ASSESSMENT OF HEALTH AND ENVIRONMENTAL EFFECTS OF MANGO INTEGRATED FRUIT FLY MANAGEMENT STRATEGY IN MERU COUNTY, KENYA

BY

MIYINZI CHRIS MWUNGU

A THESIS SUBMITTED TO THE SCHOOL OF BUSINESS AND ECONOMICS IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL ECONOMICS AND RESOURCE MANAGEMENT OF MOI UNIVERSITY, KENYA.

DEPARTMENT OF AGRICULTURAL ECONOMICS AND RESOURCE MANAGEMENT

JUNE 2016

DECLARATION

Declaration by the student

I declare that this thesis is my original work and has not been submitted for the award of degree in any other university or institution. No part of this work may be reproduced without prior permission of the researcher and or Moi University.

Signature…………………………………… Date……………………………………..

Miyinzi Chris Mwungu

REG No: SBE/PGA/002/13

Declaration by University Supervisor

This thesis has been submitted for examination with our approval as University supervisors.

Signature………………………………… Date………………………………

Dr. Beatrice Muriithi

Social Science and Impact Assessment Unit

International Centre of Insects Physiology and Ecology (ICIPE), Nairobi.

Signature………………………………… Date ……………………………………

Dr. Vincent Ng'eno

Department of Agricultural Economics and Resource Management

School of Business and Economics

Moi University

DEDICATION

I dedicate this thesis to my nephew Edgar Mwungu.

ACKNOWLEDGEMENT

I would like to express my special appreciation to the Social Science and Impact Assessment Unit at International Centre of Insects Physiology and Ecology (ICIPE) for funding this research and giving me an opportunity to grow as a researcher. I am heartily grateful to my supervisors at ICIPE, Dr. Beatrice Muriithi and Dr. Hippolyte Affognon, for making this work possible. Indeed, without their guidance, I would not be able to put the topic together. I am greatly indebted to my University Supervisor Dr. Vincent Ngeno for his support, guidance, advice throughout the process. I am grateful to Prof. Philip Nyangweso for his encouragement and trusting in me to undertake this master's programme. The experience has been an interesting and rewarding one. Last but not least, I would like to thank my parents for their unconditional support, both financially and emotionally throughout my degree. In particular, the patience and understanding shown by my mum is greatly appreciated.

ABSTRACT

Mango is among the three most imperative crops in Kenya in terms production and crop area. However, mango production is limited by a number of issues, among which pests and fungal disease infestation are major. Among the pests, mango fruit fly present a real challenge to producers due to losses incurred at the farm level. Majority of the farmers have decided to use of pesticides which have negative impacts on health and environment. To promote sustainable and environmentally friendly agriculture, International Centre of Insect Physiology and Ecology (icipe) developed and implemented an Integrated Pest Management (IPM) fruit fly control package in Meru County, Kenya. Health and environmental impacts of this intervention, however, had not been evaluated. This study therefore evaluated the impact of this intervention on health and environment. The study used survey research design in which a structured questionnaire was administered to 371 randomly selected participants and non-participants from the intervention and control areas. Environmental Impact Quotient (EIQ) was used to determine the magnitude impact of IPM on health and environment while Endogenous regression was used to evaluate the impact of IPM on EIQ field use. Descriptive results indicated that on average EIQ field use for participants was lower with a difference of 2770.87 while empirical results indicate that adopters reduced EIQ field use by 6.81% after adopting IPM. This imply that IPM participants are better off in terms of health and environmental benefits of IPM. The study recommends expansion of IPM intervention to the entire mango growing area in Meru County to improve health and environmental conditions of farmers.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

