FACTORS INFLUENCING THE ADOPTION OF CONSERVATION TILLAGE PRACTICES AND THEIR IMPLICATION ON PROFITABILITY IN MAIZE-COWPEA CROPPING SYSTEMS - A CASE OF MAKUENI DISTRICT, KENYA

BY

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DECLARATION

This thesis is my original work and has not been presented for any other degree in any other University.

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ACRONYMS AND ABBREVIATIONS

AEZ	Agro-Ecological Zone
KNBS	Kenya National Bureau of Statistics
CIMMYT	Centro International de Mejoramiento de Maizy Trigo (International Maize and Wheat Improvement Centre)
FAO	Food and Agricultural Organisation of the United Nations
Ha	Hectare
KENDAT	Kenya Network for Draught Animal Technology
Km	Kilometre
Ksh	Kenya Shillings
MoA	Ministry of Agriculture
OLS	Ordinary Least Squares
R^2	Coefficient of determination
SALs	Semi Arid Lands
SPSS	Statistical Package for Social Sciences

ABSTRACT

In the semi arid areas of eastern Kenya, the farmers are faced with food insecurity and low farm incomes due to rainfall unreliability. The low soil moisture resulting from low rainfall cannot support productive agriculture to meet the increasing population in the semi arid areas. In the year 2000 and 2001, the Food and Agricultural Organization of the United Nations disseminated conservation tillage practices, which included ripping and tied ridging. The Ministry of Agriculture and Kenya Network for Draft Animals Traction have been training the farmers on the use of ripping and tied ridging and informing the farmers on the technical gains of these technologies. However, the adoption rate of these practices is below the expectation of researchers and policy makers. Further, the information on financial returns of these technologies is relatively scarce. The objective of this study is to analyze household and technology attributes that influence the adoption of ripping and tied ridging and to evaluate the financial returns of these technologies.

A total of 177 farmers were purposively sampled from Kalawa and Kathonzweni divisions in Makueni district. The divisions were chosen based on their importance in conservation tillage. A logit model was used to identify the factors influencing the use of ripping and tied ridging. Partial budgets were drawn to account for the extra benefits and costs of these practices.

The results confirmed that farmers have adopted the technologies but the adoption is still relatively low. About 1.8 percent of the farmers in the Makueni district was using ripping and tied ridging as forms of conservation tillage. The adopters of ripping were more than those of tied ridging since tied ridging required specialized planters that operate better in heavy crop residue. The non-adopters reported lack of information, lack of equipment and lack of interests as reasons for not using the technologies. Partial budgets showed that the

conservation tillage practices were more profitable than conventional tillage. A farmer who used ripping realized a net farm income of Ksh 21,277 per hectare per year, while a tied ridging farmer realized a net farm income of Ksh 17,677 per hectare per year with the returns bound to increase in the subsequent years due to reducing costs. The adopters also realized intangible benefits and costs.

Regarding the factors determining the use of ripping and tied ridging, contact with extension services, off farm employment, family labour, group membership and farming experience positively influenced the adoption of ripping and tied ridging. Distance to the nearest market was significant but negatively influenced the adoption of ripping and tied ridging.

Understanding these factors will facilitate a targeted approach in promoting use of conservation tillage in order to enhance maize and cowpea production in the semi-arid areas. Therefore, these factors should be incorporated in the design of policies and strategies developed to promote the use of conservation tillage practices. Further, farmers should intensify the use of these technologies so that average output per hectare is increased.

CHAPTER 1: INTRODUCTION

1.1 Background

Kenya's population was estimated in 1999 to be 29 million and is projected to increase to 37.4 million by 2010 (Kenya National Bureau of Statistics, 2001). The government recognizes that the country has high unemployment and population growth rate, and these have adverse economic effects. The regions with greatest long-term vulnerability of low per capita food production and food security are concentrated in the semi arid zones of Kenya (Biamah *et al.*, 2000). The reason for low per capita food production and security in the semi arid lands (SALs) include inappropriate farming technologies, inadequate investment in irrigated agriculture, accelerated soil degradation and high cost of production inputs (Mbogo, 2000).

In semi arid lands of Kenya, rainfall is bimodal and characterized as low, erratic and poorly distributed. Short intense storms coupled with prolonged dry spell, in the SALs, make crop production difficult, if not impossible (Biamah *et al.*, 2000). The four major problems in the semi arid areas are severe soil erosion, low soil fertility, high soil crusting and low soil moisture. Of the four, soil moisture is the most critical as it directly affects agriculture in these areas (Biamah, 2001).

There have been various incentives by the government, researchers, non-governmental organization and even the farmers in the semi arid areas to counter the effects of low soil moisture. Agriculture has been practiced in the semi arid areas, for instance, by planting crops adapted to water stress such as cassava, millet, sorghum, cowpeas, Katumani composite maize variety, lab lab (*dolichos*) and velvet bean. However, with conventional tillage low soil moisture limits the yield of these crops as the sole source of food for the SAL population.

Several sustainable techniques for water conservation advanced in the semi arid areas of Kenya include terracing, contour ridging, cover cropping, mulching and sub soiling. While considerable success has been achieved in this regard, there is still evidence of continued decline in land productivity even in the best-conserved land, suggesting that more needs to be done to improve soil moisture. This implies more efforts should shift to integrated conservation farming approaches that address effective use of water and minimizing production costs. The farming strategies should be cheap and economically viable.

A study done by Nixon *et al.*, (2000) in Machakos district found out that 36 percent of farmers used *fanya chini*, a technique of terracing, to harvest water and bring it onto the farm. The study found out that the cost of installing such structure is too high for resource poor farmers. The structures were appropriate for some steep slopes in Machakos. However, as conservation efforts are moving towards the semi arid areas, the same techniques are not necessarily suitable since these terraces are appropriate for areas with high rainfall (Liniger and Kironchi, 1992).

Willcocks (1994) reported that one of the reasons for low yields in SALs is the limited amount of moisture available to crop roots. Willcocks study in Botswana suggested that available moisture would be increased if the rooting depth is increased and it has been shown that in some cases deep tillage can help, for example on the dense sandy soils. However, deep tillage is neither beneficial to all crops nor to all soils. Also deep tillage requires greater draught power that is usually in short supply in semi-arid areas.

At the turn of the decade (1999-2001), the Food and Agricultural Organization of the United Nations (FAO) introduced ripping and tied ridging in Makueni district (Biamah, 2001). Ripping and tied ridging are forms of conservation tillage practices. Ripping is a form of minimum tillage where by only parallel furrows are cut using a ripper without disturbing the soil between planting rows (Gachene *et al.*, 2003). Its objective is to restore micro-pores for maximum water infiltration and increased root depth. Tied ridges are usually discontinuous furrows made by cross-ties that interrupt water flow in the furrow thus creating pools to retain water for a while and to promote slow seepage (Gachene *et al.*, 2003).

Various institutions have been promoting the ripping and tied ridging among the farmers since the year 2000. These institutions include the Kenya Network for Draft Animal Traction (KENDAT), the FAO, Ministry of Agriculture (MoA) and the Agricultural Technology Development Center (ATDC). Ripping and tied ridging are mainly disseminated and demonstrated in farmer groups. These institutions have made the physical benefits and costs of ripping and tied ridging known to the farmers. The physical benefits are in terms of yield and environment preservation (FAO, 2004).

Conservation tillage as an aspect of environment preservation is of global, regional and national importance. For Eastern and Southern Africa (ESA) the subject has special importance since it touches directly on agricultural production in the semi arid and arid regions, which carry over 50 percent of the population (Biamah *et al.*, 2000). About 80 percent of the population in the ESA is involved in smallholder agricultural production using traditional means of land preparation. According to Boserup (1981), intensification of technologies already known to the farmers should be applied on a wider scale, so that average output per hectare increases.

Producers are sensitive to long-term soil-productivity issues, but their primary short-term concern is profitability. Producers will readily adopt new technologies provided profit potential is maintained or enhanced (Kiome and Stocking, 2000). Drylands conservation technologies designed to enhance or sustain agricultural productivity must be profitable. Enhancing productivity and profitability in drylands farming demands those factors that limit yield the most be reduced or eliminated. Water is the most limiting resource to attaining maximum drylands crop yield potential. Drylands conservation technologies that reduce water stress enhance yield response to other inputs. Therefore, producers in the SALs could enhance drylands agricultural productivity and profitability through the adoption of ripping and tied ridging.

There is sufficient evidence that conservation tillage is superior to conventional tillage in terms of the technical gains though information on the financial returns is relatively scarce. Ripping and tied ridging assure the farmer of good timing of farming operations and less labour and energy requirements. The ripper is significantly faster than ploughing since tillage is limited to only a thin opening for planting, (Gachene *et al.*, 2003). Because of this narrow working width, pulling a ripper requires about half the drought force of that needed for pulling a conventional single furrow plough (Gachene *et al.*, 2003). Yield is a major factor in farm level profitability and increases substantially under conservation tillage both in the first year and over time. A 50 to 100 percent increase in basic grain yield is clearly possible (Pretty, 1999). Tied ridging requires high labour for preparation of the depressions. However, the tied ridges are permanent and only need minimal maintenance in the subsequent years (Harper, 2002).

1.2 Problem Statement

There have been continued promotional efforts of ripping and tied ridging by various government and non-government organizations in Makueni and other semi-arid districts in Kenya with the purpose of improving crop yields in these areas. In Makueni District the organizations promoting conservation tillage include the Kenya Agricultural Research Institute (KARI), KENDAT, FAO, MoA and ATDC. These organizations have been making the technical gains of these technologies known to the farmers. However information on the financial gains of these technologies is relatively scarce. Further proper targeting of farmers is not done since farm and farmers' characteristics that influence technology uptake are not precisely known. This may explain the slow adoption of ripping and tied ridging practices. Understanding these factors and the profitability of ripping and tied ridging will facilitate a targeted approach in promoting use of conservation tillage in order to enhance crop production in the study area.

1.3 Objectives of the study

The purpose of this study was to evaluate the factors that influence the adoption of conservation tillage practices and the implication of these practices on profitability in the semi arid areas of Kenya. The specific objectives were:

1. To analyze the farmer characteristics and technology attributes that influence the decision to adopt ripping and tied ridging as conservation tillage technologies in Makueni district.
2. To analyze the net farm income of conservation tillage compared to conventional tillage.

