9*** | 4,142.3 |
| (labor hours) | (188.9) | (217.9) | (140.4) | (104.1) |
| Average farm size (ha) | 1.3 | 1.1 | 1.0 | 1.1 |
| | (0.2) | (0.1) | (0.1) | (0.1) |

Figures in the brackets are standard errors for mean
*** = Significant at 1% level
** = Significant at 5% level
* = Significant at 10% level

## 4.3 Household Size

The overall average household size for the sampled households was 5.2 persons. The average household size for farmers practicing mixed tree intercropping was 5.6 persons, which was the largest and above the overall mean household size. The average family size for relay cropping farmers was also above the overall average family size at 5.3 persons. Non-adopters had the smallest family size at 4.7 persons, which was below the overall family size. Table 4.1 reports that the average household size for non-adopters was significantly different from the average family size for both mixed tree-intercropping farmers ($p<0.01$) and relay cropping farmers ($p<0.10$). Household size determines the amount of family labor available in a household for farm activities. The adopters of agroforestry had bigger households than non-adopters implying more family labor available for the agroforestry farmers than non-adopters.

## 4.4 Labor Availability

Mixed tree intercropping farmers had the highest average labor available per household per year at 4,508.23 labor-hours followed by relay cropping farmers with an average of 4,314.6 labor-hours. The average labor available for non-adopters was the smallest. The non-adopters had an average of 3,718.9 labor-hours, which was below the overall mean labor available for the sampled households (Table 4.1). T-test showed that there was no significant difference between labor availability for mixed tree intercropping farmers and relay cropping farmers. However, there was a highly significant difference between mean labor available for non-adopters and mixed tree intercropping farmers ($p<0.01$). There was also a high significant difference between labor availability of non-adopters and relay cropping farmers ($p<0.05$). This implies that households practicing mixed tree intercropping and relay cropping agroforestry technologies had more labor units available for their field activities than non-adopter households making labor a very important factor in the adoption of agroforestry. In a study that was aimed at assessing the socioeconomic performance of short-term improved fallow agroforestry technology, Nyirenda (2002), found that agroforestry farmers had more labor units available than non-agroforestry farmers. This is consistent with Munthali *et al.* (2006) who reported that most recommended soil and water conservation technologies have not been fully adopted by smallholder farmers since they are labor demanding and intensive which is a limited resource among smallholder farmers.

## 4.5 Farm Size

The overall average farm size for the sampled households was 1.1 hectares. The average farm size for mixed tree intercropping farmers was 1.3 hectares, which is above the overall average farm size. The average farm size for both relay cropping farmers and non-adopters were below the overall average farm size at 1.1 hectares and 1.0 hectare respectively. T-test showed that the average land size for the three technologies were not significantly different (Table 4.1).

## 4.6 Gender of Household Head

Seventy two percent of the sampled households from Thondwe, Dzaone and Malosa EPAs were male-headed. Non-adopters had the highest percentage (74.8%) of male-headed households, which was higher than the overall percentage of male-headed households in the study area. The percentages of male-headed households for mixed tree intercropping and relay cropping were less than the overall percentage of male-headed households at 71.3% and 69.2%, respectively (Table 4.2). This means that there were more female headed households among adopters. Most of the men in the area of study engage in off-farm employment hence reducing the amount of farm labor available for the households. This makes most of the non-adopter households, which are male-headed not to adopt labor intensive technologies such as agroforestry. Relay cropping farmers had the highest percentage of female-headed households at 30.8% followed by mixed tree intercropping farmers at 28.7%. However, the chi-square test of these differences was not significant.

**Table 4.2: Proportion of household type by technology**

| | Mixed Intercropping (%) | Relay (%) | Non-adopter (%) | Total (%) |
|---|---|---|---|---|
| Male-headed | 71.3 | 69.2 | 74.8 | 72.1 |
| Female-headed | 28.7 | 30.8 | 25.2 | 27.9 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

### 4.7 Marital Status of Household Head

There were a lot of married respondents (73.5%) from the sampled households (Table 4.3). About 72% of the respondents practicing mixed tree intercropping were married compared to 70.5% and 76.5% of the respondents practicing relay cropping and non-adopters, respectively. The percentage of respondents who were divorced was highest among relay cropping farmers (12.8%) and lowest among non-adopters (5.9%). There were more singles among non-adopters (5.0%) compared to the rest of the categories. Chi-square test showed that the differences were not significant.

**Table 4.3: Proportion of marital status of household head by technology**

| | Mixed Intercropping (%) | Relay (%) | Non-adopter (%) | Total (%) |
|---|---|---|---|---|
| Single | 4.0 | 1.3 | 5.0 | 3.7 |
| Married | 72.3 | 70.5 | 76.5 | 73.5 |
| Widowed | 12.9 | 15.4 | 12.6 | 13.4 |
| Divorced | 10.9 | 12.8 | 5.9 | 9.4 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

## 4.8 Literacy

About 75% of the respondents were literate (Table 4.4). Literacy was measured by the ability to read and write Chichewa. Relay cropping farmers had the highest percentage (79.5%) of literate farmers followed by mixed tree intercropping farmers (75.2%). The percentage of literate farmers practicing the two technologies was higher than the overall percentage of literate farmers in the sample. The percentage of educated farmers among non-adopters was the lowest at 71.4%. This shows that there were more literate farmers among adopters than non-adopters. The chi-square test showed that the differences in literacy among the farmer categories were not significant.

**Table 4.4: Proportion of literacy by technology**

| | Mixed Intercropping (%) | Relay (%) | Non-adopter (%) | Total (%) |
|---|---|---|---|---|
| Literate | 75.2 | 79.5 | 71.4 | 74.8 |
| Illiterate | 24.8 | 20.5 | 28.6 | 25.2 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

Although the percentage of literate farmers was highest among relay cropping farmers, the mean number of years spent in school was highest for mixed tree intercropping farmers (7.1 years). The lowest average number of years in school was among non-adopters at 5.5 years. T-test showed that there was a significant difference between the mean education level for non-adopters and the mean education level for mixed tree intercropping farmers ($p<0.01$). There was also a significant difference between the mean education level for non-adopters and relay cropping farmers at $p<0.05$ (Table 4.5). The highest percentage (52%) of farmers attained standard 5 and 8. There were a lot of relay cropping (61.3%) in this category followed by mixed tree intercropping farmers (52.6%).

About 17% of non-adopters attained secondary education. This was the highest percentage of farmers who attained secondary education followed by relay cropping farmers (11.3%). The chi-square test showed that the differences in education level among the farmers were significant ($p<0.01$). The results on education level have shown that the adopters of agroforestry had more number of years spent in school than non-adopters. This implies that education plays a crucial role in the adoption the technology. The more educated farmers are more likely to adopt agroforestry since they can easily read and follow instructions in the implementation of the technology.

**Table 4.5: Education level**

| | **Mixed Intercropping (%)** | **Relay (%)** | **Non-adopter (%)** | **Total (%)** |
|---|---|---|---|---|
| Standard 1-4 | 26.3 | 24.2 | 38.8 | 30.5 |
| Standard 5-8 | 52.6 | 61.3 | 44.7 | 52.0 |
| Secondary | 9.2 | 11.3 | 16.5 | 12.6 |
| Adult literacy | 11.8 | 3.2 | 0.0 | 4.9 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |
| Mean education level (number of years spent in school) | 7.1 (0.4) | 6.6 (0.3) | 5.5 (0.4) | 6.3 (0.2) |

### 4.9 Household Income and Farm Capital

Most (38.5%) of the sampled households depended on sales of crops for their income (Table 4.6). The majority of mixed tree intercropping farmers depended on sale of crops. The sampled farmers had other sources of income including sale of livestock, sales of labor, small businesses, formal employment, and skilled labor. There were more non-adopters who depended on off-farm formal employment (11.8%) than mixed tree intercropping farmers (5.3%) and relay cropping farmers (9.4%). The non-adopters also had most of respondents who depended on small businesses (26.7%). This indicates that mixed tree intercropping farmers and relay cropping farmers spent their effort in the field as their main source of income than non-adopters. The percentage of farmers who depended on sales of livestock as their income source was highest (4.3%) among non-adopters as compared to mixed tree intercropping farmers (3.8%) and relay cropping farmers (1.7%).

**Table 4.6: Income sources**

| | **Mixed Intercropping (%)** | **Relay (%)** | **Non-adopter (%)** | **Total (%)** |
|---|---|---|---|---|
| Sales of livestock | 3.8 | 1.7 | 4.3 | 3.4 |
| Sales of crops | 51.9 | 42.7 | 38.5 | 44.0 |
| Labor sales | 5.3 | 11.2 | 11.1 | 9.0 |
| Small businesses | 23.3 | 23.1 | 26.7 | 24.6 |
| Formal employment | 5.3 | 9.4 | 11.8 | 9.0 |
| Skilled labor | 6.1 | 4.3 | 3.7 | 4.6 |
| Others | 3.6 | 7.7 | 3.7 | 5.2 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

Others includes remittances, pension, sales of agroforestry seeds

The overall average annual income level for the sampled households during the 2005/06 agricultural season was MK 24,261.22[2] (Table 4.7). The average income level for relay cropping farmers during the year was the highest at MK 26,565.39 followed by mixed tree intercropping farmers (MK 24,403.17). Non-adopters had the lowest average income level (MK 22,616.62). There was no significant difference in the mean income levels for

[2] At the time of estimation of results, US$ 1.00 was equivalent to MK 140.00

the farmer categories. Despite having the highest average income level, relay-cropping farmers were not highest in spending on agricultural activities. Mixed tree intercropping farmers had the highest average income (MK 7,527.66) invested in agriculture during the 2005/06 cropping season. Non-adopters allocated the lowest amount of income (MK 5,570.76) to agriculture during the 2005/06 agricultural year. There was a significant difference ($p<0.1$) between mean farm capital for mixed tree intercropping farmers and non-adopters.

**Table 4.7: Income level and farm capital**

| **Income** | **Mixed Intercropping** | **Relay** | **Non-adopter** | **Total** |
|---|---|---|---|---|
| Mean 2005/06 income level (MK) | 24,403.17 (2,929.60) | 26,565.39 (4,271.65) | 22,616.62 (2,331.52) | 24,261.22 (1,759.17) |
| Mean 2005/06 farm capital (MK) | 7,527.66 (1,012.30) | 6,739.27 (1,467.29) | 5,570.76 (572.29) | 6,584.14 (582.41) |

## 4.10 Extension Contact

Seventy one percent of the sampled households had extension contact (Table 4.8). Relay cropping farmers (78.2%) and mixed tree intercropping farmers (76.2%) had more extension contact as compared to non-adopters (63.9%). This means extension is important in the adoption of mixed tree intercropping and relay cropping in the area of study. This is the case since extension is of paramount importance in the transmission of new technologies to smallholder farmers from research. The chi-square test showed that the differences in extension contact for the adopters and non-adopters was significant ($p<0.05$). In a study to assess the socio-economic factors affecting farmers' adoption of organic soil fertility technologies, Chamdimba (2003) also found that there was more extension contact to adopters of organic soil fertility enhancement technologies than non-adopters.

**Table 4.8: Extension contact**

| | Mixed Intercropping (%) | Relay (%) | Non-adopter (%) | Total (%) |
|---|---|---|---|---|
| Extension contact | 76.2 | 78.2 | 63.9 | 71.8 |
| No extension contact | 23.8 | 21.8 | 36.1 | 28.2 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

### 4.11 Food Security

Food security is important in agriculture since it entails the energy of the farmer and consequently determines the effort that the farmer puts in the field. Results in Table 4.9 indicate that during the 2005/06 season, a lot of the sampled households had food shortages (77.9%). There were more non-adopters (81.5%) who reported facing food shortage followed by relay cropping farmers (80.8%). Mixed tree intercropping farmers had the lowest percentage of households (71.3%) with food shortages during the season. However, the differences were not significant.