AFFP African Fruit Fly Programme
ATT Average treatment on the treated
ATU Average treatment on the untreated
BIOP Bio pesticide
CVM Contingent valuation method
DC Developed Countries
DOI Diffusion of Innovation
EIA Economic Impact analysis
EIA Environmental Impact Assessment
EIL Economic Injury Level
EIQ Environmental Impact Quotient
ESR Endogenous Switching Regression
FB Food Bait
FFS Farmers' Fields School
FIML Full Information Maximum Likelihood
ICIPE International Centre of Insects Physiology and Ecology
IPM Integrated Pest Management
IV Instrument Variable
KSHs Kenyan Shillings
LDC Lowly Developed Countries
MAT Male Annihilation Technique
MAT Male Annihilation Technique
MOA Ministry of Agriculture
ODK Open Data Kit
OLS Ordinary Least Squares
OS Orchard Sanitation
P Parasitoids
PCPB Pesticide Control Products Board
PSM Propensity Score Matching
SDG Sustainable Development Goals
UNEP United Nations Environmental Programme
VIF Variance Inflation Factors
WHO World Health Organization
WTP Willingness to Pay

CHAPTER ONE

INTRODUCTION

1.0 Introduction

This chapter discusses background of the study, statement of the problem and objectives of the study. It goes further to discuss the justification and the scope of the study.

1.1 Background of the Study

Management of crop pests and diseases is mostly done using synthetic chemicals across the globe. Pesticides increase agricultural production by reducing pre-harvest crop losses. This leads to increased food supply that lower food prices to affordable levels that may also lead to improved food security (Aktar *et al*., 2009). However, pesticides pose negative environmental effects such as death of beneficial organisms such pollinating and nitrogen fixing agents, contamination of ground water, climate change and global warming (Damalas *et al*., 2011). According to Padovani *et al*. (2004), regular use of pesticide has health and environmental costs that are not reflected in the market price of pesticides or the price of farm outputs. These costs do not reflect in the market price because unlike other man made products, they are not explicitly priced thus their monetary values cannot be easily estimated. It is also difficult to assess impact of pesticides on health and environment since the interaction of pesticides with soil and water is controlled by several simultaneous biological, physical and chemical reactions (Blessing, 2001). Reus *et al*. (1999) stated that environmental and ecological factors that determine the impacts of pesticides include; the properties of the active ingredient, dose, application frequency and method, environmental conditions, available surface water resources, and presence of biological species.

Various methods such as damage cost avoided, lost productivity, and willingness to pay (WTP) to avoid pesticide risk have been used in estimating economic impacts of pesticides on health and environment. Some studies have adopted non-market valuation techniques and people's perceptions since it is difficult to value environmental components in a survey. Mourato *et al*. (2000) and Oluwole *et al*. (2009) proposed use of price differentials as a way of attaching monetary value to the environmental damage caused by use of pesticides. That is products produced from IPM pest control strategy to cost more than pesticide strategy and the difference between the prices to serve as monetary value for the environment.

Pesticide use is common in mango production mainly due to high infestation of pests such as fruit flies. The pest has numerous generations per season and has developed resistance overtime necessitating frequent use of pesticides (Ekesi *et al.,* 2002; Ekesi *et al.,* 2009). Fruit flies contribute about 40% loss of annual mango production in Kenya (Ekesi *et al*., 2010). Mango famers and exporters incur losses due to numerous interceptions of the fruit fly infested mango consequently limiting their access to lucrative international markets.

International Centre of Insects Physiology and Ecology (ICIPE), under the African Fruit Fly Program (AFFP) has developed and disseminated an Integrated Pest Management (IPM) strategy in Kenya and other affected sub-Saharan Africa to promote sustainable and environmentally friendly agriculture (ICIPE, 2009). This approach combines selected chemical, biological, physical and cultural pest control methods that promote improved productivity at the same time reducing environmental and health risks due to low use of pesticides. ICIPE IPM strategy for suppression of fruit flies consists of various combinations of the following, (1) spot spray of food bait, (2) male annihilation technique, (3) *Metarhizium anisopliae*-bases biopestide application, (4) release of parasitoid- *Fopius arisanus* and *Diachasmimorpha longicaudata,* and (5) use of orchard sanitation with the Augmentorium (Muriithi *et al.*, 2016). The augmentorium, is a tent-like structure made of durable netting material with mesh size. It sequesters fruit flies that emerge from fallen rotten fruits collected from the field and deposited in the structure, while at the same time conserving their natural enemies by allowing Parasitoids to escape through a fine mesh at the top of the tent (Klungness *et al*., 2005).Adoption of IPM is expected to reduce mango losses, lower cost of production, increase income and improve market access and processing through increased quality and productivity of mango both in the local and international markets. Minimal use of chemical pesticide in mango production will also provide positive health and environmental gains hence contributing to the overall ICIPE's mission of reducing negative externalities of pesticides.