1.4 Hypothesis

The following hypotheses were tested: -

1. Household characteristics and technology attributes have no influence on the decision to adopt conservation tillage.
2. Net farm income under conservation tillage are not different to those under conventional tillage (H_0: Net farm income conserve tillage= Net farm income conventional tillage)

1.5 Justification of the study

Justification for this study stemmed from the widespread evidence that there is low food production and farm incomes in the semi arid areas while farmers continue to avoid those technologies that could ensure improved crop production and sustainability. The adoption of these technologies cannot be achieved en masse unless the profitability and the influencing factors are known. The purpose of this study was to enhance food sufficiency in Makueni district through increased adoption of technologies which conserve the soil moisture leading to better utilization of water resources. No quantitative study had been carried out to generate information on factors influencing the use of ripping and tied ridging adoption and implication of these technologies on profitability. Thus, this study aimed at filling up this information gap in order to unlock the apparent potential. The information will be used to draw inferences regarding appropriate research, extension and any other policy interventions that may augment the use of appropriate conservation tillage practices. Further, acquiring this knowledge is important since the Kenyan rural population continues to increase and more people are moving from high and medium potential areas to arid and semi arid (low potential) areas where they continue to rely on farming for their livelihoods.

CHAPTER 2: LITERATURE REVIEW

2.1 Sustainable management of the arid and semi arid lands

The Government of Kenya has had a well-articulated Arid and Semi-Arid Land policy with the main objectives being resource conservation, exploitation of productive potential, development of human resources and integration of the ASAL into the national economy (Government of Kenya, 1995). This document places substantial emphasis on drought contingency planning in order to strengthen the coping mechanisms of local communities. Guidelines for policy implementation emphasize that projects and programs will be undertaken within the District Focus Strategy, communities and local institutions will be involved in design, preparation and implementation of the projects. The current study focused on technologies that farmers could learn in groups and minimize the input costs by making the purchases in groups and hence the farmers could realize the objectives of these policies especially resource conservation and food security.

Over the last three decades the focus of soil and water conservation efforts in the arid and semi arid lands in Kenya has been erosion control using mechanical means. Such structures have included diversion ditches, terraces and waterways (Okwach *et al.*, 2000). The concern for improvement of crop productivity per unit area calls for a radical shift in thinking from erosion control practices to practices which can conserve the soil and water with reduced farming costs (Hagmann *et al.*, 1996). Some of technologies recommended by the past studies were addressed by the current study. Further the present study analyzed the financial implication of these technologies which was lacking in the earlier studies.

Rainwater harvesting, understood to be the harvesting of runoff water, has proved to be an appropriate method for crop production in the semi arid areas (Mbise *et al.*, 2000). Rainwater harvesting is of little or no help if not conserved for use during dry spell, when crops suffer from short periods of water stress. The combination of rainwater harvesting with conservation tillage can offer optimal soil moisture management (Pretty, 1999) in the semi arid areas. However the adoption of the conservation tillage practices in the semi arid areas is below the expected (Biamah *et al.*, 2000). This study focused on profitability and factors influencing the use of ripping and tied ridging that had not been previously addressed.

The FAO has been promoting sustainable development practices especially in the drylands (FAO, 2004). The main focus of FAO activities in soil and water conservation was to promote land use systems and management practices in drylands that can provide economic gains to farmers as well as enhance environmental benefits to society by increasing crop productivity (Robert, 2002). Important strategies to improve productivity identified by the FAO programme were growing adapted species, managing and enhancing soil fertility and adopting improved cropping systems (Lal, 2003). The present study focused on practices that once adopted by the farmers could advance sustainable development especially in drylands farming. Apart from the environmental benefits that farmers can reap from improved technologies, there are financial returns that a farmer stands to gain from these technologies. This financial analysis had not been addressed by the past studies.

Shiferaw *et al.* (2007) reported that most early soil and water conservation approaches focused on top-down intervention using structural methods. The initiative further indicated that there were policies that included forced adoption of soil erosion control, planting of trees on hillsides, and protection of water catchments in order to improve farming in the ASAL areas. However, the subsistence farmer cannot afford to respond to emotional appeals to care for the soil and water (Shiferaw *et al.*, 2007) and this means that conservation measures must have visible short-term benefits to the farmer. For the subsistence farmer the benefit he would most appreciate might be increased yields per unit of land, or perhaps better production per unit of labour, or improved reliability of yield (Shiferaw *et al.*, 2007). The current study is related to the Shiferaw *et al* study in that it involved technologies whose primary output to the farmer is increased farm yield and income through improved soil moisture. However Shiferaw *et al* did not consider that farmers might be reluctant to adopt new technologies when the financial returns per unit of land are not known. The current study filled this information gap.

2.2 Conservation tillage in Makueni District

Draught animal power has been determined as a major prerequisite in the use of ripping. The animals are used to pull the rippers during the preparation of the parallel furrows. A study in Makueni district (Kaumbutho and Mutua 2002) found out that draught animals were available in the area of study and extension visits were made to train equipment and animal handling as crucial conditions for successful adoption of conservation tillage by farmers. The combination of already existing resources with other factors influencing the adoption of conservation tillage, which the earlier study had omitted, will lead to mass adoption of conservation tillage practices.

Mwangi (2002) carried out a study in Machakos district at the divisions bordering Makueni district. The objective of the study was to sensitize and train farmers on conservation tillage methods using lab lab (*dolichos*) in order to reduce soil moisture loss, control weeds and increase crop yields. Maize yields in mulched plots were on average

2.4 tons per hectare compared to 1.0 ton per hectare obtained in conventionally tilled plots. The high maize yield achieved in lab lab mulched plots was attributed to soil moisture conservation and less weed infestation. The herbicide treatment gave promising results of suppressing weeds but it was dropped because of high costs. The current study aimed at adding knowledge by analyzing the financial aspects of the already existing technologies in Makueni district. Further, the current study sought to find out the factors influencing the use of various conservation tillage practices.

A field experiment was conducted for two seasons in Makueni District to compare the effect of tied ridging and integrated nutrient management practices on the yield of rain fed maize and cowpeas (Miriti, 2005). The main treatments were flat bed (traditional farmers' practice) and tied ridging as main plots. Manure and fertilizer were applied on the plots. The combination of tied-ridges with manure or nitrogen gave higher maize and cowpea yields than when these factors are applied alone. These preliminary results indicated that tied ridging in combination with integrated nutrient management had the potential to improve crop production in semi-arid eastern Kenya. The costs and benefits, however, had not been addressed in the past and have now been captured in this study.

2.3 Adoption of various conservation tillage practices

Gould *et al.* (1990) analyzed the factors influencing use of conservation agriculture in Ethiopia. The study included farmer's awareness of soil problems, education level, gender and farmers age as variables determining the farmer's decision to adoption of conservation agriculture. They found out that education level of the farmer was significant to the adoption of conservation agriculture while the other variables were insignificant. The earlier study was too broad on conservation agriculture while this study narrowed to conservation tillage, a sub set of conservation agriculture, and included group membership, off employment and farm size which had been omitted by the earlier study

Anderson and Dillon (1992) analyzed the technologies used to conserve water and soil in Malawi. The study showed that ridges constructed by hand-hoes are the most common practice used by about 95 percent of the smallholder farmers and zero tillage was not used at all. The study revealed that virtually all the farmers were applying the technologies at rates far below the standard recommended rates, but did not analyze the factors likely to cause the low utilization rates and recommended further investigation.

In Zimbabwe some of the conservation tillage systems demonstrated to farmers are ripping, tied ridging, tied furrows and mulch tillage. However, the adoption rates were still very low and were estimated at less than 1 percent (Hagmann *et al.*, 1996). Reasons for the low adoption included lack of awareness and unavailability of equipment. There has been intensive campaign by various governmental and non-governmental organizations on the use of ripping and tied ridging and thus lack of awareness is not an issue in Makueni district. The current study was undertaken to find out factors that influence the adoption of ripping and tied ridging in the Makueni district.

Mashvira *et al.* (1997) in Zimbabwe described yield response of the commercial cotton to reduced tillage systems. The tillage practices adapted farmer practices and implements that were available to the communal area farmer hence higher yields. They further revealed that planting with ox-plough and ripping to a depth of 30 cm offered alternative crop establishment options and increased maize yield between 20 and 300 percent. The study concentrated mainly on yield as a factor affecting the adoption and ignored any other possible household and access factors that could influence the decision to adopt conservation tillage. The present study sought to evaluate any other factors.

Misika (1998) undertook a study on adoption of conservation tillage among the large scale and smallholder farmers in Namibia. The study revealed a positive relationship between the adoption potential and farm size. Labor constraint and institutional support influenced feasibility of technology use. Acceptability of the technology was influenced by gender, off farm income, previous use of alternative methods of soil and water conservation, economic importance of cover cropping and wealth level. This study aimed at adding value by evaluating the financial aspects of ripping and tied ridging that was not considered by Misika in Kenya.

Kiome and Stocking (2000) carried out a study on soil and water conservation at three field sites in semi-arid Kenya. Five conservation treatments (bench terrace, tied ridging, contour tillage, trash lines and a control treatment (hand tillage).) The treatments were assessed for their performance and compared with farmers' views of the need for conservation and their actual adoption of soil and water conservation measures. Analyses of marginal rates over ten years indicated that tied ridging and terracing were worthwhile but only under specific circumstances of soil quality and labour availability. The current study is related to the Kiome and Stocking study in that they both dealt on soil and water conservation measures in the semi arid Kenya. However the foregoing study did not address the profitability of tied ridging and other conservation measures which have been handled by this study.

Mulugeta *et al*. (2001) carried out a study on the determinants of adoption of physical soil conservation measures in the central highlands of Ethiopia. It was found that technical and institutional settings have a relationship with the dissemination and adoption of soil conservation practices. The variables included age, education level, and total cultivated land, and extension contact, perception of soil erosion, labour shortage, tenure arrangements and characteristics of the technology. The results showed that size of land cultivated, technology specific characteristics and level of schooling were important determinants of physical soil conservation practice. The presents study adopted similar variables and added group membership and off farm employment to analyse factors that influence adoption of ripping and tied ridging practices that primarily conserve soil moisture.

Lars *et al.* (2003) did an adoption study on conservation tillage in Tanzania and found out that little had been known about the technology and hence had been necessary to apply a step-by-step approach, starting with availability of the technique, adaptation to the local conditions and to create awareness in the farming population. He reveled that the adoption of conservation tillage could be relatively faster if attractive extension messages, proper training, sufficient resources and inputs were available. This study is related to Lars *et al.* (2003) study in that it incorporated some of the factors such as extension contact as factors that could possibly influence conservation tillage adoption. However the earlier studies were deficient of the financial returns of conservation tillage that was handled by the current study.

A case study on conservation tillage practices in Laikipia (Kaumbutho and Josef 2004) found out that ripping and tied ridging are labour and time saving especially during land preparations. The study further pointed out that participatory approach, in particular farmer field schools were a cost-effective way of participatory training. Groups of 10–30 farmers' engaging in collective and individual experimentation and learn conservation tillage principles and practices.