**Table 4.9: Food security situation**

| | Mixed Intercropping (%) | Relay (%) | Non-adopter (%) | Total (%) |
|---|---|---|---|---|
| Food shortage | 71.3 | 80.8 | 81.5 | 77.9 |
| No food shortage | 28.7 | 19.2 | 18.5 | 22.1 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

The households that had food shortages used a number of strategies as copping mechanisms during the time they had no food. Most of the farmers bought maize to supplement their food reserves during the season. There were more non-adopters (64%) who bought maize compared to the rest of the categories (Table 4.10). Some farmers depended on food aid to supplement their food reserves. Very few non-adopters (8.1%) sold their labor for food as a way of supplementing food shortages. This was though the highest percentage among farmers who sold labor for food out of the rest of the categories. Selling of labor for food reduces the amount of labor available for their field hence affecting their uptake of new technologies. Nyirenda (2002) also found that a lot of farmers who had not tested improved fallow agroforestry technology sold their labor for food in a study to investigate the socioeconomic performance of shot-term improved fallow agroforestry technology.

**Table 4.10: Coping strategies**

| **Strategy** | **Mixed Intercropping (%)** | **Relay (%)** | **Non-adopter (%)** | **Total (%)** |
|---|---|---|---|---|
| Buying maize | 59.1 | 51.7 | 64.0 | 58.7 |
| Winter maize harvest | 4.5 | 3.4 | 0.9 | 2.8 |
| Selling of labor | 3.4 | 3.4 | 8.1 | 5.2 |
| Given by others | 10.2 | 1.1 | 4.5 | 5.2 |
| Found alternative crops | 6.8 | 18.0 | 0.9 | 8.0 |
| Food aid | 15.9 | 22.5 | 21.6 | 20.1 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

### 4.12 Reasons for Adoption

There are several reasons for farmers' adoption of any technology. Understanding these reasons is important for the promotion of good technologies. Table 4.12 shows that most of the farmers who adopted mixed tree intercropping (81.4%) and relay cropping (75.5%) adopted the technology to improve soil fertility. Other farmers adopted the technologies for soil and water conservation. There was no relay cropping farmer who indicated fuel wood as a reason for adoption while 0.8% of mixed tree intercropping farmers wanted to earn fuelwood. About 10% of relay cropping farmers adopted the technology to sell tree seeds. Some farmers adopted agroforestry to conserve moisture, to reduce witch weed and to generate medicine (Table 4.11). This is consistent with Mangisoni, (1999) who found that the majority (65%) of agroforestry/vetiver grass (AV) farmers in the study adopted the technology for soil fertility reasons in a study to assess the economic returns to investment in AV combination as an erosion control technology. This means that in the promotion of agroforestry technologies, there is need to put more focus on the soil fertility component in order to achieve positive results.

**Table 4.11: Reasons for adoption**

| | **Mixed Intercropping (%)** | **Relay (%)** | **Total (%)** |
|---|---|---|---|
| Soil fertility improvement | 81.4 | 75.5 | 77.5 |
| Soil and Water Conservation | 11.7 | 12.6 | 11.7 |
| Fuel wood | 0.8 | 0.0 | 0.4 |
| To sell seed | 0.0 | 9.8 | 4.3 |
| Others | 6.4 | 3.0 | 6.1 |
| Total | 100.0 | 100.0 | 100.0 |

Others includes poles, medicine, ICRAF testing in the field, to reduce witch weed, directive from extension worker

### 4.13 Agroforestry Challenges

There are a number of challenges that farmers encounter during the implementation of mixed tree intercropping and relay cropping agroforestry technologies. These challenges pose as impediments to adoption of the technologies by non-adopters. Understanding these challenges is important for research on improvement of the technologies and promotion of the technologies among smallholder farmers. Table 4.12 shows that a large number of farmers indicated that high labor demands in the implementation of the technology is a reason for non-adoption. The problem of high labor demands was high in the mixed tree-intercropping category (32 %) than relay cropping category (7.5%). The peak period for mixed tree intercropping activities corresponds to the peak period for the activities for maize. The problem of high labor demand for most of the agroforestry technologies was also highlighted by Munthali *et al.*, (2006) in a study to assess the socioeconomic factors affecting the adoption of soil and water conservation technologies among smallholder farmers in Malawi. Some farmers indicated lack of technical knowledge as a challenge in the implementation of mixed tree intercropping (1.9%) and relay cropping (8.8%) agroforestry technologies. Results in Table 4.8 indicated that there was no extension contact even to some adopters which may affect their technical knowledge of the technologies. This highlights the need for more extension support since lack of technical knowledge can affect output in the implementation of the technologies. Despite all the challenges that were cited, a large number of farmers indicated that they faced no challenges in the implementation of the technologies (Table 4.13).

**Table 4.12: Agroforestry challenges**

| | Mixed Intercropping (%) | Relay (%) | Total (%) |
|---|---|---|---|
| High labor demands | 32.0 | 7.5 | 21.3 |
| Lack of seed | 7.8 | 7.5 | 7.1 |
| Lack of technical knowledge | 1.9 | 8.8 | 4.4 |
| Lack of time | 1.9 | 2.5 | 2.2 |
| Lack of tools for management | 8.8 | 3.5 | 5.5 |
| No problem | 40.8 | 48.8 | 44.3 |
| Pests | 3.9 | 7.6 | 5.4 |
| Weeding problems | 1.0 | 7.5 | 4.3 |
| Others | 1.9 | 6.5 | 5.5 |
| Total | 100.0 | 100.0 | 100.0 |

Others include: limited extension support, some parts not responding to agroforestry, lack of market for agroforestry seeds, agroforestry still needs fertilizer, cannot harvest seed when you use biomass, land limitations

## 4.14 Concluding Summary

This chapter has compared socioeconomic characteristics of the sampled households. Some of the characteristic including labor availability, average age of household head, household size, education level, mean farm capital and extension contact were found to be significantly different among the three farmer categories in the study. Such differences in the socioeconomic characteristics of the farmer categories are important in the understanding of the differences that may exist among the technologies. Means and percentages were used in the analysis of the socioeconomic characteristics. T-test and chi-square test were used to check if there were any significant differences between the socioeconomic characteristics for the different categories.

# CHAPTER FIVE

## 5. ASSESSMENT OF RELATIVE PROFITABILITY

### 5.1 Introduction

This chapter presents results of the analysis of the profitability of mixed-tree intercropping of maize and *Gliricidia sepium*, relay cropping of maize and *Tephrosia vogelli/candida* agroforestry technologies and maize grown without agroforestry. The profitability of the technologies was assessed using the Benefit-Cost Ratio (BCR), Net Present Value (NPV), and Gross Margins analysis. The t-test was used to test if there were any significant differences in the profitability of the technologies. Sensitivity analysis was conducted to assess how the profitability of the technologies would respond to changes in the cost of fertilizer, cost of maize seed, price of maize grain and the discount rate.

### 5.2 Enterprise Budget Analysis

Enterprise budget analysis of the three maize production options under the study yielded gross margins for each enterprise. Market prices of maize seed, fertilizer, maize grain and labor were used in the enterprise budget analysis to estimate the gross margins. Results in Table 5.1 show that maize produced under mixed tree intercropping, relay cropping and without agroforestry produced positive gross margins. However, maize under mixed tree intercropping had the highest mean gross margin per hectare at MK 3,813.77. The mean gross margin for relay cropping farmers was MK 1,787.79. Maize produced without agroforestry had the lowest mean gross margins of MK 865.67. T-tests showed that there were significant differences in the mean gross margins of the three production options ($p<0.01$).

**Table 5.1: Enterprise budget analysis**

| Year | Discounted Gross Margins (MK/ha) | | |
|---|---|---|---|
| | **Mixed** | **Relay** | **Non-adopter** |
| 0 | 12,589.18 | 5,901.46 | 2,857.55 |
| 3 | 7,461.66 | 3,497.82 | 1,693.68 |
| 7 | 3,714.95 | 1,741.46 | 843.23 |
| 11 | 1,849.56 | 867.02 | 419.82 |
| 15 | 920.85 | 431.67 | 209.02 |
| 19 | 458.46 | 214.91 | 104.06 |
| **Mean Gross Margin (0-19)** | **3,813.77** | **1,787.79** | **865.67** |

Source: own calculation from survey results

### 5.3 Cost Benefit Analysis

Benefit-cost analysis (BCR) is important in the analysis of profitability of long-term enterprises since it takes into account the time value of money. In the analysis of the profitability of the three production options, cost benefit analysis was done because agroforestry is a long-term production option. Net Present Value (NPV) and Benefit-Cost Ratios (BCR) for the three production options were estimated on maize yield and costs of production data projected over 20 years.

#### 5.3.1 Net Present Value (NPV)

The Net Present Values for the two agroforestry technologies were positive indicating that the two agroforestry technologies were worthwhile investments (Table 5.2). The Net Present Value for mixed tree intercropping was the highest at MK 52,418.53 followed by the NPV for relay cropping at MK 10,573.69. Maize produced without any agroforestry intervention had negative returns to investment. The NPV for this production option was MK -7,283.84. This can be due to the high cost of inorganic fertilizer on the market which was the main source of nutrients for maize production used by the non-adopters of agroforestry coupled with low production levels since the farmers were not able to apply the recommended levels of fertilizer. This shows that it is not worthwhile investing in maize production without any agroforestry intervention or adequate inorganic fertilizer.

**Table 5.2: Present value of net benefits**

| Year | Net Present Value (MK/ha) | | |
|---|---|---|---|
| | **Mixed** | **Relay** | **Non-adopter** |
| 0 | 7,762.15 | 806.30 | -2,119.26 |
| 3 | 4,990.22 | 889.09 | -854.45 |
| 7 | 2,702.64 | 672.93 | -200.48 |
| 11 | 1,434.93 | 429.35 | -7.68 |
| 15 | 751.01 | 252.40 | 33.91 |
| 19 | 388.90 | 141.48 | 32.34 |
| **Total NPV (0-19)** | **52,418.53** | **10,573.69** | **-7,283.84** |
| **Benefit-Cost Ratio** | **1.60** | **1.12** | **0.93** |

Source: own calculation from survey results

Note: Present value of net benefits in year 0 is different from gross margins in year 0 because the cost of production in estimating gross margins do not include fixed costs while the cost of production in the estimation on Net Present Value include fixed costs.

### 5.3.2 Benefit-Cost Ratio (BCR)

Benefit-cost ratio (BCR) gives benefits of a production process relative to its costs. It is an important indicator of the worth of any production option and it is important in farmers' decision to invest. The BCRs for mixed tree intercropping and relay cropping were greater than 1 (Table 5.2), which shows that the two technologies were worthwhile since their benefits exceeded the cost of production. The BCR for relay cropping farmers was, however, marginal at 1.12. This means that the returns from relay cropping barely exceed the cost of production. The BCR for mixed tree intercropping was slightly higher

(1.60). The financial analysis of maize produced without any agroforestry yielded a BCR of less than one (0.93). This implies that it is not worthwhile investing in maize production with inadequate inorganic fertilizer as a soil fertility improvement technology under prevailing market prices since the cost of production exceeded the returns. It is worth noting that the smallholder farmers under the study applied inadequate levels of inorganic fertilizer.

### 5.4 Sensitivity Analysis

Sensitivity analysis was conducted to evaluate how changes in key variables affect the profitability of agroforestry. The sensitivity analysis was done on the cost of fertilizer, cost of maize seed, price of maize grain, and discount rate.

#### 5.4.1 Change in the Price of Fertilizer

During the 2005/06 cropping season, smallholder farmers received two prices of fertilizer. Some farmers accessed the subsidized fertilizer price of MK950.00 per 50 kg bag of fertilizer while others received the prevailing market price ranging of MK3,200.00 per 50 kg bag. It was necessary to assess if changes in the price of fertilizer would affect the profitability of agroforestry because under agroforestry production, yields are greatly improved when the use of agroforestry trees is combined with inorganic fertilizers. Sensitivity analysis was, therefore, conducted to assess the change in the profitability of agroforestry if all the farmers received the subsidized fertilizer price.

With the subsidized fertilizer price, mixed tree intercropping and relay cropping agroforestry technologies, as well as non-adopters proved to be profitable (Table 5.3).

This was due to the reduction in the cost of production per hectare for the smallholder farmers at the same output level. The BCR for mixed tree intercropping increased from 1.6 to 2.35 showing an improvement in the profitability of the technology. The BCR for non-adopters improved from 0.93 to 1.56 with the subsidized fertilizer price. This means that it is worthwhile to invest in the production of maize without agroforestry when fertilizer is subsidized.