ICIPE avails the technology to farmers in a package consisting of three or more of the five components. While release of Parasitoids and orchard sanitation is universal for all the farmers, the packages are differentiated using the three other components. For instance, a farmer may receive a package containing in addition to Parasitoids and orchard sanitation, food bait and male annihilation technique. Although the packages are not differentiated in this study, this design was adopted in order to evaluate the combinations of packages with the highest economic impact. This study is part of the overall fruit fly project at ICIPE that aims at developing and implementing effective approaches to reduction of mango loses due to fruit fly infestation leading to sustainable socio-economic and environmental impacts in Africa. Although the IPM strategy is expected to contribute to ICIPE's mission of reducing health and environmental risks due to reduced use of chemical pesticides (ICIPE, 2009), no study has been carried out to quantify the extent of the strategy's impact in Kenya, thus the motivation for this study. This study aims at assessing the impact of the IPM strategy on health and environmental benefits among mango producers in Kenya, using Meru County, one of the projects' action sites, as a case study.

1.2 Problem Statement

Integrated Pest Management practises have increasingly been embraced in many countries, including Kenya as a major strategy for insects and pests control. Synthetic pesticides are poisons and without proper usage, they can cause human illness such as headaches, stomach pains, vomiting, skin rashes, respiratory problems, eye irritations, sneezing, seizures and coma, and also environmental contamination (Swinton *et al.*, 1998; Maumbe *et al.*, 2003; Orornje *et al.*, 2007; Macharia *et al.*, 2013). The world health organisation (WHO) and the United Nations Environmental Programme (UNEP) estimate that 20,000 workers die from pesticide exposure annually in developing countries (Okello, 2005; Wilson, 2005). Researchers promote use of IPM practices as a more sustainable alternative to the prevalent chemical pesticide use in developing countries. However, studies on the potential benefits of IPM techniques and negative effects of pesticides are limited in developing countries (Atreya, 2007). Earlier studies on the ICIPE's IPM focus on direct benefits of the strategy. For instance,(Kibira *et al.*, 2015) and (Muriithi *et al*., 2016) evaluate the impact of the IPM strategy on pesticide expenditure, mango fruit yield loss and profit in Embu and Meru Counties of Kenya respectively. While those studies show clear indications of positive economic impact of the strategy, the indirect effects, such as human and environment effects have not been quantified, hence possible underestimation of the gains delivered from the package. This study thus addresses this gap by evaluating the health and environmental effects of ICIPE's IPM strategies among mango producers in Meru.

1.3 Objectives

The general objective of this study is to assess health and environmental effects of IPM technologies for suppression of Mango fruit flies in Meru County.

1.3.1 Specific Objectives

i) To characterize the magnitude of health and environmental effects of IPM technologies for controlling Mango fruit flies in Meru county

ii) To evaluate the determinants of health and environmental effects of IPM technologies for suppression of Mango fruit flies in Meru County

iii) To assess the impact of integrated mango fruit fly management strategy on health and environment.

1.4 Hypothesis

1 H_0 IPM technologies have no effects on health and environment.

2 H_1 IPM technologies have no impact on health and environment effects.

1.5 Justification of the Study

Many farmers in developing countries, including Kenya, rely on chemical pesticides to control pests such as fruit flies. The use and misuse of pesticides is associated with high health and environmental risks that are not only detrimental to the producers but also reduce competitiveness of agricultural products especially in the international market and Participation of farmers in the international markets. To sustain production and ensure small-scale mango producers in Africa enjoy the benefits of lucrative markets, the African Fruit Fly Program (AFFP) has developed and disseminated IPM strategy, as a more sustainable alternative to prevalent chemical pesticide application for control of mango fruit flies. This is line with the global sustainable development goals (SDG's), that proposes the need for healthy and environmentally friendly agriculture (Sachs, 2012). To understand the overall implications of AFFP IPM strategy, it is important to demonstrate the magnitude of health and environmental gains derived from the strategy, which has not been done before. This understanding will guide policy makers, manufactures and other stakeholders in the mango sub-sector in designing IPM up-scaling policies. The findings will also contribute to the existing literature on impact assessment of IPM technologies.