Beyond the issue of groups, projects and institutions can potentially develop more participatory and responsive approaches, with farmers more clearly in control. Most of the conservation work in Makueni district has been done in groups hence the current study considered group membership as a factor that would influence the adoption of conservation tillage. However Kaumbutho and Josef only emphasized the importance of groups as a factor contributing to adoption of conservation tillage without considering other factors such as off farm employment, family labour and extension services that were considered by the current study.

A study carried out in Zambia on conservation agriculture (Haggblade, 2004) found out that while the effects of conservation agriculture may occur through time both in a single farmer's land and across a landscape, adoption of conservation agricultural technologies depended on the financial incentives and risk decisions facing individual households particularly in the first year of adoption. Lack of short-term profitability will generally discourage farmers from adopting, unless there is a major reduction in risk with change in technology. The work was an aggregation of all conservation agriculture as compared to the current study that only dealt on conservation tillage and specifically on ripping and tied ridging.

2.4 Qualitative response models

The mode of analysis is known to affect results of a study and their suitability for application. Several studies have applied qualitative response models on analysis of regression, where the dependent variable is dichotomous i.e. take values of 0 and 1 while the independent variables are continuous. An example of such a case is technology adoption, where a value of 1 can be given for adopters and 0 for non-adopters. To analyze the regression, the simplest procedure is called the *linear probability model* (Greene, 2004; Maddala, 2001). The model is specified as follows:

$$Y_i = \alpha + \beta_i + \mu_i \qquad (2.1)$$

Where $Y_i = \{^1_o$

Because of the problem of heteroscedasticity, the Ordinary Least Squares (OLS) estimates of β from the above equation are not efficient. The OLS mode may lead to wrong conclusions based on the parameter estimates, hence the limitation in using this model.

In the quest for more efficient qualitative response models, other models have been developed. These are the Logit and Probit models. These models assume a variable Y_i * that is not observed, commonly known as "latent" variable as expressed in the following equation (Maddala, 2001).

$$Y_i* = \beta_0 + \sum_{j=1}^{k} \beta_i x_{ij} + \mu_i \qquad (2.2)$$

What is observed is a dummy variable Y_i (e.g. technology adoption) defined as Y_i is 1 if Y_i * is greater than zero (0) and 0 otherwise.

The logit and probit models differ in the kind of distribution followed by the error term μ_i. If the cumulative distribution of μ_i has logistic errors, we have the logit model. The model is expressed as follows:

$$P = F(Z) = 1/(1+e^{-z}) = 1/(1+e^{-(\alpha+\beta x+\mu})) \qquad (2.3)$$

Where P is the probability that Y_i is 1.

If the error μ_i follows a normal distribution, we have the probit model. Suppose, however, that Y_i * is observed if Y_i *> 0 and is not observed if $Y_i * \leq 0$. Then the observed Y_i will be defined as:

$$Y_i = Y_i^* = \beta x_i + \mu_i \text{ If } Y_i^* > 0 \text{ and } 0 \text{ if } Y_i^* \leq 0 \qquad (2.4)$$

This is known as the Tobit model. It is a *censored normal regression model* because some observations on Y* are censored (Greene, 2004; Maddala, 2001). To estimate the logit, probit and Tobit models, Maximum Likelihood Estimation (MLE) is used.

The three models are used to solve different econometric problems. The Tobit is used to analyze factors influencing the probability and intensity of a quantitative phenomenon, while the logit and probit are used to analyze the factors influencing the probability of a quantitative phenomenon. The interpretation of the logit and probit is similar, hence both can be used to solve the same problems. However, the probit model assumes a variance of one, $variance(E/X) = 1$ while the logit model assumes a variance of 3.29.

$variance(E/X) = \Pi^2/3 = 3.29$ Where: X =independent variable and $\Pi^2 = 3.14$

Since the problem under the study was to find ways of improving the probability of adoption of ripping and tied ridging in the semi arid areas of Kenya, the logit model, which is computationally easier than probit was selected and used. The logistic distribution gives an S-shaped curve which uses input variables to make predictions about likelihood of certain outcomes. The S-shaped curve of the logistic cumulative distribution is substantively useful in description of how the probability of an event or other outcome rises as a function of some input variables.

2.5 Past studies that used the logit model

Adesina and Sirajo (1995) used the logit model to evaluate farmer's perception and adoption of new agricultural technology of modern mangrove rice in Guinea-Bissau. They formulated the following model: -

$$Q_{ik} = F(L_{ik}) = e^{zik} / (1 + e^{zik}) \tag{2.5}$$

For $Z_{ik} = X_{ik} B_{ik} and -\infty < Z_{ik} < \infty$

Where, Q_{ik} is the dependent variable that takes the value of one for adopters and zero otherwise. X_{ik} is a matrix of explanatory variables related to the adoption of modern mangrove rice varieties by farmers. B_{ik} is the vector parameter to be estimated. L_{ik} is an implicit variable that indexes adoption. $F(L_{ik})$ is the probability that the i^{th} farmer chooses to cultivate the modern mangrove rice over a local variety, zero otherwise.

The explanatory variables considered included farmer specific and socio-economic variables; that is age, family size, farm size, contact with extension, education status, years of farming experience, access to non-farm income and commercialized or subsistence orientation. Besides these, technology specific characteristics such as the shortness of crop cycle, yield on farmers fields, the ease of threshing, taste and starch content were considered. The present study adopted the logit model and included some of the explanatory variables in the past study to analyze the factors influencing the use of ripping and tied ridging. The influence of group membership on adoption was not covered. This study addressed this research gap.

Erenstein and Cadena (1997) carried out a study on the adoption of conservation tillage in Chiapas. A multivariate logistic regression model was developed to predict the probability that a farmer will adopt either mulch or no-till or both of the components.

Their study included adopters either of the components of conservation tillage or both while the independent variables included farm size, family size, off-farm employment and the slope. The current study integrated some of these variables in the logit regression analysis and added group membership and gender that were not analyzed in the previous studies.

Saito *et al,* (1994) analyzed the factors that could raise the productivity of women in Kakamega, Muranga and Kilifi districts in Kenya. In analyzing the factors influencing the adoption of improved technologies such as fertilizer, improved seeds and farm mechanization, their study made use of the logit framework. The probability of adoption was used as the dependent variable while the exogenous variable considered included land, capital, education, age, gender, labour, risk, extension contact, ecological factors and infrastrural development. The factors influencing the use of agricultural technologies do not cut across the board. Hence the present study considered some of these variable in the logit model but on different technologies of conservation tillage.

Gamba *et al*, (2002) examined the factors that influence farmers' adoption of new wheat varieties in Nakuru, Narok and Uasin Gishu district. The study used primary data collected from a sample of 80 wheat farmers from the three districts. The logit model was used to determine the factors affecting adoption of new wheat varieties. The present study focussed on more recent technologies and how the adoption of ripping and tied ridging could be increased.

Ouma *et al*, (2002) reviewed the socio-economic and technical factors that affect adoption of improved maize and fertilizer use in Embu district, Kenya, and the role of credit in improved maize and fertilizer use adoption. A total of 127 farmers were interviewed. The logit model was used to determine the factors that determine maize seed adoption, while linear regression was used to determine the factors that influence amount of fertilizer used. The present study differed from the previous study in that it considered a different technology to determine factors that influence the adoption of conservation tillage.

2.6 Analysis of profitability of conservation tillage technologies

A number of studies have used partial budget approach to analyze returns to technologies in general and returns to conservation tillage in particular. Hanks and Stevens (2004) used partial budgets to carry out an economic analysis for treatments of conventional tillage with a wheat cover crop, and no-till with a wheat cover crop. Partial budgets were developed for each treatment over the study period of five seasons. Within the partial budgets, both direct and total specified expenses for the specified tillage and cover crop practices were calculated. Results indicated that the highest returns and the lowest relative risk were obtained from a traditional no-till system compared with the other systems.

The conventional tillage system had relatively high returns but was among the riskiest (highest variance) of the treatments analyzed. The current study adopted a similar methodology (the partial budgets) as they only take into account the additional benefits and costs associated with the new practice.

An economic analysis of conservation tillage done by Harper (2002) also used partial budgets. The partial budgets took into account the variable and fixed costs that would change depending on the use of either conventional tillage or conservation tillage. The variable costs included were fuel, labour, and pest control costs while the fixed costs were those that were incurred because of the ownership. The intangible benefits were omitted from the analysis and included increased soil moisture in conservation, improved soil fertility and reduced soil erosion. The current study adopted a similar methodology in analyzing the effects of ripping and tied ridging. The earlier study was an aggregation of all conservation tillage practices and may not reflect the extra benefits and costs of individual practices. Thus the present this study singled out ripping and tied ridging and analyzed their partial budgets as forms of conservation tillage.

CHAPTER 3: METHODOLOGY

3.1 The Conceptual framework

This study was conceptualized as a technology adoption study. Feder and Slade (1984) define adoption as the degree to which a new technology is used in the long run equilibrium when farmers have complete information about the technology and its potential. Since farmers are rational consumers of agricultural technology, they were conceptualized to choose technology packages that give maximum utility. They were categorized into adopters and non-adopters of conservation tillage practices. Adoption was assumed to be a function of the household characteristics and technology specific characteristics (Adesina and Zinnah, 1993).

The decision to adopt an innovation is a behavioral response arising from a set of alternatives and constraints facing the decision maker (Leagans 1979). These alternatives and constraints can be grouped into incentives and disincentives. Adoption proceeds only when the incentives outweigh the disincentives. Economically, incentives are the returns while the disincentives are the costs. If the benefits are more than the costs, the farmers are motivated to take up a new innovation due to the expected high returns on investment.

Adoption should be viewed as a process that represents a change of behaviour on the part of the decision maker. Farmers' adoption behaviour is thus dependent on numerous influences from two major sources, that is, internal and external. This influence can be translated into two classes as mentioned above, namely incentives (reasons for) and disincentives (reasons against) of adoption. In order to facilitate the adoption process, incentives are increased while the disincentives are weakened. This necessitates the need for identification and analysis of the factors that influence farmers' adoption behaviour.

Such can only be achieved within theoretical frameworks, which are designed to accommodate a wider range of significant variables. However, many of the earlier adoption studies were conducted within disciplines based on theoretical framework such as sociology and philosophy that were incapable of adequately explaining the complex behaviour of farmers with respect to adoption of agricultural innovations (Leagans, 1979).

Due to these theoretical framework shortcomings, Leagans (1979) developed a comprehensive and functional theoretical framework within which investigations and explanations of intricate adoption behaviour of farmers can be made. The theoretical framework accommodates discipline specific variables and takes into account the interdisciplinary nature of the variables, which commonly affect adoption. The framework has a problem-focused orientation and hence allows for flexibility in its applications.