**Table 5.3: Impact of fertilizer subsidy on NPV**

| **Year** | **Net Present Value (MK/ha)** | | |
|---|---|---|---|
| | **Mixed** | **Relay** | **Non-adopter** |
| 0 | 12,351.64 | 5,790.24 | 4,636.39 |
| 3 | 7,710.42 | 3,843.09 | 3,149.65 |
| 7 | 4,056.96 | 2,143.64 | 1,793.05 |
| 11 | 2,109.20 | 1,161.58 | 984.84 |
| 15 | 1,086.71 | 616.95 | 528.06 |
| 19 | 556.03 | 322.99 | 278.36 |
| **Total NPV (0-19)** | **80,225.38** | **40,770.43** | **33,647.35** |
| **Benefit-Cost Ratio** | **2.35** | **1.71** | **1.56** |

When enterprise budget analysis was conducted using the subsidized fertilizer price, the mean gross margins from both agroforestry maize production and non-agroforestry maize production greatly improved. The mean gross margins for mixed tree intercropping increased from MK 3,813.77 to MK 5,204.11. The gross mean margins from relay cropping and non-agroforestry maize production also increased (Table 5.4).

**Table 5.4: Impact of fertilizer subsidy on gross margins**

| Year | Discounted Gross Margins (MK/ha) | | |
|---|---|---|---|
| | **Mixed** | **Relay** | **Non-adopter** |
| 0 | 17,178.67 | 10,885.40 | 9,613.20 |
| 3 | 10,181.87 | 6,451.82 | 5,697.78 |
| 7 | 5,069.26 | 3,212.17 | 2,836.76 |
| 11 | 2,523.84 | 1,599.25 | 1,412.34 |
| 15 | 1,256.55 | 796.22 | 703.16 |
| 19 | 625.60 | 396.41 | 350.08 |
| **Mean Gross Margin (0-19)** | **5,204.11** | **3,297.63** | **2,912.23** |

Increasing the price of fertilizer decreased the NPV of all the production options. There was a sharp decrease in the NPV of the technologies. With a 5% increase in the market price of fertilizer, the NPV for relay cropping farmers decreased from MK 10,573.69 to MK 8,378.93 (Appendix 3). The NPV for relay cropping continued decreasing but was still positive as the price of fertilizer continued increasing until 25% increase was attained. At this point the NPV for the farmers decreased to MK -400.17. This means that the technology moved from being a viable investment to a non-profitable investment. The BCR for the technology also moved from 1.12 to 0.99. Mixed tree intercropping remained profitable despite the increase in the price of fertilizer.

The mean gross margins for mixed tree intercropping and relay cropping agroforestry technologies were also affected when the price of fertilizer was increased. The gross margins kept on decreasing as the price of fertilizer increased but still remained positive. The gross margins for mixed tree intercropping and relay cropping declined from MK 3,813.77 to MK 3,510.77 and MK 1,787.79 to MK 1,458.57 respectively at a 15% increase in the price of fertilizer. The gross margin for non-adopters also declined from

MK 865.67 to MK 411.09 at the same level of increase in the price of fertilizer (Appendix 3).

Decreasing the price of fertilizer also had an impact on the profitability of the three production options. The NPV for mixed tree intercropping farmers increased from MK 52,418.53 to MK 54,438.57 when the price of fertilizer was reduced by 5%. The NPV gradually increased as the price continued decreasing (Appendix 3). The NPV for relay cropping farmers also kept decreasing as the price of fertilizer decreased. On the other hand, the NPV for non-adopters also increased as the price of fertilizer decreased and became positive at a decrease of 15% in the price of fertilizer.

### 5.4.2 Change in Price of Maize Grain

The price of maize grain was also varied to assess how it affects the profitability of the technologies. When the price of maize grain was increased by 10%, the profitability of the technologies improved. The NPV for non-adopters became positive at MK 2,108.74 (Appendix 4). The BCR for mixed tree intercropping increased from 1.6 to 2.0 at a 25% increase in the price of maize grain. It is worth noting that by improving the maize grain price by 10%, the BCR for non-adopters increased from 0.93 to 1.02 (Appendix 4). This means that the non-adopters maize production moved from being a non-profitable investment to a profitable one.

Enterprise budget analysis based on increased maize grain prices indicated that the gross margins for mixed tree intercropping relay cropping and maize without agroforestry greatly improved. The gross margins for mixed tree intercropping increased from MK 3,813.77 to MK 4,862.00 with an increase of 15% in the price of grain and MK 5,560.82

at a higher increase of 25%. The gross margins for relay cropping and non-adopters also increased from MK 1,787.79 to MK 3,013.40 and MK 865.67 to MK 2,039.74, respectively at a 25% increase in the price of maize grain (Appendix 4).

When the maize grain price was reduced the profitability of the three production options also reduced. As the price of maize grain decreased, relay cropping agroforestry technology moved from being a worthwhile investment to a non-profitable investment. The NPV for the technology moved from MK 10,573.69 to MK -4,133.65 at a 15% reduction in the price of maize grain. The BCR for the technology declined from 1.12 to 0.95 at 15% increase in the price of grain (Appendix 4). Even though the profitability of mixed tree intercropping declined to MK 2,066.73 at a 25% decrease in the price of grain, it was still profitable.

Enterprise budget analysis based on the reduced maize grain price produced positive gross margins with a 5%, 10% and 15% decrease. The gross margins became negative at a 20% decrease. The non-adopters' gross margins declined from MK 865.67 to MK -308.41 at a 25% decrease in the price of grain. At the same level of decrease, the gross margins for mixed tree intercropping and relay cropping also decreased from MK 3,813.77 to MK 2,066.73, and from MK 1,787.79 to MK 562.18, respectively (Appendix 4).

### 5.4.3 Change in the Price of Maize Seed

Increasing the price of maize seed did not have any substantial impact on the profitability of maize produced under mixed tree intercropping, relay cropping and without agroforestry. At a 5% increase in the price of maize seed, the NPV for mixed tree intercropping and relay cropping was MK 51,297.44 and MK 9,653.80, respectively. At a higher increase of 20%, the NPVs for the two technologies were MK 47,934.22 and MK 6,894.13 respectively (Appendix 5). A 25% increase in the price of maize seed changed the BCR of mixed tree intercropping farmers from 1.60 to 1.50, relay cropping farmers from 1.12 to 1.06 and non-adopters from 0.93 to 0.89 (Appendix 5). This implies that change in the price of maize seed has little impact on the profitability of maize production. This is because the cost of seed is very minimal to have an impact on the overall cost of production.

With the increased maize seed price, the gross margins for the three maize production options under the study decreased. The decrease in the gross margins was, however, not much. The gross margins for mixed tree intercropping decreased from MK 3,813.77 to MK 3,757.72 at 5% and MK 3,533.50 at 25% (Appendix 5). The mean gross margins for non-adopters decreased from MK 865.67 to MK 669.52 at a 25% increase in the price of maize seed (Appendix 5).

Reducing the price of maize seed did not have as much influence on the profitability of mixed tree intercropping and relay cropping. When the price of maize seed was reduced by 5%, the BCR of maize produced under mixed tree intercropping increased from 1.60 to 1.62 compared to 1.71 at a 25% decrease. There was also an increase in the BCR of relay cropping agroforestry technology and non-adopters from 1.12 to 1.81 and from 0.93 to 0.97, respectively at a 25% decrease in the price of maize seed (Appendix 5).

The decrease in the maize seed price did not produce a substantial impact on the gross margins of the three production options. The gross margins for mixed tree intercropping increased from MK 3,813.77 to MK 3,701.66 at a 10% increase and MK 4.094.04 at a 25% increase. The gross margins for relay cropping and maize without agroforestry also increased from MK 1,787.79 to MK 2.017.76 and from MK 865.67 to MK 1,061.81, respectively at the 25% decrease in the price of maize seed (Appendix 5).

### 5.4.4 Change in the Discount Rate

Changing the discount rate had an influence on the profitability of maize produced under the three production options. The impact was however minimal. When the discount rate was increased from 25% to 40%, the profits of maize production under the three production options did not change substantially. The BCR for mixed tree intercropping declined from 1.60 to 1.57, relay cropping from 1.81 to 1.10 and non-adopters from 0.93 to 0.91 (Appendix 6). At a higher discount rate 50%, the BCR for mixed tree intercropping was 1.56, relay cropping was 1.09 and non-adopters was 0.90. This implies that increasing the discount rate does not have much impact on the future profitability of maize production. There is need for a substantial increase in the discount rate in order to produce an impact on the future productivity of maize production.

The gross margins for the technologies did not respond substantially to the increase in the discount rate. At the 40% discount rate, the gross margins for mixed tree intercropping were MK 2,240. 94 compared to MK 3,813.77 at 25% and MK 3,103.36 at 30% discount rates (Appendix 6). There was a slight reduction in the gross margin for the technology. The gross margin for relay cropping and maize without agroforestry also declined.

Decreasing the discount rate also did not have much impact on the profitability of maize produced under the three production methods. When the discount rate was reduced to 10%, the BCR for mixed tree intercropping, relay cropping and non-adopters changed from 1.60 to 1.66, from 1.12 to 1.17, and from 0.93 to 0.96, respectively (Appendix 6). When the discount rate was further reduced to 5%, the BCR for mixed tree intercropping was 1.69, relay cropping was 1.19 and non-adopters was 0.97.

Decreasing the discount rate greatly improved the gross margins. The mean gross margins for mixed tree intercropping increased from MK 3,813.77 at 25% discount rate to MK 9,530.07 at 10% discount rate. The mean gross margins for relay cropping agroforestry technology were MK 4,467.34 at 10% discount rate compared to MK 1,787.79 at 25% discount rate. The gross margins for maize without agroforestry also increased greatly from MK 865.67 to MK 2, 163.17 (Appendix 6). Reducing the discount rate further to 5% increased the gross margins further. The gross margins for mixed tree intercropping increased to MK 14,987.12, relay cropping to MK 7,025.53 and non-adopters to MK 3,401.32 (Appendix 6).

## 5.5 Concluding Summary

This chapter has analyzed the profitability of mixed tree intercropping of maize and *Gliricidia sepium*, relay cropping of maize and *Tephrosia vogelli/candida* and maize produced without any agroforestry technology. In the analysis, the Benefit Cost Ratio (BCR), Net Present Value (NPV) and Gross Margin analysis have provided a measure of profitability of the technologies. Mixed tree intercropping produced the highest BCR, NPV and GM followed by relay cropping. Maize produced without any agroforestry technology produced negative NPV and a BCR of less than one. This implies that mixed tree intercropping and relay cropping agroforestry technologies are profitable to smallholder farmers. Sensitivity analysis was conducted to assess how changes in different variables affect the profitability of the two technologies. The profitability of relay cropping agroforestry technology moved from being positive to negative when the price of fertilizer was increased and the price of maize grain was reduced. The profitability of mixed tree intercropping however remained positive despite all the changes. Changing the price of maize seed did not have a substantial impact on the profitability of the three production options. Varying the discount rate also did not affect the profitability of the technologies significantly. Mixed tree intercropping and relay cropping agroforestry technologies remained profitable while maize without agroforestry remained unprofitable.

# CHAPTER SIX

# 6. OPTIMISATION OF MIXED TREE INTERCROPPING AND RELAY CROPPING AGROFORESTRY TECHNOLOGIES

## 6.1 Introduction

This chapter presents optimization results of mixed tree intercropping of maize and *Gliricidia sepium* and relay cropping of maize and *Tephrosia vogelli/candida* agroforestry technologies. The Expected-variance (E-V) programming model was used to generate optimal net farm income and optimum input levels for the two techniques. Mixed tree intercropping results are presented first followed by relay cropping results.