Leagans treats adoption of agricultural innovations as the dependent variable while the independent variables are all interdisciplinary factors comprising a primary set of socio-economics, physical and institutional factors. It is therefore the interaction of these opposite forces (incentives versus disincentives) that create tension that motivates action resulting in change and thus adoption or non- adoption (Leagans, 1979).

The framework conceptualizes these incentives and disincentives as having some weight attached to them depending on their respective degree of influence on the adoption as perceived by farmers. It is argued that only and until the effects of incentives exceed that of disincentives can adoption begin. This theoretical framework is referred to as the behavioral differential model and it illustrates the nature of human behavioral change process (Leagans, 1979).

The change process in the model shows that incentives and disincentives are seen as exerting equal importance. This means the behavioral pattern remains in a status quo condition. To activate the change process, change incentives such as technology and education must be introduced in magnitudes sufficient to create imbalance and overcome disincentives, which must also be weakened so that large numbers, but usually not all, of the respondents can adopt the change over time.

Adoption takes position because the physical, environmental, technological and educational and other type of input reach their optimum level of effect. This requires a few years to decades to achieve. On the strength of the forgoing characteristics, therefore the model proposed by Leagans (1979) was used by this study as the framework for economic analysis of factors influencing farmers' decision to adopt or not adopt conservation tillage practices. The independent variables used in the study included the farm and farmer specific characteristics (years of formal education, family size, hired labour use, gender, off-farm income, farmers' farming experience and farm size) and external factors (contact with technology promoter and distance to the nearest market).

3.2 Analysing factors that influence the adoption of conservation tillage practices

3.2.1 The Econometric Model

Based on the above conceptual framework, a limited dependent variable model, the Logit model was used in analyzing the factors that influence the decision to adopt or not adopt conservation tillage. The phenomenon we seek to model, the adoption behaviour, is discrete rather than continuous. In this case, the dependent variable takes a limited set of values. These are cases where the dependent variable can be characterised as 0 or 1. The dependent variable takes the value of 1 if technology has been adopted and 0 otherwise.

The regressand in these circumstances is the decision to adopt conservation tillage technology and the decision not to adopt on the other hand.

A form of qualitative response model is required to analyse this phenomenon. Binary choice models such as logit and probit models are often applied in modelling adoption decisions (CIMMYT, 1993). These are techniques for estimating the probability of an event (such as adoption) that can take one of two values (adopt, do not adopt). The basic difference between the two models is that logit assumes a cumulative logistic distribution with a higher variance hence flatter, while probit model assumes cumulative normal distribution with a unit variance hence more bell-shaped. Generally, the interpretation of the two models is similar. However, the logit model, which is computationally easier than probit gives an S-shaped curve which uses input variables to make predictions about likelihood of certain outcomes. The S-shaped curve of the logistic cumulative distribution is substantively useful in description of how the probability of an event or other outcome rises as a function of some input variables.

In the logit model, the expectation of the Y is a number P, which is related to the independent variables, (X) as follows (Pindyck and Rubenfield, 1991; Greene, 2004; Maddala, 2001).

$$
\begin{aligned}
&E(Y / X) = P = F(Z) = \alpha + \beta X + \mu \\
&= 1/(1 + e^{-z}) \\
&= 1/\{1 + e^{-(\alpha + \beta x + \mu)}\}
\end{aligned}
\qquad (3.1)
$$

Where $P =$ conditional probability of being adopter given the values of independent variables, (X)

e =Base of natural logarithm which is approximately equal to 2.718

α =Constant

β =Regression coefficients

μ =Stochastic error term

The above expression P is referred to as Logistic probability function. When the Logistic function is expressed in terms of odds, it is called the logit and takes the following form.

$$probability(event)/(noevent) = \{P/(1-P)\} = e^{Z} = e^{(\alpha+\beta X+\mu)} \quad (3.2)$$

In order to estimate the logit model, the dependent variable is transformed by taking natural logarithms of both sides to yield "log odds" as follows.

$$In\{P/(1-P) = Z = \alpha + \beta X + \mu \quad (3.3)$$

3.2.2 Model specification

The adoption models were specified using several factors, derived from the adoption literature (Asambu 1993; CIMMYT 1993). The factors represented household characteristics (education, family size, and experience of the farmer, gender and off farm employment), external factors (contact with extension agents and technology promoters and distance to the nearest1 market). Factors that maximized the predictability of the model were included while the factors, which reduced the model predictability, were excluded from the analyses.

3.2.2.1 Dependent variables

1=adopted either ripping or tied ridging or both, 0= no adoption

3.2.2.2 Independent variables

EDTN: Formal education level in years (+)

GENDER: Dummy 1 for male and 0 otherwise

OFFEMP: Off farm employment. Dummy 1 for those with off-farm employment and 0 otherwise (+)

EXP: The number of years the farmer has been in farming (+/-)

FAMLB: The number of adults providing family labour (+/-)

FARM SIZE: Size of the cropland in hectares (+)

EXT: The number of times the farmer has had extension contact in the last four years (+).

GRPMB: Membership to a farmers group. Dummy 1 for members, 0 otherwise (+)

DTM: Distance to the nearest market in Km (-)

The specification of the model was influenced by a number of working hypotheses. It was hypothesized that a farmer's decision to either adopt or not adopt the conservation tillage practices at any point in time is influenced by the combined effect of a number of factors related to farmers' objectives and constraints (CIMMYT, 1993). The variables in the model were hypothesized to influence the adoption of conservation tillage practices positively (+), negatively (-), or both positively and negatively (+/-). The hypothesized variables included:

Education (EDTN): This was the number of years of formal schooling for the household head. Education was hypothesized to positively influence the decision to adopt (Gould *et* *al*., 1990). This is because more years of schooling tend to make farmers less risk averse thus, enabling them to try out new innovations (Chuma *et al*., 1998). Well-educated farmers easily acquire and comprehend new information hence, demand and utilize complex agricultural technologies. In this study, education of the household head was expected to have a positive influence on the adoption of ripping and tied ridging. The hypothesis that education has a negative influence on adoption of ripping and tied ridging would be rejected in the event that the coefficient of education is positive.

Gender: This variable was coded as a dummy variable, representing the sex of the household head, where male =1, and female =0. Ripping and tied ridging are demonstrated in farmer groups in the study area so that farmers take full control of the practices. Women tend to be more in groups than their male counterpart. Further, the practices are labour intensive in the initial years and women provide most of the labour for food production (Blackden and Bhanu, 1998).

Off farm employment (OFFEMP): This variable was coded as a dummy variable, 1 = household heads with off farm employment and 0 = for those without. The financial resource obtained through off farm can enable a family to acquire the implements; herbicide and other inputs needed for conservation tillage technologies (CIMMYT, 1997). This is related once again to cash flow on the farm, given that someone with a side business is likely to have more cash on hand. The presence of a business is also likely to raise the opportunity cost of family labour.

Family labor (FAMLB): This was the quantity of labour in man-days per year available to the household for farming. The amount of family labour available on the farm was estimated based on the composition of the family and the participation of the family members. Smallholder farmers have a low propensity to hire labour outside their farms, because they are resource constrained. They mainly use family labour to do most of the farm work (CIMMYT, 1997). Family labour is increasingly scarce in the study area. This situation should ultimately lead to technologies such as reduced tillage systems, direct seeding technologies, herbicides, weed wipes or sprayers that save labour, although many farmers may not find them accessible or affordable. The hypothesis that family labour has a negative influence on the adoption of the conservation tillage practices would be rejected in the event that the coefficient of family labour is positive.

Farm size: This was the size of land, in hectares, cultivated for maize and cowpea production. Farmers with bigger farm sizes are more likely to adopt conservation tillage than those with small farm sizes. (Gould *et al.*, 1990). Farmers with bigger farm sizes may have an extra land to try the new practices before they decide switching from the conventional practices. The hypothesis that farm size has a negative influence on the adoption of the conservation tillage practices would be rejected in the event that the coefficient of farm size is positive.

Experience (EXP): This was the number of years of farming experience of the household head. Frank, (1995) observed that individuals assess the utility of new practices by relating their perception of the practice to their experience. Consequently, years of farming experience and exposure are likely to aid adoption. Experience of the household head was measured by the number of years one had been farming up to the time of the study. If, through experience, adoption leads to higher rewards compared to costs, farmers are likely to adopt new technologies. The hypothesis that farmer's farming experience has a negative influence on adoption of conservation tillage practices would be rejected in the event that the coefficient of farming experience is positive.

Extension services and technology promoters (EXTORG): This was the number of times a farmer has had contact with the researchers and extension officers in the last four years. The farmer was asked to recall or refer to farm records for the number of times the extension officer or technology promoters had visited him/her for the purpose of conservation tillage. It was hypothesized that the frequency of contact would highly enable adoption. Regular contact would facilitate access to farm inputs especially herbicides, seeds and information. Hence the hypothesis that extension contact has a negative influence on the adoption of the conservation tillage practice would be rejected in the event that the coefficient of extension contact is positive.

Membership in farmer organizations (GRPMB): This variable was coded as a dummy variable, where members to a group=1, and non-members=0. Members of an organization for instance, farmer groups, and non-governmental organizations are more privileged compared to other farmers in terms of access to information on agricultural innovations (de Harrera and Sain, 1999). Groups have taken an active role in mitigating drought impacts on their members and the scope of drought mitigation appeared to expand as groups mature over time (Coopock *et al.,* 2005). Membership in a farmer organization is expected to relate positively to the adoption of conservation tillage practices.

Distance to the nearest market (DTM): This variable was measured as the number of kilometers (Km) the farm is to the nearest local market. Farmers who are closer to the input dealer have better access to production inputs necessary for ripping and tied ridging. These inputs may include herbicides, ridgers, subsoilers, cover crop seeds and rippers. Long distance to the market disconnects farmers from the supply chain (Jonas *et al.*, 2008). Low use of farm inputs by smallholder farmers in Sub-Saharan Africa is responsible for the gap between potential farmers yield and actual crop yields at farm level (Jonas *et al.*, 2008).It was hypothesized that the distance to the nearest market (DTM) is negatively related to the adoption process. The set hypothesis that distance to the nearest market has positive influence on adoption would be rejected in the event that the DTM coefficient is negative.

3.3 Problems experienced in estimation

3.3.1 Testing for degree of Multicollinearity

Multicollinearity refers to the presence of linear or near linear relationship among explanatory variables. (Kuotsoyiannis, 1973) Since economic data is often not experimental but based on observations, many econometric variables tend to move together in a systematic way and hence are termed as collinear. The Gauss Markov theorem states that among all linear unbiased estimators, the least square estimator has the smallest variance. However, if two variables are highly or near perfectly correlated then the variance is infinite. As a result, hypothesis testing becomes weak so that diverse hypothesis parameter values cannot be rejected (Greene, 2004).

Standard errors and overall coefficient of determination (R^2) may be used for testing for multicollinearity. If the independents R^2 is greater than 0.8, then multicollinearity is present. If the tolerance value defined as 1 - R^2 is less than 0.20, the independent variable should be dropped from the analysis due to multicollinearity. High multicollinearity leads to infinite standard errors, large insignificant coefficients, large covariance and large confidence intervals.

3.3.1 Testing of Heteroscedasticity

One of the major problems with cross-sectional data is the tendency of the disturbances to vary with some or all the explanatory variables (Kennedy, 1985). This violates the constant variance assumption of the disturbance terms resulting in heteroscedasticity. Heteroscedasticity renders the estimated β (beta) inefficient and thus invalid for use in making predictions about the dependent variable (Green, 2004)

Heteroscedasticity was tested using the log likelihood ratio (LR) statistic. The null hypothesis was that the model in question was heteroscedastic against the alternative that it was homoscedastic. The LR statistic is similar to the F test in OLS. It is asymptotically distributed as the chi-square χ^2 with k degree of freedom, where k is the number of the independent variables in the model. The LR was calculated with the following formula: -

$$LR = -2(Ln_{het} - Ln_{hom}) \quad (3.4)$$

Where:

Ln_{het} is heteroscedasticity log-likelihood

Ln_{hom} is log-likelihood functions.

3.3.2 Assessing the goodness of fit

The goodness of fit is a summary statistic indicating the accuracy with which a model approximates the observed data. To measure the goodness of fit in qualitative models, Greene (2004) suggests the use of likelihood ratio index (LRI). The LRI also called McFadden's R^2 or Pseudo R^2 and is analogous to the R^2 in the conventional regression. It was computed with the following formula:

$$LRI = 1 - LnL/Ln_o \quad (3.5)$$

Where LnL is the log-likelihood function for the model having all the independent variables and Ln_o is the log-likelihood function for the model computed only with the constant term. A zero value of LRI indicates lack of fit while a value of one indicates a perfect fit.

3.4 Computation of partial budgets

Partial budgets were used to evaluate extra costs and extra benefits derived from the use of conservation tillage on maize and cowpea farming system. The extra benefits are the additional revenues while the extra cost are the additional expenses, as a result of ripping and/or tied ridging. The saved costs are the expenses that the farmer does not incur as a result of ripping and tied ridging use. The forgone benefits included the revenues that a farmer forgoes as a result of the new technologies. The net farm income was computed by summing up the extra benefits and saved costs of ripping or tied ridging then subtracting from it the sum of extra costs and forgone benefits costs. The budgets were used to analyse marginal changes in costs and benefits as a result of use of conservation tillage. This allowed comparison of adopters and non-adopters thus the impact of the technology on the net farm income.

The study evaluated increased maize and cowpea yields, saved ploughing costs at land preparation and reduced labour costs. The extra costs included costs of preparing the depressions for tied ridging, cost of harvesting the extra maize and cowpea yields, the extra pesticide used for pest control and any herbicide used for weed control not previously used under conventional tillage.

3.5 Area of study

Makueni District has a population of over 245,768 people (CBS Kenya, 2001) who are mainly subsistence farmers. It is one of the districts where several water conservation measures have been introduced and used by the residents (Tiffen *et al.*, 1994). Ripping and tied ridging are the most recent conservation tillage practices that were introduced by FAO and the practices advanced by KENDAT, ATDC and MoA in the district. Other practices for conservation tillage in the district are zero tillage, sub soiling and mulching that are mainly applied for biennial crops such as bananas (Biamah *et al*., 2001).

Maize and cowpea are the major food crops in the district. They are grown as intercrop under either ripping/tied ridging or conventional tillage. Other types of crops grown are beans, pigeon peas, cassava, sweet potatoes, local mangoes, sorghum and kales.

The district receives bimodal rainfall with the most reliable rains occurring in October to December (short rains). The long rains occurring in April to May are unreliable in both amounts and distribution (Okwach *et al*., 2004). A lot of rainfall is lost through water surface runoff and this, together with poor tillage practices have resulted in low soil moisture thus low crop yields. To address this problem, appropriate conservation tillage technologies were introduced in the area with the objective was to sensitize and train farmers on the methods of conservation tillage in order to reduce soil moisture loss and increase yields.

3.6 Data collection and Sampling procedure

The model used in this study required both primary and secondary data. Primary data were collected by use of questionnaire interviews from Kalawa and Kathonzweni divisions in Makueni district from December 2006 to June 2007. Four enumerators were recruited and trained on the collection of primary data for the study. Secondary data were collected from institutional libraries which included World Agro-forestry Research Centre, University of Nairobi and the Ministry of Agriculture.

In this study, an adopter was identified as a farmer who had been using either ripping or tied ridging or both for the last four years up to the time the study was conducted. A farmer was considered an adopter despite the size of land allocated to the technologies. A sampling frame of 90 farmers who had adopted conservation tillage practices within maize-cowpea crop systems was gathered from the local non-governmental organizations, mainly ATDC, and public extension personnel operating in the study area. All the farmers in this list were selected. However, only 87 of them were interviewed since the rest were unavailable. The sampling frame for the non-adopters consisted of adopters' neighbours who were growing maize and cowpeas but had not adopted the conservation tillage practices. For every adopter the closest neighbouring household was selected. Thus a total of 90 non-adopters were purposively sampled and interviewed.

The final sample therefore consisted of 177 purposively sampled farm households. All of them were interviewed using a semi structured questionnaires. The data gathered during these interviews included socio-economic characteristics, reasons for adopting/not adopting the conservation tillage practices, agronomic characteristics, market access characteristics and perceptions towards conservation tillage practices. The data was entered and analyzed by use of the Scientific Package for Social Sciences (SPSS) and the NLogit was used estimate the model. Due to the low adoption of ripping and tied ridging, analysis for technology adoption was not done separately since each group sample size does not meet the large sample size requirement i.e. $n > 120$.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Descriptive analysis of the socio-economic characteristics for adopters

The study interviewed 87 adopters of ripping and tied ridging with an average land size of 1.22 hectares (Ha) per household who devoted an average of 10 percent of their total cropping area to ripping and tied ridging during the long and short rains cropping season. Of the adopter, 93 and 7 percent had used conservation tillage for at least four and six years respectively by the time of the study.

Maize and cowpea intercrop was grown after the preparation of tied ridges and rips. Non-adopters had an average land size of 1.13 hectares. Land size was not significantly different between adopters and non-adopters. The minimum and maximum land size was 3 Ha and 15 Ha respectively. A farmer was considered as an adopter despite the size of land allocated to the conservation tillage technologies. Thus, 93 percent of the adopters were using at most 0.4 Ha for ripping and tied ridging and only four farmers were practicing the technology at 1.7 Ha.

Table 4.1.1 below presents the descriptive analysis of some discrete variable for the adopters of ripping and/or tied ridging.

Table 4.1.1 Descriptive analysis of discrete variables for the adopters

Variable	Category	Number reporting	Percent
Gender	Female Male	55 32	63 37
Group membership	No Yes	16 71	18.4 81.6
Off-farm employment	No Yes	21 66	24.4 75.8

Source: Own survey, 2007

The adopters were more in off farm employment (Table 4.1.1). Off farm employment provided more cash flow to the household. The income earned off farm enabled farmers to purchase farm inputs for either ripping or tied ridging or both components which included rippers, ridgers, and herbicides for weed control and wages for hired labour. The rippers and ridgers were owned by 4 and 5 percent of the adopters respectively who also had a side business. Therefore, farmers in off farm employment were more likely to adopt ripping and/or tied ridging.

The study found out that public extension officers and non-government organisations promoting ripping and tied ridging preferred working with farmers who showed common interests and hence in groups. Group membership is crucial in the study area since most of the demonstrations and farm trials on ripping and tied ridging were carried out among farmers in groups. The groups are also important in the procurement and ownership of implements for conservation tillage practices. Hence 55 percent of the rippers and ridgers were group owned by 82 percent of the adopters who were member to farmers' group (Table 4.1.1). Of the non-adopters, 38 percent reported that the status was due to lack of information which is accessible from groups. This illustrates that non-adopters joining groups or forming new ones could lead to more adoption of the technologies. The groups mainly included self-help groups, common interest groups and farmer co-operatives. The main objective of these groups was to improve the farm incomes by procuring the farm inputs and marketing the products, collectively.

The mean age of household heads for adopters and non-adopters was 51 and 49 years respectively. The age difference between the two groups was not significant. Majority of the household heads in both groups were male but 63 percent of the adopters were female ripping and tied ridging than their male counterpart. This is attributed to the fact that women provide most of family labour for crop production. In addition the practices contribute to increased crop yields and farm income as a result of soil moisture conservation hence more food to the household.

4.1.2 Descriptive analysis of the sample socio-economic characteristics

The sample socio-economic characteristics for adopters and non adopters were analyzed and presented in Table 4.1.2 below. The mean, standard deviation, maximum and minimum analysis of each continuous variable is described table 4.1.2 below. Not all the continuous variables were included in the model.

Table 4.1.2 Descriptive analysis of some continuous variables for the adopters and non adopters

Variable	Definition	Mean N=177	Standard deviation	Minimum	Maximum
Extension services	Number of contacts by technology promoters for last four years	1.122	0.740	1.451	3.042
Farming Experience	Farming Experience of the household head in years	18.769	1.876	1.046	49.01
Farm size	Total farm size in hectares	4.676	.856	3.086	15.43
Education	Level of Education in years in formal school	9.231	.961	7.99	15.78
Family labour	Family size as per the number of people providing family labor	1.413	2.469	1.00	13.00
Distance to market	The number of kilometers the farm is to the nearest local market	2.970	1.623	0.20	18.09
Farm size under crops	Farm size under maize and cowpea in hectares	1.109	0.171	0.150	3.772
Age	Age of farmer in years	43.39	9.75	16.00	75.00

Source: Own survey, 2007

Contact with technology promoters and public extension agents were found to increase the probability of using the technologies. Backstopping and information provision for ripping and tied ridging was done by both the governmental and non governmental organizations. The major technology promoters in the area of study were reported as KENDAT, MoA and the FAO and promoted the technologies at 36, 21 and 9 percent respectively in the last four years. Table 4.1.2 above shows that farmers had been contacted at least once by these organizations for the last four years. The respondents reported that during farm visits, technology promoters also educated farmers on crop husbandry besides ways of countering moisture stress to improving the farm yield and income.