## 6.2 Model Results

### 6.2.1 Mixed tree intercropping

#### 6.2.1.1 Risk Neutral Case

The mixed tree intercropping farmers optimize returns from investment at a net present value (NPV) of MK 3,328.58 (Table 6.1). This is achieved through production of 1.27 hectares of maize under mixed tree intercropping agroforestry technology (MA). No land is allocated to maize without agroforestry (MNA). At this production level 2,627.744 labor hours and MK 6,381.75 capital are used to produce 1,831.010 kg of maize. The optimal production level leaves 1,880.456 labor hours and MK 1,145.91 capital as slack. The amount of food produced in the optimal solution is 549.260 kg more than the food security requirement of the average household. The results also indicated that while the other resources have no shadow value, land has a shadow value of MK 2,620.93. This means that investing one more hectare of land adds MK 2,620.93 to the optimal returns.

**Table 6.1: Risk neutral scenario for mixed tree intercropping agroforestry technology**

| **NPV (MK)** | **3,328.58** | | |
|---|---|---|---|
| Optimal Production (ha) | | | |
| MA | 1.270 | | |
| MNA | 0.000 | | |
| **Resources** | **Amount used** | **Amount unused** | **Shadow price** |
| Land (ha) | 1.270 | 0.000 | 2,620.93 |
| Labor (hrs) | 2,627.744 | 1,880.456 | 0.00 |
| Capital (MK) | 6,381.750 | 1,145.91 | 0.00 |
| **Production** | **Amount produced** | **Amount produced over requirement** | **Shadow value** |
| Food (kg) | 1,831.010 | 549.260 | 0.00 |

#### 6.2.1.2 Risky Scenario

When risk was introduced into the optimization problem, expected income declined throughout the simulations (Table 6.2). The land allocation to maize in mixed tree intercropping agroforestry technology (MA) and maize without agroforestry (MNA) also changed. For example, at a risk level of 0.001, the land allocation to MA declined from 1.270 ha under risk neutral case to 0.267 ha when risk was considered. At the same risk level, the land allocation to MNA was at 1.003 ha compared to no land allocation when risk was not considered (Table 6.1). At higher risk level of 0.009, the land allocation to MA and MNA was 0.058 ha and 1.051 ha, respectively. The results show that when risk is considered in the optimization of farm resources, smallholder farmers start allocating portions of their land to maize under mixed tree intercropping but some land is put to maize only as a risk management technique. As the risk coefficient increased, the amount of land allocated to MA kept declining and the amount of land allocated to MNA continuously increased. This indicates that with increasing risk levels smallholder farmers are more comfortable investing in MNA because they are more experienced in it than in the risky new MA technology (Table 6.2). The change in expected income represent risk premium for MA farmers. This is the loss in income as risk levels increase and hence what the farmers would want to be compensated with in the event of risk.

**Table 6.2: E-V optimal solution for mixed tree intercropping agroforestry technology**

| Production plan | Risk Coefficient | MA (ha) | MNA (ha) | Income Variance | Expected Income (MK) | Change in expected income |
|---|---|---|---|---|---|---|
| 1 | 0.000 | 1.270 | 0.000 | 8,043.925 | 3,328.57 | - |
| 2 | 0.001 | 0.267 | 1.003 | 306.983 | 589.92 | 2,738.65 |
| 3 | 0.002 | 0.152 | 1.118 | 98.005 | 422.26 | 167.66 |
| 4 | 0.003 | 0.114 | 1.156 | 59.305 | 347.48 | 74.78 |
| 5 | 0.004 | 0.095 | 1.175 | 45.760 | 295.91 | 51.57 |
| 6 | 0.005 | 0.083 | 1.187 | 39.490 | 253.63 | 42.28 |
| 7 | 0.006 | 0.075 | 1.193 | 36.000 | 216.00 | 37.63 |
| 8 | 0.007 | 0.065 | 1.043 | 27.257 | 185.09 | 30.91 |
| 9 | 0.008 | 0.061 | 1.048 | 26.001 | 158.50 | 26.59 |
| 10 | 0.009 | 0.058 | 1.051 | 25.139 | 132.96 | 25.54 |

The graph of expected income from investing in MA and MNA enterprise combination against risk coefficient is downward slopping (Figure 2). This indicates that as risk level increases the expected income from investing in a combination of MA and MNA declines. This is because as risk increases, farmers opted more for MNA than MA. This behavior reduces the net returns that the farmers get from investment since MA is more profitable than MNA (Table 6.2).

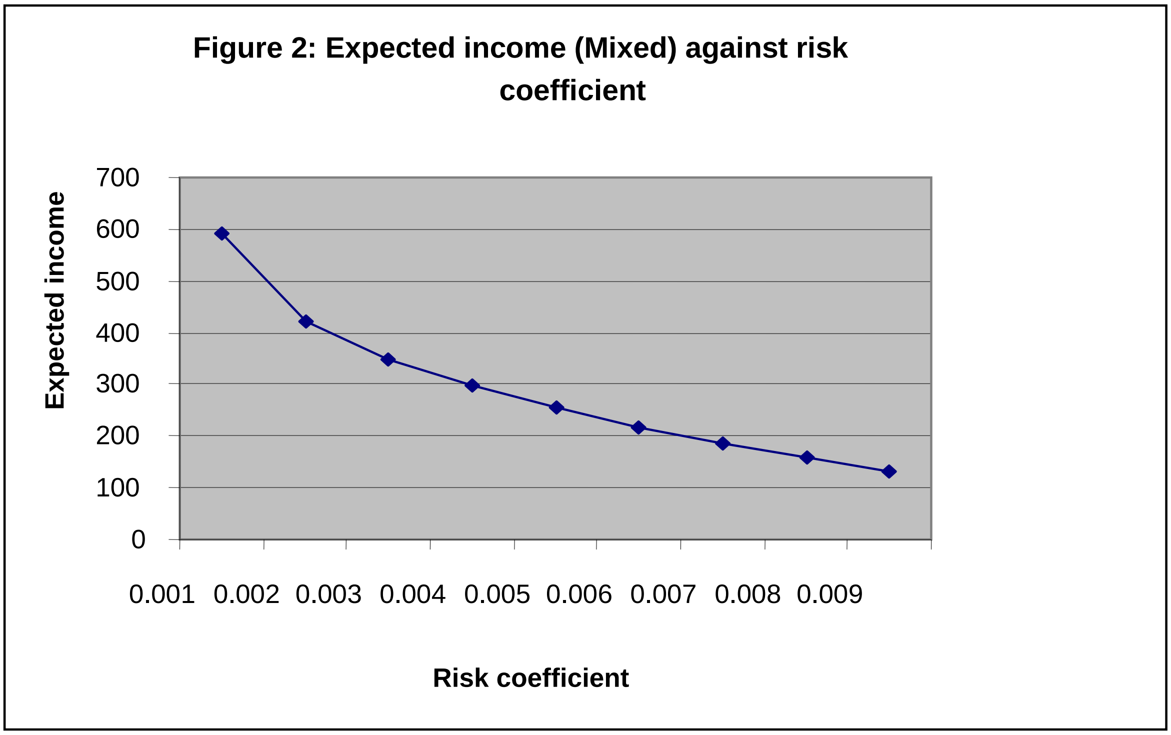
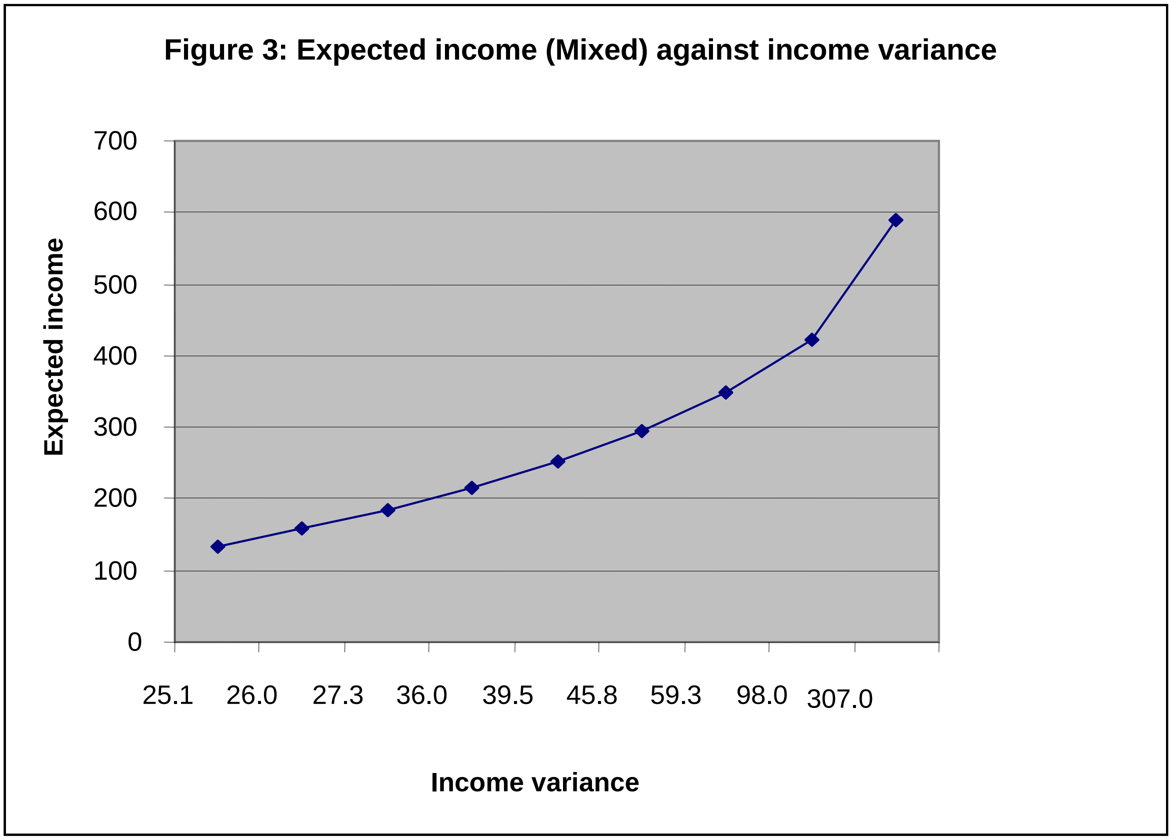



Figure 3 indicates that as income variance increased, the expected income from investing in MA and MNA also increased. This was the case because in any investment, if an investor chooses to devote a higher fraction of wealth to a risky asset, the investment yields a higher expected return, but it also incurs higher risk. The shape of the graph indicates that the smallholder farmers in the study were risk averse, which is typical of smallholder farmers. If people are risk averse, a higher expected return makes them better off and a higher standard deviation (variance) makes them worse off (Varian, 1993). Smallholder farmers always consider risk in their decision making on the type of enterprise or enterprise combinations to invest in. This highlights the importance of considering risk when introducing any agricultural technology to smallholder farmers.




#### 6.2.1.3 Mixed tree intercropping optimal resource allocation

##### 6.2.1.3.1 Land allocation

When risk was introduced in the optimization, the amount of land invested in the production of both MA and MNA did not change until the risk level of 0.006 was reached (Table 6.3). From this point any increase in the risk level reduced the amount of land invested in the enterprise combination. This means that since smallholder farmers are risk averse, when the risk level of producing MA and MNA increased, they withdrew the amount of land invested in the enterprise combination to other less risky investments. On the other hand, the shadow price of land drastically decreased from MK 2,620.93 to MK 222.79 when risk is introduced in the optimization problem. The shadow price of land declined continuously when the risk level was increased until 0.005. From a risk coefficient of 0.006, the shadow price of land was 0.000 meaning that the land constraint was no longer binding. This indicates that when the risk coefficient increased beyond 0.005, the entire land was not put to crop production, some of the land was slack.