Among the non-adopters, 38 percent of the farmers did not practice conservation tillage due to lack of information, 23 percent were not interested and 15 percent expressed lack of equipment for conservation tillage while 3 percent gave the reason of land constraint. The conservation tillage implements are perceived to be expensive by most farmers. Hence most implements are group owned whereby the group members hire the implement at a fee. From personal interviews with the group members the fee is Ksh 100 and Ksh 300 per acre for members and non members respectively.

On average, the distance walked by farmers to the nearest market was 3 kilometers (Table 4.1.2). Accessibility to the market contributed to more adoption of ripping and tied ridging. The study found that 45 percent of the adopters were at least one kilometer away from the market, hence could easily access farm inputs like herbicides, rippers and effectively market their farm produce. The study found out that farmers far away from the market used other conservation measures to improve the soil moisture.

Farming was the primary occupation for over 75 percent and 72 percent of the adopters and non-adopters respectively. Only 93 percent of all household heads were farm managers. There was no significant difference in land ownership between adopters and non-adopters and most of the land was inherited from parents, hence many farmers from both groups had not acquired title deeds.

From personal interviews with the adopters, 79 percent perceived farm yield reduction due to the effect of low soil moisture as a problem requiring intervention while only 20 percent did not. Farm yield reduction was reported as a major problem by 83 percent the non-adopters. The results further showed that 65 percent of the adopters used other options to improve soil moisture and consequently crop yields. These options included cover cropping, intercropping and sub soiling.

Most of the respondents had acquired up to primary education level (Table 4.1.2). In the whole sample, 30 and 15 percent had up to secondary and tertiary education level respectively while 1 percent had adult education. Among the adopters 33, 14 and 10 percent had primary secondary and tertiary education respectively. The adopters and non-adopters were almost equally educated implying that the technologies were simple enough to be understood by all farmers at whatever education level.

Generally, adopters of conservation tillage were more in off farm employment, had more farming experience, were more in farmer groups and had more contact with technology promoters in the past four years. Contact with technology promoters provided access to information thus enhancing adoption.

4.2 Methods used by farmers to conserve soil moisture

As discussed earlier, soil moisture is the most critical constraint that limits crop production in the semi arid areas. Table 4.2.1 below presents an adoption matrix on the two major conservation tillage measures used to conserve soil moisture in Makueni district.

Table 4.2.1 Adoption matrix for conservation tillage in maize-cowpea production system in Makueni district

		Adopted Ripping Component		
Adopted Tied Ridging Component		No	Yes	Σ
	No	13%	28%	31%
	Yes	14%	45%	59%
	Σ	27%	73%	100%

Source: Own survey, 2007

Table 4.2.1 shows how relatively more farmers adopted the ripping component than tied ridging since the latter practice requires specialized planters that operate better in heavy crop residues. In the study area most farmers do not leave the crop residues on the farm because there is strong demand of crop residue as forage for livestock. The study found out that farmers in ripping or tied ridging had something to harvest especially in times of unreliable rainfall unlike those in conventional tillage. The farmers attributed the improved yields to conservation of soil moisture as a result of ripping and tied ridging use. Other farmers reported that in seasons of abundant rainfall the yields of maize and cowpea under conservation tillage and conventional tillage are almost the same. The adopters for either of the technologies were more food secure than the non-adopters.

The farmers cited soil moisture conservation to be important due to rainfall uncertainty during and between seasons hence 79 percent of the farmers reported to experience reduced yields and sometimes total crop failure. Despite crop failure in the previous seasons, farmers in the study area still continued to take risk of planting maize and cowpea. The study found out that both the adopters and non adopters were using other measures to conserve soil moisture besides ripping and tied ridging. These methods included cover cropping, sub soiling and mulching.

4.3 The financial benefits of ripping and tied ridging

The partial budgets were used to compute the financial returns of ripping and tied ridging. As discussed in section 3.2, the partial budget required the extra costs and benefits from the use of the technologies. Table 4.3.1 presents the mean, minimum and maximum yields of maize and cowpea under conservation tillage and conventional tillage. The mean yields of maize and cowpea were used in the preparation of the partial budgets to account for the net farm income as a result of use of ripping and tied ridging.

Table 4.3.1 Yields of maize and cowpea (90kg bag) under conservation and conventional tillage

Variable	Crop	Mean	Std. dev.	Minimum	Maximum	Case (n)
Yield under conventional tillage	**Maize**	7.384	5.0102	3.000	20.000	90
	Cowpea	5.9	5.234	.747	4.0000	90
Yield under conservation tillage	**Maize**	8.538	6.752	7.000	30.000	87
	Cowpea	10.4	8.750	2.780	7.0000	87

Source: Own survey, 2007

The prices of maize and cowpea were obtained from the farmer's records. The study took the prices at harvest and of three months after harvest. Food insecure households mainly sell their crop yields while still in the field or immediately after harvest as compared to food secure households, who harvest, store and sell their food after some time. The price for maize at harvest was Ksh15 per kilogram while three months after harvest the price was Ksh25. The average price for maize was thus Ksh20 per kilogram. For cowpea, the price at harvest was Ksh35 per kilogram while three months after harvest the price was Ksh45. Thus the average price for cowpea was Ksh40 per kilogram.

The mean yields for maize and cow pea were obtained for both conservation tillage and conventional tillage (Table 4.3.1). These yields were used to calculate the net farm income resulting from the use of ripping and tied ridging. The study attributed 95 percent increase of the maize and cowpea yields as a result of ripping and tied ridging.

Table 4.3.2 below presents the partial budgets when farmer substitutes ripping for conventional tillage. The net farm income as a result of ripping was computed and analyzed.

Table 4.3.2 Partial budgets to estimate net farm income, in maize cowpea cropping system, from substituting ripping for conventional tillage per hectare per year

1. Specification

One hectare of ripping substituted for one hectare of conventional tillage (CONTIL)

2. Items in present system likely to be changed
   a) loss of output of one Ha of maize and cowpea
   b) change in total labour force
   c) no change in total land use
   d) use of herbicides for weed control

3. Estimated gains and costs (Ksh)

Gains		Costs	
a) Extra returns		b) Extra costs	
Maize and cowpea yields under ripping	52,808	Cost of ripper hire	100
		Cost of ripping	500
		Herbicide costs	600
		Cost of harvesting the extra yield (100*4)	400
c) Saved costs		d) Forgone benefits	
Ploughing costs	3,000	maize and cowpea yield under CONTIL	34,531
Total extra benefits	55,808	Total extra costs	36,131

Net farm income 52,808 - 36,131 = 21,277

Source: Own survey- partial budget analysis, 2007

The labour value for planting, ripping and creating the rectangular depressions was obtained by multiplying the man-days required to carry out the activities by the average wage rate that was Ksh100 per 7-hour man-day. The prices of hiring the implements were obtained from the farmers who belonged to farmers groups.

The adopters of ripping experienced more yields than the non-adopters hence more farm income from the sale of maize and cowpea. Further, the forgone ploughing costs also meant more farm incomes for the adopters. Thus the positive net income (Table 4.3.2) is as a result of change that increases revenue by more than the increase in the expenses, when a farmer uses ripping. The forgone revenue i.e. expected value of income that will no longer be received from conventional tillage which is Ksh 34,531 is less than the additional revenue, Ksh 52,808 which is as a result of ripping. In addition the added expenses, Ksh 1600, as a result of ripping are less than the reduced expenses, Ksh 3000, which were emerging from the use of conventional tillage. Therefore, this implies that the technology is more profitable than conventional tillage. Hence non adopters should be encouraged to use this technology and experience the benefits of the technology. Government and non governmental organizations should intensify campaigns to adoption of ripping which result to more food to the household.

In addition, the adopters reported to experience intangible benefits from the use of ripping. From personal interviews with the adopters of ripping 89, 13 and 99 percent stated to experience increased soil moisture, improved soil fertility and advantage of early planting respectively. Further, the adopters stated to have more time freed to work in other farms, attend to other farm activities and reducing time needed for draught animals in the field thus more time available for tilling additional land.

The net farm income as a result of use of tied ridging was also computed and analyzed from the partial budgets. Table 4.3.3 below presents the partial budgets when farmer substitutes tied ridging for conventional tillage.

Table 4.3.3 Partial budgets to estimate net farm income, in maize cowpea cropping system, from substituting tied ridging for conventional tillage per hectare per year

1. Specification

One hectare of tied ridging substituted for one hectare of conventional tillage (CONTIL)

2. Items in present system likely to be changed
   a) Loss of output of one Ha of maize and cowpea
   b) Change in total labour force
   c) No change in total land use
   d) Use of herbicides for weed control
   e) Construction of rectangular depressions

3. Estimated gains and costs (Ksh)

Gains		Costs	
a) Extra returns		b) Extra costs	
Maize and cowpea yields under ripping	52,808	Hire of ridger	100
		Cost of ripping	500
		Costs of depressions	2000
		Herbicide costs	600
		Cost of harvesting the extra yield (100*4)	400
c) Saved costs		d) Forgone benefits	
Ploughing costs	3,000	maize and cowpea yield under CONTIL	34,531
Total extra benefits	55,808	Total extra costs	38,131

Net farm income 55,808 - 38,131 = 17,677

Source: Own survey- partial budget analysis, 2007

The positive net income (Table 4.3.3) is as a result of change that increases revenue by more than the increase in the expenses. The expected value of income that will no longer be received from conventional tillage which is Ksh 34,531 is less than the additional revenue, Ksh 52,808, which is as a result of tied ridging. In addition the added expenses, Ksh 3600, as a result of tied ridging are slightly more than the saved costs, Ksh 3000, which were emerging from the use of conventional tillage (Table 4.3.3). However, the extra costs were reported to reduce in the subsequent years. Therefore, tied ridging is more profitable than conventional tillage and hence more farmers should be encouraged to adopt tied ridging which has the potential of increasing farm income and crop yields and more food to the household.

The adopters of tied ridging experienced the same intangible benefits as those of ripping. However, the adopters of tied ridging reported lot of labour is required for the preparation of the rectangular depressions especially in the first year of adoption. However, the adopters of tied ridging stated to experience reduced costs for depression construction, in the subsequent years since the depressions only require minimal maintenance.

Thus ripping and tied ridging have higher financial gains than conventional tillage. The hypothesis that the net farm income of conservation tillage is not different from that of conventional tillage was rejected.

4.4 Factors influencing the decision to adoption of ripping and tied ridging

The results of marginal effects for the factors influencing the adoption of the conservation tillage practices were analyzed by use of the logit model as shown in Table 4.4.1 below. The Table also includes the list of independent variables used in the model and the expected effect.