**Table 6.3: Optimal allocation for mixed tree intercropping agroforestry technology farmers under risky scenario**

| Risk Coeff | Land (ha) | Capital (MK) | Labor (labor hrs) | Food security (Kg) | Shadow price of land (MK) | Shadow price of capital (MK) | Shadow price of labor (MK) | Shadow value of food security (MK) |
|---|---|---|---|---|---|---|---|---|
| 0.000 | 1.270 | 6,381.75 | 2,627.744 | 1,831.010 | 2,620.93 | 0.00 | 0.00 | 0.00 |
| 0.001 | 1.270 | 5,040.65 | 1,600.101 | 1,527.652 | 222.79 | 0.00 | 0.00 | 0.00 |
| 0.002 | 1.270 | 4,886.97 | 1,482.346 | 1,492.891 | 178.15 | 0.00 | 0.00 | 0.00 |
| 0.003 | 1.270 | 4,835.75 | 1,443.094 | 1,481.303 | 133.51 | 0.00 | 0.00 | 0.00 |
| 0.004 | 1.270 | 4,810.14 | 1,423.468 | 1,475.510 | 88.88 | 0.00 | 0.00 | 0.00 |
| 0.005 | 1.270 | 4,794.77 | 1,411.693 | 1,472.034 | 44.24 | 0.00 | 0.00 | 0.00 |
| 0.006 | 1.268 | 4,777.45 | 1,401.801 | 1,467.536 | 0.00 | 0.00 | 0.00 | EPS |
| 0.007 | 1.108 | 4,172.42 | 1,223.889 | 1,281.750 | 0.00 | 0.00 | 0.00 | 0.004 |
| 0.008 | 1.109 | 4,171.00 | 1,220.934 | 1,281.750 | 0.00 | 0.00 | 0.00 | 0.039 |
| 0.009 | 1.110 | 4,169.90 | 1,218.636 | 1,281.750 | 0.00 | 0.00 | 0.00 | 0.073 |

#### 6.2.1.3.2 Capital allocation

The amount of money invested in MA and MNA decreased when risk was introduced in the optimization problem from MK 6,381.75 to MK 5,040.65 at 0.001 risk coefficient level (Table 6.3). The amount of capital invested in the activities also decreased continuously when the risk coefficient level increased. This means that when the risk of investing in MA and MNA enterprise combination increased, smallholder farmers in the study withdrew some of the capital from the enterprise combination to other investments. This is also a result of less land being put to the two activities. The results in the table also indicate that capital had a shadow price of 0.000 meaning that it was not binding and adding more capital into investing in MA and MNA at the levels of risk would not have any impact on the objective function value.

#### 6.2.1.3.3 Labor allocation

Results in Table 6.3 show that labor invested in MA and MNA enterprise combination decreased when risk was introduced into the optimization problem. The amount of labor invested in the enterprise combination declined from 2,627.744 labor hours to 1,600.101 labor hours at 0.001 risk coefficient. When the risk coefficient was raised to 0.009, the labor allocation reduced further to 1,218.636 labor hours. Thus, when the risk level increased, the amount of optimal labor invested in both MA and MNA reduced. This indicates that smallholder farmers reallocated their labor from the investment as risk levels increased to other activities. Results from the table also show that labor had a shadow price of zero. The results on labor were based an annual labor requirements. However, the results would have been better if labor requirements were disaggregated per activity.

#### 6.2.1.3.4 Food security

Food production level was also affected when risk was introduced into the optimization problem. The amount of food produced decreased from 1,831.010 to 1,527.652 kg when risk was introduced (Table 6.3). The amount continuously declined when the risk coefficient level was increased until the risk coefficient of 0.007. From the risk coefficient of 0.007, any increase in risk did not impact on the food production level. This is because the food security constraint was binding.

### 6.2.2 Relay Cropping

#### 6.2.2.1 Risk Neutral Case

Relay cropping farmers also produced some maize under relay cropping agroforestry technology (RA) and the rest without relay cropping agroforestry technology. The portion of land not under RA was designated as RNA. Consequently the optimization problem treated RA and RNA as activities or choice variables.

The optimal level of farm income for relay cropping farmers without taking into consideration risk was MK 581.55 (Table 6.4). The optimal level of NPV was achieved with the production of only RA using 1.1 hectares of land, 1,855.700 labor hours and MK 4,867.50 of capital. The input use produced 1,332.573 kg of food. In the optimal solution, all the land available was utilized but 2,458.880 labor hours and MK 1,871.77 capital were slack. The food production level was 169.830 kg more than the required amount. Since labor and capital were not binding, the shadow prices for the two resources were zero. The shadow price for land was MK 528.68.

**Table 6.4: Risk neutral scenario for relay cropping agroforestry technology**

| NPV (MK) | 581.55 | | |
|---|---|---|---|
| Optimal Production (ha) | | | |
| RA | 1.100 | | |
| RNA | 0.000 | | |
| **Resources** | **Amount used** | **Amount unused** | **Shadow price** |
| Land (ha) | 1.100 | 0.000 | 528.68 |
| Labor (hrs) | 1,855.700 | 2,458.880 | 0.00 |
| Capital (MK) | 4,867.500 | 1,871.770 | 0.00 |
| **Production** | **Amount produced** | **Excess production** | **Shadow value** |
| Food (kg) | 1,332.573 | 169.830 | 0.00 |

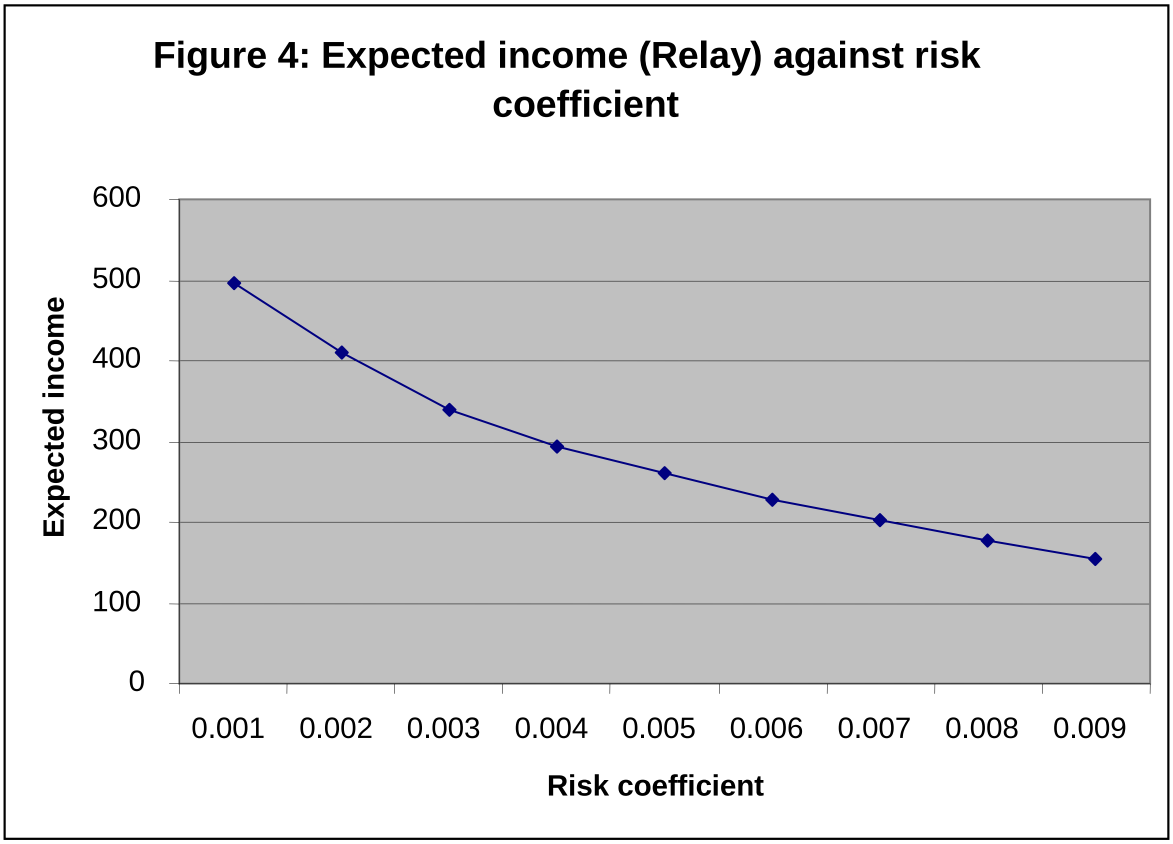
#### 6.2.2.2 Risky Scenario

Risk was introduced into the model in order to assess how risk impacts farm income and resource allocation. When risk was introduced into the optimization problem the amount of land allocated to RA remained constant at 1.100 hectares until the risk coefficient level of 0.002. This indicates that relay cropping agroforestry technology is less risky than mixed tree intercropping since land allocation to MA starts decreasing at a risk level of 0.001. MA requires more labor at critical times than RA and this makes smallholder farmers to view it as risky. In relay cropping, land continues to be under RA up to 0.002 risk coefficient. From the risk coefficient level of 0.003 farmers substituted land from RA to RNA. This is because as risk levels increase, farmers want to invest in enterprises that they are sure of. Expected income decreased from MK 581.55 to MK 495.68 (Table 6.5) when risk was introduced into the optimization problem. Increasing the level of risk gradually reduced the level of expected income because farmers were allocating more and more land to a less remunerating activity. Table 6.5 also indicates risk premium for RA farmers. This is shown by the change in expected income as the risk levels increase.

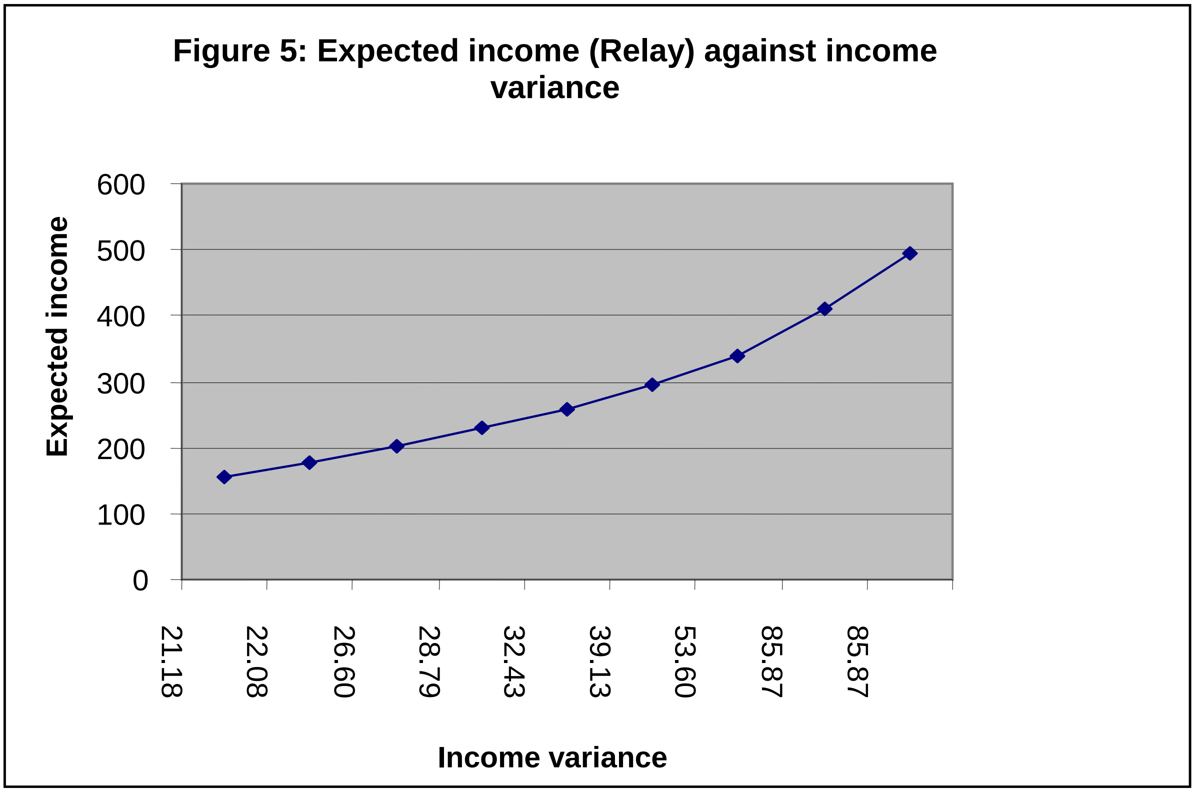
**Table 6.5: E-V optimal solution for relay cropping agroforestry technology**

| Production plan | Risk Coefficient | RA (ha) | RNA (ha) | Income Variance | Expected Income (MK) | Change in Expected Income |
|---|---|---|---|---|---|---|
| 1 | 0.000 | 1.100 | 0.000 | 85.866 | 581.55 | - |
| 2 | 0.001 | 1.100 | 0.000 | 85.866 | 495.68 | 85.87 |
| 3 | 0.002 | 1.100 | 0.000 | 85.866 | 409.82 | 85.86 |
| 4 | 0.003 | 1.033 | 0.067 | 53.601 | 340.27 | 69.55 |
| 5 | 0.004 | 0.991 | 0.109 | 39.130 | 294.94 | 45.33 |
| 6 | 0.005 | 0.966 | 0.134 | 32.432 | 259.53 | 35.41 |
| 7 | 0.006 | 0.950 | 0.150 | 28.794 | 229.08 | 30.45 |
| 8 | 0.007 | 0.938 | 0.162 | 26.600 | 201.47 | 27.61 |
| 9 | 0.008 | 0.861 | 0.153 | 22.080 | 176.64 | 24.83 |
| 10 | 0.009 | 0.855 | 0.159 | 21.181 | 155.07 | 21.57 |

Figure 4 shows that just like with the mixed tree intercropping agroforestry technology farmers, as risk coefficient increased, expected income for the relay cropping agroforestry farmers decreased. This can be attributed to the fact that as the risk level increases, smallholder farmers under the study withdrew some of their land from RA, which is more profitable to RNA, which is less profitable. This reduced expected income from investing in the combination of RA and RNA (see also Table 6.5).