Table 4.4.1 Marginal Effects of the factors influencing the adoption of ripping and tied ridging

Variable	Coefficient	S.E	T-value	Hyp-sign	obs-sign
Experience	.036**	.0195	1.876	+	+
Contact with Extension & promoters	1.317*	.533	2.469	+	+
Group membership	.344**	.738	.466	+	+
Off farm employment	.778*	.453	.0860	+	+
Family labour	.253**	.179	1.416	+	+
Distance to nearest market	-3.44	.631	5.467	-	-
Farm size	-.309	.153	-2.021	+	-
Education	-.247	.093	-2.650	+	-
Gender	-.244	.629	-.388	+	-
Constant	-1.8051				
Pseudo R^2	.3576				
Percent correctly predicted	89.231				
Model chi-square	69.941***				
Log likelihood function (LnL)	-101.4868				
Log likelihood function (LnLo)	-157.9848				

***, **, * Significant at 1%, 5%, 10% level of error probability respectively

Model size N= 177

Source: Own survey- results of Logit analysis 2007

The significant variables were listed and the rationale behind them explained.

The coefficient of farming experience was positive and significant at 5 percent level. Farmers with more farming experience were more likely to adopt ripping and tied ridging.

This relationship implied that experienced farmers have a better technical knowledge and thus could evaluate technologies easily. As farmers gain experience, their decision-making skills are influence positively (Adesina *et al*, 1993). At the mean score, a unit increase in farming experience increased the log-odds of adopting ripping and tied ridging by .036 when the other variables are held constant (Table 4.4.1). This part of the observation agrees with the human capital theory, which holds that farmers become less risk averse as they gain more experience (Welch, 1979). Thus farmers with more farming experience make decisions and are able to adopt new innovations easily once their gains and costs are evaluated. Thus the hypothesis that experience of a farmer has negative influence on use of ripping and tied ridging was rejected.

The coefficient of public extension service contact and other technology promoters was positive and significant at 10 percent level. Direct contact with extension services and organizations promoting the technologies provided technical backstopping in terms of information, rippers, farm demonstrations and other inputs to the framers. This implies that there is need for frequent contact of farmers and the promoters of the technology if mass adoption is to be achieved. The demonstration of Ripping and tied ridging to farmers by the extension officer made the technology use easier for the farmers and thus increased the probability of the farmer adopting the technologies. Kaumbutho and Mutua (2002) study found that the already existing draught animal resource backed with thorough extension services could boost the use of conservation tillage technologies in Makueni and Laikipia districts. At the mean value, a unit increase in public extension contact and technology promoters increased the log-odds of adopting ripping and tied ridging by 1.317 when the other variables are held constant. Thus the hypothesis that extension contact has a negative influence on ripping and tied ridging was rejected.

The coefficient of group membership was positive and significant at 5 percent level. Farmers who were members of a group were more advantaged since they could hire the implements owned by the group at a reduced fee. The farmers being in groups could get new ideas and even loans for development. The members of self help groups and common interest groups could buy seeds and herbicides collectively and benefit from reduced prices. Furthermore, the members could learn from each other particularly those not reached by extension agents. Non-governmental and government organisation preferred disseminating information to farmers in groups due to scarcity of personnel and other resources. This implies that group membership is important in the dissemination of technologies at the grass root level. At the mean score, a unit increase in group membership increased the log-odds of adopting ripping and tied ridging by 0.344 when the other variables are held constant. This findings relate to work done by Grootaert (2001) described the group formation as collective active action well known as a positive force for improving risk management in many rural communities of the developed world. The hypothesis that group membership has a negative influence on adoption of the conservation tillage practices was rejected.

Off farm employment was and significant at 10 percent level. Farmers who were employed off farm had more cash flow on the farm thus was convenient to practice conservation tillage since they could hire or buy the implement with the income earned off farm. This corresponds with the findings of descriptive analysis. The presence of off farm employment is likely to raise the opportunity cost of family labour. This finding supports the importance of agriculture in the reverse linkage especially in the meso-level development (CIMMYT, 1993). At the mean score, a unit increase in off farm employment increased the log-odds of adopting ripping and tied ridging by 0.778 when the other variables are held constant. This meant that farmers with off farm employment were better adopters of the conservation tillage practices.

Family labour was significant at 5 percent level. Ripping and tied ridging require labour in the preparation of the rectangular depressions, rips, weeding and harvesting the extra yields. Hence farmers with more family members living in the household meant more family labour and thus were able to adopt ripping and/or tied ridging. At the mean score, a unit increase in family labour increased the log-odds of adopting ripping and tied ridging by 0.253 when the other variables are held constant (Table 4.4.1). The hypothesis that family size had a negative influence on the adoption of ripping and tied ridging was not accepted.

Distance to the nearest market negatively influenced the adoption of ripping and tied ridging. The distance to the nearest market was significant at 10 percent level. The set hypothesis that distance to the nearest market has a negative influence on the adoption of ripping and tied ridging was rejected. This might have been because farmers far from the market do not have access to farm input and information on ripping and tied ridging hence they tend to use other soil and moisture conservation measures such as cover cropping. Also, farmers far from the market may not market their additional farm yield effectively.Long distance to the market disconnects farmers from the supply chain (Jonas et al, 2008). At the mean score, a unit increase in distance to the nearest market decreased the log-odds of adopting ripping and tied ridging by 3.44 when the other variables are held constant (Table 4.4.1).

Variables that did not influence the decision to use conservation tillage were gender, education, and hired labour. This led to rejecting the null hypothesis that the decision to adopt conservation tillage was significantly influenced by the mentioned variables. The lack of significance on gender variable did not imply that there was no difference in the decision to adopt conservation tillage between male and female farmers. It rather points out that differential access to productive resources such as land; capital and information are more important determinants of conservation tillage adoption than gender *per se*. This is supported by the differential land size owned by men and women. The fact that education is not significant implies that the technology is not complex to understand thus can be used by anybody at any level of education. Farm size was negative, implying that farmers with smaller piece of land were more likely to make a decision to use the technology at a higher level than farmers with bigger farm sizes. This was contrary to expectation but could be attributed to farmers being risk averse and still want not to abandon to their old technologies.

4.5 Data and estimation problems

The included variables were tested for multicollinearity, heteroscendasticity and goodness of fit. Multicollinearity was tested in this study by a combination of inspection of the standard errors, R^2, tolerance value and use of partial correlation. Based on this, the variable showed no problem of multicollinearity. See appendix 1.

On the other hand, The computed LR value for the model on the probability of adoption of ripping and tied- ridging was 6.539 while the tabulated chi-square value, at $\alpha = 0.01$ and $k = 8$ was 36.725. Since the calculated LR value was less than the tabulated chi-square value, the null hypothesis of heteroscedasticity was rejected. These results are indicated on appendix II. The computed Pseudo R^2 was 0.3576 for the probability of conservation tillage adoption model, indicating near perfect fit. The illustration of these results is in appendix III.

CHAPTER 5: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY

The study was carried out in Makueni District of Eastern Kenya. The study covered two divisions Kalawa and Kathonzweni. Two locations were selected from each division based on their importance on conservation tillage. The study analyzed the factors that influence the adoption of ripping and tied ridging and the net farm incomes of these technologies. Data was collected by use of semi-structured questionnaires through interviews. The study interviewed 87 adopters of ripping and tied ridging and 90 non-adopters of ripping and/or tied ridging. The adopters were identified by use of a sampling frame, of 90 farmers, kept by the ATDC at Machakos district. The adopters identified the non-adopters and a sampling list of 120 non-adopters was developed from which the non-adopters were purposively selected. An adopter was a farmer who had been using ripping and/or tied ridging technology in the last four years and was still using the technology, up to the time of the study despite the size of land under the technologies. A non-adopter was a farmer who had never used ripping and/or tied ridging and thus was purely practicing conventional tillage.

The adopters had average land size of 1.22 hectares (Ha) per household who devoted an average of 10 percent of their total cropping area to ripping and tied ridging during the long and short rains cropping season. By the time of the study, 93 and 7 percent of the adopter had used ripping and tied ridging conservation tillage for at least four and six years respectively. Only 95 percent and 5 percent of the adopters used at most 0.4 Ha and 1.7 Ha respectively for the conservation tillage practices.

Of the adopters 28, 14 and 45 percent had adopted ripping, tied ridging and both ripping and tied ridging respectively, by the time the study was conducted. Ripping was used more than tied ridging since the ridgers operates better in heavy crop residue that is not feasible in Makueni district since the crop residue is preserved as livestock foliage.

Majority of the household heads were male aged on average 51 years and literate. The adopters comprised of 63 and 37 percent of female and male respectively. This shows that women are in the front-line for uses of conservation tillage practices that have the potential to increase maize and cowpea yields hence ensure a household food security.

The non adopters expressed lack of; information, interest, implement and land as the major reasons for not adopting ripping and tied ridging at 28, 23, 15 and 3 percent respectively. The groups were important especially in the acquisition of the implements which are deemed to be expensive to an individual farmer hence 55 percent of the implements were group owned while 5 percent were individually owned. Only 67 percent of the adopters belonged to a farmer group which was either self help group or a cooperative.

The descriptive statistics further showed that off farm employment was significant to the adoption of ripping and tied ridging. Off farm employment increase the farm cash flow hence the high probability of acquiring ripper, ridgers and other inputs.

The descriptive statistic further revealed that farmers far away from the market used other means to conserve the soil moisture such as sub soiling, mulching and cover cropping since they could not easily access the implements, information and other inputs necessary for conservation tillage.

Logit analysis showed that off farm employment, farming experience, group membership, family labour, extension contact and distance to the nearest market were factor that significantly influenced the adoption of conservation tillage. Farm size, gender, education and hired were factor not significant. Education being insignificant could mean that the technology is simple to be understood by farmers despite the education level as long as the technology is well communicated and disseminated at the farm level.

Extension services positively influenced the adoption of conservation tillage and would mean that extension contact is important in the adoption of ripping and tied ridging since demonstration of the technologies at on farm by the extension agents boosts the farmers' confidence in the use of the technology and more information gained.

Most organisations prefer disseminating technologies to farmers already in groups since they show a common interest thus most of the adopters in the study area were in groups. Ripping and tied ridging freed up labour hence the adopter of conservation tillage practices had more time to work off farm hence more cash flow to purchase the inputs necessary for ripping and tied ridging. Family labour was crucial in the adoption of the practices since the practices are labour intensive especially weeding and preparation of the depressions for tied ridging.

The partial budgets revealed that ripping and tied ridging are more profitable than conventional tillage. Farmers have higher yields with ripping and tied ridging especially in times of poorly distributed rainfall. However, in times of abundant rainfall the yields under ripping, tied ridging and conventional tillage were reported to be almost equal.