Expected income from investing in RA and RNA increased as the income variance level increased (Figure 5). This is similar to mixed tree intercropping agroforestry farmers and shows that the relay cropping farmers in the study were also risk averse. This implies that these farmers would always consider risk before making any investment decisions.




### 6.2.2.3 Relay cropping optimal resource allocation

#### 6.2.2.3.1 Land allocation

Unlike in the mixed tree intercropping agroforestry technology farmers' category, the total land allocated to the production of RA and NRA did not instantly change when risk was introduced into the optimization problem. Land allocation to the production of RA and NRA decreased when the risk coefficient was 0.008 (Table 6.6). At the risk coefficient levels of 0.008 and 0.009 the amount of land allocated to the enterprise combination declined to 1.014 ha. The shadow price of land on the other hand started decreasing instantly when risk was introduced in the optimization problem. When the risk coefficient reached 0.008, the shadow price of land became 0.000 meaning that any additional land to the enterprise combination at this point would not change the objective function value. This is also the point where land started being slack.

**Table 6.6: Optimal resource allocation for relay cropping agroforestry technology farmers under risky scenario**

| Risk Coeff | Land (ha) | Capital (MK) | Labor (Labor hrs) | Food (kg) | Shadow price of land (MK) | Shadow price of capital (MK) | Shadow price of labor (MK) | Shadow value of food (MK) |
|---|---|---|---|---|---|---|---|---|
| 0.000 | 1.100 | 4,867.50 | 1,855.700 | 1,332.573 | 528.68 | 0.00 | 0.00 | 0.00 |
| 0.001 | 1.100 | 4,867.50 | 1,855.700 | 1,332.573 | 372.56 | 0.00 | 0.00 | 0.00 |
| 0.002 | 1.100 | 4,867.50 | 1,855.700 | 1,332.573 | 216.44 | 0.00 | 0.00 | 0.00 |
| 0.003 | 1.100 | 4,817.94 | 1,812.503 | 1,304.981 | 163.15 | 0.00 | 0.00 | 0.00 |
| 0.004 | 1.100 | 4,787.39 | 1,785.871 | 1,287.970 | 125.83 | 0.00 | 0.00 | 0.00 |
| 0.005 | 1.100 | 4,769.06 | 1,769.893 | 1,277.763 | 88.51 | 0.00 | 0.00 | 0.00 |
| 0.006 | 1.100 | 4,756.84 | 1,759.240 | 1,270.959 | 51.20 | 0.00 | 0.00 | 0.00 |
| 0.007 | 1.100 | 4,748.11 | 1,751.631 | 1,266.099 | 13.88 | 0.00 | 0.00 | 0.00 |
| 0.008 | 1.014 | 4,372.90 | 1,611.988 | 1,165.342 | 0.00 | 0.00 | 0.00 | EPS |
| 0.009 | 1.014 | 4,368.22 | 1,607.916 | 1,162.740 | 0.00 | 0.00 | 0.00 | 0.03 |

#### 6.2.2.3.2 Capital allocation

Capital allocation to RA and NRA enterprise combination was also affected when risk was introduced into the optimization problem. However, capital allocation remained constant until the risk coefficient level of 0.002 (Table 6.6). After this point any increase in the risk coefficient level resulted in the reduction of capital allocation to RA and NRA. This implies that as risk increases in the production of RA and NRA, farmers reallocate their capital to other activities. This highlights the fact that smallholder farmers are risk averse. The results in the table also show that capital had a shadow price of zero because it was slack throughout.

#### 6.2.2.3.3 Labor allocation

Combined labor allocation to RA and RNA was decreased as the level of risk increased. However, when risk was introduced into the optimization problem, optimal labor allocation did not change instantly. Change in labor allocation came when the risk coefficient reached 0.003 (Table 6.6). When risk coefficient continued to increase, the combined level of labor allocation to RA and NRA declined continuously. This implies that farmers relocated labor from the enterprise combination to other enterprises. The shadow price of labor was also zero because labor was slack throughout. Just like in the MA case, the results for labor would have been more informative if labor requirements were not annual but disaggregated per activity.

#### 6.2.2.3.4 Food production

Introducing risk into the objective function had an impact on food production levels. Under risk neutral scenario, the food production level was 1,332.573 kg (Table 6.6). At 0.001 and 0.002 risk coefficients, the food production level was still at 1,332.573 kg. As the risk levels increased beyond 0.002, the level of food production dwindled because more and more land was being allocated to RNA (Table 6.6).

## 6.3 Concluding Summary

This chapter was set out to optimize mixed tree intercropping of maize and *Gliricidia sepium* agroforestry technology and relay cropping of maize and *Tephrosia vogelli/candida* agroforestry technology. Net present values (NPV) from the two technologies were optimized subject to land, labor, capital and food security constraints. Net present value was used to provide a measure of expected income from the enterprises because agroforestry takes a number of years to start showing benefits. The E-V programming model was used in the optimization in order to incorporate risk into the profitability of the enterprises.

Results of the optimization showed that if risk is not included in the optimization, only maize produced in agroforestry would give optimal farm income levels. When risk was introduced into the optimization, farmers withdrew some of their land from maize in agroforestry to non-agroforestry maize production. For both mixed tree intercropping and relay cropping agroforestry technologies, the graph of expected income against income variance showed that the farmers were risk averse. However, RA farmers' graph was flatter than MA farmers' graphs depicting that RA is less risky than MA in the eyes of the smallholder farmers. Increasing risk levels in the optimization of both mixed tree intercropping and relay cropping agroforestry technologies also showed that farmers gradually reduced their labor, land and capital from the production of the combination of maize in agroforestry and maize without agroforestry. Food production levels for both mixed tree intercropping and relay cropping agroforestry technologies also decreased as risk was introduced into the optimization problem. These results are consistent with field observations where no farmer treated the entire farm only to agroforestry.

# CHAPTER SEVEN

# 7. CONCLUSION AND RECOMMENDATIONS

## 7.1 Conclusion

The main objective of the study was to evaluate the profitability of mixed tree intercropping of maize and *Gliricidia sepium* (MA) and relay cropping of maize and *Tephrosia vogelli/candida* agroforestry (RA) technologies. The result of the study showed that mixed tree intercropping had the highest average gross margins at MK 3,813.77 per hectare followed by relay cropping at MK 1,787.79 per hectare. Maize grown without agroforestry had the lowest gross margins of MK 865.67 per hectare. Results from cost benefit analysis showed that MA and RA had positive Net Present Values (NPV) of MK 52,418.53/ha and MK 10,573.69/ha respectively. The two technologies also had Benefit Cost Ratios (BCR) of greater than one with MA having a BCR of 1.6 and RA having a BCR of 1.12. However, MA had the highest NPV and BCR. Despite having positive gross margins, maize produced without agroforestry had a negative NPV of MK -7,283.84 and a BCR of 0.93. This means that in the study area agroforestry is profitable to smallholder farmers. Mixed tree intercropping is however more profitable compared to relay cropping.

Sensitivity analysis was also conducted on the profitability of the three production options to evaluate how changes in key variables affected the profitability. The results showed that at subsidized fertilizer price, the profitability of the technologies greatly improved. Increasing the price of fertilizer reduced the profitability of the technologies. When the fertilizer price was increased by 25%, relay cropping agroforestry technology was not profitable with a NPV of MK -400.17. When the price of maize grain was increased, the profitability of the technologies greatly improved while reducing the price greatly reduced the profitability of the technologies. Relay cropping agroforestry technology was also not profitable when the maize grain price was reduced by 15%. At this level of grain price, the NPV for RA was MK -4,133.65. Changing the price of seed and the discount factor did not have substantial impact on the profitability of the technologies. The results of the sensitivity analysis imply that the profitability of mixed tree intercropping agroforestry technology is more resilient to changes in key variables in the economy compared to relay cropping agroforestry technology. When the prices of fertilizer, maize grain and maize seed were varied in the range of 25% increase and 25% decrease, mixed tree intercropping remained profitable.

The study was also set out to establish production plans for mixed tree intercropping and relay cropping agroforestry farmers. This was achieved through the optimization of mixed tree intercropping and relay cropping agroforestry technology farmers' production. Both mixed tree intercropping and relay cropping farmers in the study combined the production of maize in agroforestry with maize produced without agroforestry trees. The results of the optimization of the two agroforestry technologies using the expected variance (E-V) programming model showed that when risk is not considered, farmers optimized the use of their resources in the production of maize using the two agroforestry technologies only disregarding the production of maize without agroforestry. At this level the MA farmers allocated all their 1.27 ha to maize in agroforestry and the RA farmers also allocated all their 1.1 ha to maize production in agroforestry. When risk was introduced into the optimization problem mixed tree intercropping farmers withdrew some of their land from maize in agroforestry (MA) to maize grown without agroforestry (MNA). At a risk aversion coefficient of 0.001, the MA farmers allocated only 0.267 ha of their land to maize in agroforestry and the rest of their land to maize without agroforestry trees. Increasing the levels of risk further reduced the amount of land allocated to mixed tree agroforestry technology, increased the amount of land allocated to maize without agroforestry and reduced total expected farm income. When the level of risk was increased mixed tree intercropping farmers also reduced the total land allocation, capital and labor to the production of the combination of MA and MNA. The graph of expected income against risk variance showed that the smallholder mixed tree intercropping farmers were risk averse.

The optimization of relay cropping farmers' production also showed that without risk, the farmers can optimize the use of farm resources through the production of maize under relay cropping agroforestry technology only (RA). When risk was introduced into the optimization, the relay cropping farmers started withdrawing land from maize in relay cropping agroforestry technology to maize produced without agroforestry at a risk coefficient of 0.003. At his level of risk, the RA farmers allocated 1.033 ha to maize production in agroforestry. From the risk coefficient of 0.003, any increase in the risk coefficient level resulted in the reduction of land allocation to relay cropping and expected income. Relay agroforestry farmers started changing their production patterns at a risk coefficient level of 0.003 compared to mixed tree intercropping farmers whose production patterns changed at risk coefficient level of 0.001. This implies that relay cropping is considered to be less risky than mixed tree intercropping by the smallholder farmers.

## 7.2 Recommendations

1. Since the study has established that agroforestry is profitable to smallholder farmers, it is therefore recommended that smallholder farmers should be encouraged to adopt the technology in order to realize optimal profits from maize production.

2. Mixed tree intercropping was found to be more profitable than relay cropping to smallholder farmers in the study. It is therefore recommended that mixed tree intercropping should be promoted more than relay cropping agroforestry technology in Zomba District.

3. Despite mixed tree intercropping being the most profitable technology, the smallholder farmers withdrew land from the technology faster than from relay cropping when risk was considered. This means that risk is an important factor in the adoption of agroforestry technology because the farmers viewed risk as being more important than the expected profit from the mixed tree intercropping technology. Thus, smallholder agroforestry farmers in the study were risk averse. It is therefore recommended that the smallholder farmers should be trained in risk

management techniques. Risk management techniques include all the fallback plans such as alternative enterprises like poultry production, small ruminants and production of other crops that the farmers can put in place to reduce the shock of risky situations. This will promote adoption of agroforestry technologies that are considered risky but are more profitable.

4. The study focused on mixed tree intercropping and relay cropping agroforestry technologies. Further research on the other agroforestry technologies such as dispersed systematic tree interplanting, regeneration of natural soil improving trees, annual undersowing, alley cropping and improved fallow needs to be carried out. This will provide a profile of risk attitudes of farmers towards the different agroforestry technologies.

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## APPENDIX 1

**Mixed intercropping and Relay Cropping Agroforestry Technologies Adopters' Questionnaire**

**September 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 head should be number 1)*** | **Name** | **Age (in years)** | **Marital status of HH* *(Use codes below)*** | **Gender. *1: Male 2: Female*** | **Relationship to household head*** *(Use codes below)*** | **Availability** *(Use codes below)*** |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |

**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? 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 Primary school *(actual class )*______________
2 Secondary School *(actual class)*____________
3 High school and above *(actual level)*_________
4 Other *(specify)*___________________

**b) Informal education:**

**Code:**

1 Adult literacy
2 Home craft
3 Farmer training
4 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 (Ganyu)
4 Remittances
5 Other (*Specify*)____________________________________________

5. What was your income the previous year (2005/06)?

| | 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 ***(If yes, go to question 11)***

**9.** If **no**, how many are not owned by you?

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

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 The garden(s) is rented

6 Other (Specify) ___________________________________________

14. 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 | | | | |

*Codes for Agroforestry Species

1 = *Gliricidia sepium* (Gliricidia)

2 = *Tephrosia vogelli* (Mthuthu / Mtetezga)

3 = *Sesbania sesban* (Jelejele / Binu)

4 = *Leucaena diversifolia* (Lukina)

5 = *Senna spectabilis* (Keshya wa maluwa)

6 = *Senna siamea* (Keshya wa milimo)

7 = *Tephrosia candida*

8 = Other (*Specify*)______________________________

**Codes for maize variety

1 = Local

2 = Hybrid

3 = Composite / OPV

15. For how long have you been practicing the technology? _____________ years.

*16.* 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)____________________________________

17. How did you know about agroforestry technology?

Code 1 ICRAF

2 Government extension staff

3 NGO

4 Fellow farmer

5 Other *(Specify)*________________

18. How many times did you prune the agroforestry trees this farming year? __ ______times.

19. 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

20. 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*)_____________________________________________

21. What other crops and crop combinations did you plant apart from agroforestry and maize the previous year?

| | | |
|---|---|---|
| Code | 1 | Maize without agroforestry trees |
| | 2 | Tobacco |
| | 3 | Groundnuts |
| | 4 | Cotton |
| | 5 | Other (Specify)________________________________________ |

22. 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) | |

**D COST AND BENEFITS OF AGROFORESTRY**

23. 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)

24. Benefits from agroforestry garden

| **Crop Type** | **Description of Benefits** | **Amount Harvested *(record in units given)*** | **How much was sold** | **Price per unit** | **Total Revenue** |
|---|---|---|---|---|---|
| **Agriculture crop** | Maize yields | | | | |
| **Agroforestry tree** | Seed sales | | | | |
| | Fuel wood | | | | |
| | Poles | | | | |
| | Fodder | | | | |
| **Other benefits (Specify)** | | | | | |

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

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

| Activity | Cost Item | Unit of measurement | Amt Used | Unit Cost | Total Cost | Source of input | Comment |
|---|---|---|---|---|---|---|---|
| **Land Preparation** | Hired labor | Labor days | | | | | |
| | Family labor | Labor days | | | | | |
| | Casual Labor | Labor days | | | | | |
| **Planting** | | | | | | | |
| Planting of Agrof trees | Seed for agroforestry trees | Kilograms | | | | | |
| | Hired Labor | Labor days | | | | | |
| | Family labor | Labor days | | | | | |
| | Casual Labor | Labor days | | | | | |
| | Polythene tubes | | | | | | |
| | Labor for Nursery management | Labor/ days | | | | | |
| Planting of agricultural crop (Maize) | Seed for agricultural crop | Kilograms | | | | | |
| | Family labor | Labor days | | | | | |
| | Hired labor | Labor days | | | | | |
| | Casual Labor | Labor days | | | | | |
| **Pruning and Biomass mgt** | | | | | | | |
| 1st Pruning | Hired Labor | Labor days | | | | | |
| | Family Labor | Labor days | | | | | |
| | Casual Labor | Labor days | | | | | |
| 2nd Pruning | Hired Labor | Labor days | | | | | |
| | Family Labor | Labor days | | | | | |
| | Casual Labor | Labor days | | | | | |
| **Fert applic** | | | | | | | |
| Basal-dressing | Fertilizer | Kilograms | | | | | |
| | Hired labor | Labor days | | | | | |
| | Casual Labor | Labor days | | | | | |
| | Family labor | Labor days | | | | | |
| Top-dressing | Fertilizer | Kilograms | | | | | |
| | Hired labor | Labor days | | | | | |
| | Casual Labor | Labor days | | | | | |
| **Activity** | **Cost Item** | **Unit of measurement** | **Amount** | **Unit Cost** | **Total** | **Source of** | **Comment** |

| | | | Used | | Cost | input | |
|---|---|---|---|---|---|---|---|
| | Family labor | Labor days | | | | | |
| **Weeding** | Hired labor | Labor days | | | | | |
| | Family labor | Labor days | | | | | |
| | Casual Labor | Labor days | | | | | |
| **Harvesting** | Hired labor | Labor days | | | | | |
| | Family labor | Labor days | | | | | |
| | Casual Labor | Labor days | | | | | |
| **Marketing** | Hired labor | Labor days | | | | | |
| | Family labor | Labor days | | | | | |
| | Casual Labor | Labor days | | | | | |
| **Other Cost (Specify)** | | | | | | | |
| Herbicides /pesticides | | | | | | | |
| Transportation | | | | | | | |

26. Did you experience problems in accessing these inputs? Code: 1= Yes

    2= No ***(if no go to 32)***

27. 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)*.

28. 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)* _______________

29. How did that affect your input use?

    Code 1 Did not affect
    2 Reduced their use
    3 Delayed their use

30. If it **reduced/delayed** use, by how much?

| **Input** | **Reduction amount** | **Number of days delayed** |
|---|---|---|
| | | |

## E EXTENSION SERVICES

31. Do you have access to agroforestry extension services? Code: 1= Yes 2= No ***(If no, go to question 37)***

32. 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)*________________________

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

Code 1 ICRAF
2 Government extension staff
3 NGOs
4 Fellow farmers
5 Others *(Specify)*________________________

34. 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)________________________

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

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

## F SUSTAINABILITY

37. Who owns the agroforestry trees in your garden?

Code 1 ICRAF
2 Myself
3 Government
4 Other *(Specify)* ____________________

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

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

Code: 1 Absence of clubs association
2 No incentive/benefit
3. Clubs are not organised
4. Poor supervision by ICRAF/extension workers
5 Other *(specify)*____________________

40. 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)*____________________

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

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

43. 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)*____________________

44. How frequent do you record agroforestry activities?

| | | |
|---|---|---|
| Code | 1 | Daily |
| | 2 | Weekly |
| | 3 | Monthly |
| | 4 | Quarterly |
| | 5 | More than 3 months |
| | 6 | Other (*Specify)*_________________________________________ |

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

46. 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)* ______________________________________ |

47. How frequent do you write the reports?

| | | |
|---|---|---|
| Code | 1 | Weekly |
| | 2 | Monthly |
| | 3 | Quarterly |
| | 4 | Every six months |
| | 5 | Annually |

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

49. 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)* ______________________________________ |

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

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

Code 1 ICRAF

2 Government staff

3 NGOs

4 Other *(Specify)*______________________________________

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

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

Code 1 Agroforestry types

2 Agroforestry tree management

3 Field management

4 Monitoring and evaluation

5 Other (*specify*)________________________________

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

55. If **yes**, how much? _________________Bags

56. 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

57. 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)*______________________________________

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

59. If **no,** what will you do?

Code 1 Will uproot/cut/unmanage the trees

2 Will shift to tobacco industry

3 Other *(specify)*_______________________________________

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

61. 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*)________________________________________

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

Code 1 = Yes 2 = No

63. If yes what happened to the trees?

Code 1 Uprooted
2 Cut down
3 Other (*specify*)________________________________________

64. 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*) ________________________________________

65. How many agroforestry trees do you have? ______________ (*Write actual number*).

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

67. What was the original area with agroforestry tree?

Code 1 <0.5 ha/acres

2 0.5 to less than 1 ha/acres

3 1 to less than 1.5 ha/acres

4 1.5 to less than 2 ha/acres

5 2 to less than 2.5 ha/acres

6 greater than 2.5 ha/acres

68. Has there been any change in use and management of the trees with reference to previous years? Code: 1 = Yes 2 = No ***(If no go to 71)***

69. 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)* _________________

70. 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

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

72. 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/money (Ganyu)

4 Given by other

5 Ate other foods (*Specify*)______________________________

6 Other (*specify*)____________________________________

73. If you bought the supplementing food how much were you able to buy?________

_____________________________________________________________

_____

74. If you ate other foods, how much of other the foods did you have available during the season?

| **Food type** | **Amount available** |
|---|---|
| | |

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**

**Non-adopters Questionnaire**

**September 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 head should be number 1)*** | **Name** | **Age (in years)** | **Marital status of HH* *(Use codes below)*** | **Gender. *1: Male 2: Female*** | **Relationship to household head*** *(Use codes below)*** | **Availability** *(Use codes below)*** |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |

**<u>Codes for HH Marital Status*</u>** **<u>Codes for Availability</u>****

| | | | |
|---|---|---|---|
| 1 | Single | 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)* ………………… |

***<u>Codes for Relationship to household head</u>********

1 = Spouse, 2 = Child, 3 = Parent, 4 = Grandchild, 5 = Other Specify__________________

76. Do you read and write? 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) <u>Formal Education:</u>** **b) <u>Informal education:</u>**

| **Code:** | | **Code:** | |
|---|---|---|---|
| 1 | Primary school *(actual class )*______________ | 1 | Adult literacy |
| 2 | Secondary School *(actual class)*____________ | 2 | Home craft |
| 3 | High school and above *(actual level)*________ | 3 | Farmer training |
| 4 | Other *(specify)*___________________ | 4 | 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 (Ganyu)
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) | |

## D FARM COSTS AND BENEFITS

88. Benefits

| Crop Type | Description of Benefits | Amount Harvested *(record in units given)* | How much was sold | Price per unit | Total Revenue |
|---|---|---|---|---|---|
| **Agriculture crop** | Maize yields | | | | |
| | Tobacco | | | | |
| | Groundnut | | | | |
| | Cotton | | | | |
| **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 | Amt Used | Unit Cost | Total Cost | Input Source | Comment |
|---|---|---|---|---|---|---|---|
| **Land Preparation** | Hired labor | Labor days | | | | | |
| | Casual labor | Labor days | | | | | |
| | Family labor | Labor days | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Planting maize** | | | | | | | |
| | Seed for maize | Kilograms | | | | | |
| | Casual labor | Labor days | | | | | |
| | Hired labor | Labor days | | | | | |
| | Family labor | Labor days | | | | | |
| **Fertilizer application** | | | | | | | |
| Basal-dressing | Fertilize r | Kilograms | | | | | |
| | Casual labor | Labor days | | | | | |
| | Hired labor | Labor days | | | | | |
| | Family labor | Labor days | | | | | |
| Top-dressing | Fertilize r | Kilograms | | | | | |
| | Hired labor | Labor days | | | | | |
| | Casual labor | Labor days | | | | | |
| | Family labor | Labor days | | | | | |
| **Weeding** | Hired labor | Labor days | | | | | |
| | Casual labor | Labor days | | | | | |
| | Family labor | Labor days | | | | | |
| **Harvesting** | Hired labor | Labor days | | | | | |
| | Casual labor | Labor days | | | | | |
| | Family labor | Labor days | | | | | |
| **Marketing** | Hired labor | Labor days | | | | | |
| | Casual labor | Labor days | | | | | |
| | Family labor | Labor days | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Other Cost (Specify)** | | | | | | | |
| Herbicides/ pesticides | | | | | | | |
| Transport | | | | | | | |

90. Did you experience problems in accessing these inputs? Code: 1= Yes

    2= No *(If no go to 21)*

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 **reduced/delayed** use, by how much? *(Specify input and number of days accordingly).*

| **Input** | **Reduction amount** | **Number of days delayed** |
|---|---|---|
| | | |

**E EXTENSION SERVICES**

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

96. 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)*________________________________________

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

Code 1 ICRAF
2 Government extension staff
3 NGOs
4 Fellow farmers
5 Others *(Specify)*________________________________________

98. 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)________________________________________

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

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

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

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

Code: 1 Absence of clubs association
2 No incentive/benefit
3 Lack of organization in the clubs

4 Poor supervision by extension workers

5 Other *(specify)*____________________________________

103. 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)*_________________________________________

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

105. 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)*__________________________________________

106. How frequent do you record your agricultural activities?

Code 1 Daily

2 Weekly

3 Monthly

4 Quarterly

5 More than 3 months

6 Other (*Specify*)__________________________________________

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

108. 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)* ____________________________________

109. How frequent do you write the reports?

Code 1 Weekly

2 Monthly

3 Quarterly

4 Every six months

5 Annually

5 Other (*specify*)______________________________

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

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

**F FOOD SECURITY ISSUES**

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

113. 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.