Under ripping, the adopters realised a net farm income of Ksh 21,277 per hectare per year. The net farm income returns under tied ridging were Ksh 17,677 per hectare per year. The intangible benefits experienced by the adopters of both ripping and tied ridging were increased soil moisture, improved soil fertility, early planting and more time freed to work in other farms or attend to other farm activities and reducing time needed for animals in the field hence more time available for tilling additional land. The costs incurred by the adopters were herbicides for weeding and labour for ripping and ridging as well as labour for weeding where the herbicide are not used.

5.2 Conclusions

This study examined factors that influence the adoption of the conservation tillage practices and used a logistic regression to identify the significant variables. The study also analyzed the profitability of ripping and tied ridging by use of partial budgets. The factors that significantly influenced the adoption of ripping and tied ridging were group membership, off farm employment, farming experience, extension contacts and distance to the market.

Extension providers and promoters were found to enhance the confidence of farmers in adopting ripping and tied ridging through demonstrations and farm trials. This is because direct contact with extension services and organizations promoting the technologies provided information and technical backstopping on these technologies. Therefore extension services and technology demonstration could be intensified among farmers to enhance conservation tillage uptake. It is important to note that this should not be limited to farmers far from the road or market places if the current adoption rate is to be enhanced.

Off farm income positively affected the use of conservation tillage. External off farm income sources are relevant since they enable farmers to undertake agricultural practices that may otherwise jeopardise the farmer's subsistence income. Off farm income help the farmer purchase the implement needed for conservation tillage for instance a ripper.

Farmers who could not purchase the implements or access information and were interested in adopting the technologies joined farmer groups. Farmers in self help groups and other common interest groups were better adopters of ripping and tied ridging since most of the organisation found it cost effective to disseminate technologies in groups. Therefore, non-adopters should be encouraged to join existing groups or form new ones in order to learn practically from each other and access benefits that adopters in farmer groups have been enjoying.

Ripping and tied ridging are assure the farmer of improved crop yield and farm incomes. the technologies are labour intensive especially in the initial years hence the house holds with larger family members participating in the farm work were found to adopt these practices.

The partial budgets results showed that ripping and tied ridging have higher revenues and lower costs than conventional tillage. Therefore non-adopters should be encouraged to adopt these technologies. The benefits of conservation tillage described outweigh the costs. Further, ripping and tied ridging result to improved soil fertility and soil moisture that translate to higher crop yields and farm incomes.

5.3 Recommendations

Conservation tillage is one of the strategies of improving livelihoods in the semi-arid lands. The increase in income and yield due to improved soil moisture as a result of ripping and tied ridging implies that these technologies are means of empowering the farmer to be self-reliant and increase agricultural productivity and production. Therefore NGOs and government authorities should incorporate group membership, off farm employment, farming experience, extension contacts and distance to the market in the design of policies and strategies developed to promote the use of conservation tillage practices. Understanding these factors will facilitate a targeted approach in promoting use of conservation tillage in order to enhance maize and cowpea production in the semi-arid areas. In addition, in the effort of promoting ripping and tied ridging the technical gains should now be augmented with the financial gains so that mass adoption is achieved.

Group membership is significant to the adoption of conservation tillage. There is need to strengthen this membership and participation since most NGOs and extension agents mainly target farmers in groups because they have a common interest and could be efficient. Most of the farmers in groups are participative in on-farm trials and demonstrations. This already acquired knowledge and skills can be exploited to benefit other farmers especially the non-adopters by forming or joining groups.

To improve on the technology information flow, there is need to establish and strengthen network of information exchange among relevant and interested organizations like community based organizations and churches among others.

Contact with extension agents and other technology promoters were significant in the adoption of conservation tillage. There is need to strengthen this contact due to limited resources. This can be done by use of mechanisms that enhance grass root capacity building for instance working with farmers' groups and community based organizations. The formation of common interest groups is also important in the dissemination and adoption of conservation tillage. The trainings and demonstrations of conservation tillage practices should not leave out women.

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APPENDICES

Appendix I: Testing for multicollinearity

Partial Correlation Coefficients Matrix.

	FAMLB	EDTN	EXT	HRLOB	GENDER	OFFEMP	GRPMB	EXP	FARMSIZE	
DISMT										
FAMLB	1.0									
EDTN	.23	1.0								
EXT	.04	-.02	1.0							
HRLOB	.12	.19	-.01	1.0						
GENDER	.06	.08	.55	.40	1.0					
OFEMP	-.04	.16	.05	-.18	.22	1.0				
GRPMB	-.08	-.13	.08	.15	.12	-.011	1.0			
EXP	.45	-.14	.16	-.01	.36	-.23	-.15	1.0		
FARMSIZE	.21	.15	.12	.12	.18	.38	.30	.09	1.0	
DISMT	.02	-.04	.015	.11	-.05	-.004	-.13	-.14	.16	1.0

Source: Author's Survey

Appendix II: Testing for goodness of fit

Log-likelihood ratio index (LRI)

$LRI = 1 - L_n L / L_n L_o$

Where,

LRI= log-likelihood ratio index

$L_n L$= log-likelihood function value for the model with all the independent variables

$L_n L_o$= log-likelihood function value for the model computed with only the constant term.

$L_n L = -101.4868$

$L_n L_o = -157.9848$

$LRI = 1 - (-101.4868/-157.9858)$

$= .3576$

Appendix III: Testing for Heteroscedasticity

The probability of adopting ripping and tied ridging.

Likelihood ratio (LR) statistic

$LR = -2\ (L_n\ L_{het} - L_n\ L_{hom})$

Where LR = Log-likelihood ratio

$L_n\ L_{het}$ = log-likelihood of the model with heteroscedasticity.

$L_n\ L_{hom}$ = log-likelihood ratio model without heteroscedasticity (homoscedastic).

Ln Lhet= -98.2171

Ln Lhom = -101.4868

LR = -2(-98.2171-(-101.4868))

= 6.539

χ^2 at 11 degree of freedom and 0.01 significance level = 36.725

LR < χ^2 and therefore we fail to reject the null hypothesis that there is no heteroscedasticity.

QUESTIONNAIRE

Identification

Name of the enumerator……………………………………

Name of the respondent……………………………………

District……………………………………………………….Division……………………..

Location……………………………………………………..Sub-location…………………

Date………………………………………………………….Start time …………………

2.0 Household characteristics

2.1 Age of the farmer……………………..

2.2 Gender (0) female (1) male

2.3 Marital status (1) single (2) married (3) divorced (4) widow/ widower

2.4 Formal education level (years)………………………………

None (2) primary (3) secondary (4) college/ university (5) adult education

2.5 Total number of children…………………………………………

2.5.1 Total number of family members who work on the farm……….

2.6 Are there family members who work off-farm?

(0) No (1) yes

2.6.1 How many? ……

2.7 How much income has been earned off-farm in the last six months? ....

3.0 Farm characteristics

3.1 What is the number of years of farming experience by the household head or spouse?

H/head……………… spouse………..

3.1.1 What is the size of your farm in acres?

3.1.2 Do you own it? (0) No (1) yes

3.2 If yes how did you acquire it? (1) Bought (2) inheritance

3.3 What is the total available land for crop production in acres?

3.4 What is the total available land for maize and cowpea farming in acres?

3.5 Mixed cropping………… Single strands (maize)… Single strands (cowpea)

3.6 Do you use hired labour? (0) No (1) yes

3.6.1 If yes what type of labour?

(1) Temporary (2) permanent (3) both

3.7 What is the value of hired labour (man day)?

4.0 Soil and water conservation technologies

4.1 This area is relatively dry, yet agriculture requires soil moisture. Do you practice irrigation or just rain fed agriculture?

Irrigation…………… Rained……………

4.1.1 If irrigation, from what nature of water source?

Permanent………Seasonal…………..

4.1.2 What size of land……….. ? What crops?

4.2 What is the distance to the nearest water source? Km

4.3 If rain fed, how do you conserve your moisture?

4.4 Are you experiencing reduced yields? (0) No (1) yes

4.5 Is soil compaction a major problem on your farm?

(a) Not a problem (b) minor problem (c) severe problem

4.6 Do you practice conservation tillage (0) no (1) yes

4.6.1 If yes what method(s) do you use?

4.6.2 What is the total available land under conservation tillage in acres?

4.6.3 How long have you practiced conservation tillage……………… years?

4.7 How often do you practice conservation tillage?

4.8 If the answer in part 4.6 is no, why don't you use conservation tillage? Give reason (tick)

Lack of information

Land constraint

Not interested

Other- specify

4.9 What are the farms yields when you use conservation tillage?

4.9.1 If the yields are high on use of conservation tillage, what is the extra cost you bear to harvest/and market the crop?

4.9.2 What are the benefits of using conservation tillage?

Increased yields

Increased soil fertility

Reduced production costs

Others- specify

4.9.3 In how many seasons have you had crop failure for the last four cropping seasons?

1) For one season 2) for two seasons 3) for three seasons 4) for all of the four seasons

5.0 Extension and social capital information

5.1 Have you ever been in contact with any extension services?

(0) No (Yes)

5.1.1 If yes, which organisation?

5.1.2 Have you received any information on conservation tillage from the extension group?

5.1.3 If yes what sort of information?

5.2 Have you trained on how to practice conservation tillage by the extension agent?

5.2.1 If yes what method did you train?

5.3 Have you ever been in contact with any organisation involved in conservation tillage awareness?

(0) No (1) yes

5.3.1 If yes which organisation and what method of conservation tillage were you involved in?

Name of the organisation (s).

Method (s) demonstrated or trained on.

5.3.2 How many times have you interacted with the organisation for the last four years

(tick) once... twice... thrice... others...?

5.4 Have you participated in any government-sponsored programs? (0) No (1) Yes

5.4.1 If yes what programs were you involved in?

5.5 Are you a member of any farmer's group?

(0) No (1) Yes

5.5.1 If yes in part 5.5, state the farmer group.

a)

b)

c)

d)

e)

6.0 farm enterprise(s)

List the most important farm enterprise (crops) in year 2006

6.1 Crop enterprise

Long rains (mid October 06 – January07)

Crop	Intercrop or monocrop	Size of the farm in acre	Total output (90 kg bag)	Price/bag	Total
1					
2					
3					

Farm income in long rains Ksh…

Short rains (mid March 2007- may 2007)

Crop	Intercrop or monocrop	Size of the farm in acre	Output (90 kg bags)	Price/bag	Total
1					
2					
3					
4					

Farm income in short rains in Ksh…………………………..

7.0 Farm implements

List the implements that the farmer has for conservation tillage practices

a)

b)

c)

d)

e)