## APPENDIX 3

### Impact of Changes in the Price of Fertilizer

**Impact of changes in the price of fertilizer on Net Present Value**

| % change | Net Present Value (MK/ha) | | |
|---|---|---|---|
| **Increase** | **Mixed** | **Relay** | **Non-adopter** |
| 5% | 51,418.71 | 8,378.93 | -10,314.32 |
| 10% | 48,378.50 | 6,184.14 | -13,344.80 |
| 15% | 46,358.44 | 3,989.39 | -16,375.27 |
| 20% | 44,336.01 | 1,794.60 | -19,405.79 |
| 25% | 42,318.40 | -400.17 | -22,436.25 |
| **Decrease** | | | |
| 5% | 54,438.57 | 12,768.46 | -4,253.34 |
| 10% | 56,458.58 | 14,963.25 | -1,222.87 |
| 15% | 58,478.63 | 17,158.00 | 1,807.61 |
| 20% | 60,498.64 | 19,352.80 | 4,838.08 |
| 25% | 62,518.65 | 21,547.53 | 7,868.55 |

**Impact of changes in the price of fertilizer on Gross Margins**

| % change | Gross Margins (MK/ha) | | |
|---|---|---|---|
| **Increase** | **Mixed** | **Relay** | **Non-adopter** |
| 5% | 3,763.78 | 1,678.05 | 714.14 |
| 10% | 3,611.77 | 1,568.31 | 562.62 |
| 15% | 3,510.77 | 1,458.57 | 411.09 |
| 20% | 3,409.65 | 1,348.83 | 259.57 |
| 25% | 3,308.77 | 1,239.10 | 108.04 |
| **Decrease** | | | |
| 5% | 3,914.77 | 1,897.53 | 1,017.19 |
| 10% | 4,015.77 | 2,007.27 | 1,168.71 |
| 15% | 4,116.78 | 2,117.00 | 1,320.24 |
| 20% | 4,217.78 | 2,226.74 | 1,471.76 |
| 25% | 4,318.78 | 2,336.48 | 1,623.28 |

**Impact of changes in the price of fertilizer on Benefit Cost Ratio**

| % change | Benefit Cost Ratio | | |
|---|---|---|---|
| **Increase** | **Mixed** | **Relay** | **Non-adopter** |
| 5% | 1.58 | 1.09 | 0.90 |
| 10% | 1.53 | 1.08 | 0.88 |
| 15% | 1.50 | 1.04 | 0.85 |
| 20% | 1.46 | 1.02 | 0.83 |
| 25% | 1.43 | 0.99 | 0.81 |
| **Decrease** | | | |
| 5% | 1.64 | 1.15 | 0.96 |
| 10% | 1.68 | 1.18 | 0.99 |
| 15% | 1.72 | 1.21 | 1.02 |
| 20% | 1.76 | 1.25 | 1.05 |
| 25% | 1.81 | 1.28 | 1.09 |

# APPENDIX 4

## Impact of Changes in the Price of Maize Grain

**Impact of changes in the price of maize grain on Net Present Value**

| % change | Net Present Value (MK/ha) | | |
|---|---|---|---|
| **Increase** | **Mixed** | **Relay** | **Non-adopter** |
| 5% | 59,406.71 | 15,476.14 | -2,587.55 |
| 10% | 66,394.89 | 20,378.59 | 2,108.74 |
| 15% | 73,383.07 | 25,281.04 | 6,805.02 |
| 20% | 80,371.24 | 30,183.48 | 11,501.31 |
| 25% | 87,359.42 | 35,085.93 | 16,197.60 |
| **Decrease** | | | |
| 5% | 45,430.36 | 5,671.24 | -11,980.13 |
| 10% | 38,442.18 | 768.80 | -16,676.42 |
| 15% | 31,454.00 | -4,133.65 | -21,372.71 |
| 20% | 24,465.82 | -9,036.10 | -26,069.00 |
| 25% | 17,477.65 | -13,938.55 | -30,765.29 |

**Impact of changes in the price of maize grain on Gross Margins**

| % change | Gross Margins (MK/ha) | | |
|---|---|---|---|
| **Increase** | **Mixed** | **Relay** | **Non-adopter** |
| 5% | 4,163.18 | 2,032.91 | 1,100.48 |
| 10% | 4,512.59 | 2,278.03 | 1,335.29 |
| 15% | 4,862.00 | 2,523.16 | 1,570.11 |
| 20% | 5,211.41 | 2,768.28 | 1,804.92 |
| 25% | 5,560.82 | 3,013.40 | 2,039.74 |
| **Decrease** | | | |
| 5% | 3,464.36 | 1,542.67 | 630.85 |
| 10% | 3,114.95 | 1,297.54 | 396.04 |
| 15% | 2,765.55 | 1,052.42 | 161.22 |
| 20% | 2,416.14 | 807.30 | -73.59 |
| 25% | 2,066.73 | 562.18 | -308.41 |

**Impact of changes in the price of maize grain on Benefit Cost Ratio**

| % change | Benefit Cost Ratio | | |
|---|---|---|---|
| **Increase** | **Mixed** | **Relay** | **Non-adopter** |
| 5% | 1.68 | 1.18 | 0.97 |
| 10% | 1.76 | 1.23 | 1.02 |
| 15% | 1.84 | 1.29 | 1.07 |
| 20% | 1.92 | 1.35 | 1.11 |
| 25% | 2.00 | 1.40 | 1.16 |
| **Decrease** | | | |
| 5% | 1.52 | 1.06 | 0.88 |
| 10% | 1.44 | 1.01 | 0.84 |
| 15% | 1.36 | 0.95 | 0.79 |
| 20% | 1.28 | 0.90 | 0.74 |
| 25% | 1.20 | 0.84 | 0.70 |

## APPENDIX 5

### Impact of Changes in the Price f Maize Seed

**Impact of changes in the price of maize seed on Net Present Value**

| % change | Net Present Value (MK/ha) | | |
|---|---|---|---|
| **Increase** | **Mixed** | **Relay** | **Non-adopter** |
| 5% | 51,297.44 | 9,653.80 | -8,068.40 |
| 10% | 50,176.37 | 8,733.93 | -8,852.99 |
| 15% | 49,055.29 | 7,814.05 | -9,637.53 |
| 20% | 47,934.22 | 6,894.13 | -10,422.13 |
| 25% | 46,813.14 | 5,974.26 | -11,206.69 |
| **Decrease** | | | |
| 5% | 53,539.64 | 11,493.59 | -6,499.27 |
| 10% | 54,660.71 | 12,413.47 | -5,714.72 |
| 15% | 55,781.78 | 13,333.34 | -4,930.13 |
| 20% | 56,902.86 | 14,253.26 | -4,145.59 |
| 25% | 58,023.93 | 15,173.13 | -3,361.00 |

**Impact of changes in the price of maize seed on Gross Margins**

| % change | Gross Margins (MK/ha) | | |
|---|---|---|---|
| **Increase** | **Mixed** | **Relay** | **Non-adopter** |
| 5% | 3,757.72 | 1,741.79 | 826.44 |
| 10% | 3,701.66 | 1,695.80 | 787.21 |
| 15% | 3,645.61 | 1,649.81 | 747.98 |
| 20% | 3,589.56 | 1,603.81 | 708.75 |
| 25% | 3,533.50 | 1,557.82 | 669.52 |
| **Decrease** | | | |
| 5% | 3,869.83 | 1,833.78 | 904.89 |
| 10% | 3,925.88 | 1,879.78 | 944.12 |
| 15% | 3,981.93 | 1,925.77 | 983.35 |
| 20% | 4,037.99 | 1,971.77 | 1,022.58 |
| 25% | 4,094.04 | 2,017.76 | 1,061.81 |

**Impact of changes in the price of maize seed on Benefit Cost Ratio**

| % change | Benefit Cost Ratio | | |
|---|---|---|---|
| **Increase** | **Mixed** | **Relay** | **Non-adopter** |
| 5% | 1.58 | 1.11 | 0.93 |
| 10% | 1.56 | 1.10 | 0.92 |
| 15% | 1.54 | 1.09 | 0.91 |
| 20% | 1.52 | 1.08 | 0.90 |
| 25% | 1.50 | 1.06 | 0.89 |
| **Decrease** | | | |
| 5% | 1.62 | 1.13 | 0.94 |
| 10% | 1.64 | 1.14 | 0.95 |
| 15% | 1.66 | 1.16 | 0.95 |
| 20% | 1.69 | 1.17 | 0.96 |
| 25% | 1.71 | 1.18 | 0.97 |

# APPENDIX 6

## Impact of Changes in the Discount Rate

**Impact of changes in the Discount rate on Net Present Value**

| Discount rate | Net Present Value (MK/ha) | | |
|---|---|---|---|
| 5% | 224,547.96 | 61,139.44 | -9,491.05 |
| 10% | 139,232.42 | 35,126.09 | -9,699.58 |
| 15% | 94,085.70 | 21,943.67 | -9,010.84 |
| 20% | 68,267.12 | 14,761.05 | -8,128.92 |
| 30% | 42,060.29 | 7,977.19 | -6,539.34 |
| 35% | 34,913.88 | 6,276.02 | -5,902.06 |
| 40% | 29,752.32 | 5,106.44 | -5,360.78 |
| 45% | 25,878.86 | 4,268.22 | -4,900.48 |
| 50% | 22,878.09 | 3,645.78 | -4,506.98 |

**Impact of changes in the discount rate on Gross Margins**

| Discount rate | Gross Margins (MK/ha) | | |
|---|---|---|---|
| 5% | 14,987.12 | 7,025.53 | 3,401.82 |
| 10% | 9,530.07 | 4,467.43 | 2,163.17 |
| 15% | 6,592.66 | 3,090.45 | 1,496.43 |
| 20% | 4,882.46 | 2,288.76 | 1,108.24 |
| 30% | 3,103.36 | 1,454.77 | 704.41 |
| 35% | 2,605.53 | 1,221.40 | 591.41 |
| 40% | 2,240.94 | 1,050.49 | 508.66 |
| 45% | 1,963.97 | 920.65 | 445.79 |
| 50% | 1,747.10 | 818.99 | 396.56 |

**Impact of changes in the discount rate on Benefit Cost Ratio**

| Discount rate | Benefit Cost Ratio | | |
|---|---|---|---|
| 5% | 1.69 | 1.19 | 0.97 |
| 10% | 1.66 | 1.17 | 0.96 |
| 15% | 1.64 | 1.15 | 0.95 |
| 20% | 1.62 | 1.13 | 0.94 |
| 30% | 1.59 | 1.11 | 0.92 |
| 35% | 1.58 | 1.10 | 0.92 |
| 40% | 1.57 | 1.10 | 0.91 |
| 45% | 1.56 | 1.09 | 0.91 |
| 50% | 1.56 | 1.09 | 0.90 |