1.6 Scope of the Study

This study was conducted in Meru County and it mainly focussed on effects of IPM technologies on health and environmental benefits. The results generated from this study may be generalized to the extent of other Mango producing counties in Kenya and especially those with similar socio-economic and agro ecological characteristics as Meru County.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This study reviewed similar research studies done by other researchers in the past. The review was undertaken on the studies which were considered relevant in their approach to the current research. The chapter develops a conceptual framework and identifies research gaps and areas recommended for further research.

2.1 Factors influencing adoption of IPM technologies

Factors that affect adoption of agricultural innovations can be broadly classified in four categories namely; economic, social, institutional and management factors. Economic factors include size of agricultural land, income per month, availability of labour, labour management, access to irrigation water and number of productive mango trees.(Wabbi, 2002). Social factor are related to farmer characteristics such as age, gender and educational level of the household head, farming experience and household size (Wabbi, 2002). Important institutional factors that influence adoption of agricultural technologies include access to production and marketing information and access to extension services while organizational factors include membership to farmers' groups, use of protective clothes and access to credit (Gilbert, 2013). The literature on factors determining adoption of IPM technologies is vast and cannot be reviewed here. However, to provide an organisation of the theoretical framework for discussion, the important factors are reviewed in detail in the following sub-section.

2.1.1 Economic Factors

Land is an important factor of production in agricultural production. In economics, land is defined as a free gift of nature where production takes place and its supply is fixed (Marshall, 2009). It determines the level of production/economies of scale and access to credit facilities (Wabbi, 2002). In many studies the effect of farm size on technology adoption has been found to be positive (Adesina *et al*., 1995; Mugisa-Mutetikka *et al*., 2000; Gabre-Madhin *et a*l., 2004). Land size is an indication of wealth especially among African rural communities. Abara *et al*. (1993) argues that small farm size increases cost of technology adoption because of large fixed costs that may be involved. Farmers with larger farm sizes are likely to have more number of mango trees, which would enable them to invest in new technologies such as integrated pest management. High number of mango trees leads to high output which earns the famer more income hence giving him the ability to invest in new technology. Modern farming techniques are therefore likely to be practical in large farms as the monetary benefits yielded from the large number of mango trees accommodated in the farms capacitates adoption of new technologies hence improved output and operation. This is in harmony with (Korir *et al*., 2015.) who reported that famers with more number of mango trees were more likely to adopt more ICIPE's IPM components.

Household income per month enables the famer to finance new farming techniques. High income improves the famer's capacity to adapt agricultural technology as they have the necessary capital to start the innovations arising in agriculture. High income farmers are also risk takers in taking up new ideas especially where the idea requires high capital (Gilbert, 2013) Many adoption studies have not analysed the impact of access to irrigation water on adoption of agricultural technologies. However, Lawrence *et al*. (2005) emphasized that irrigation water as a useful factor in implementing IPM adoption policies and its importance sustainable agriculture as it is a cultural method of pest control. Choice of adoption of technology can be influenced by the amount of household labour available in the sense that high household labour is critical in the adoption of new farming methods (Akudugu *et al*., 2012). Previous studies have shown that labour availability has a positive impact on adoption of new technologies (JO, 2008). However, in this study we will use labour management which refers to the ratio between hired labour and total labour.

2.1.2 Social Factors

Age is a factor that has been discussed in many adoption studies perhaps because age determines risk perceptions, vigour for work, ambitions and innovativeness. Some studies contend that age has a negative impact on adoption while others argue the contrary. For instance Adesina *et al*. (1995) finds that age had positive affect on adoption new sorghum varieties in Burkina faso, while Boahene *et al*. (1999) finds that age negatively affects adoption of hybrid cocoa in Ghana. Von Braun and Kennedy, (1994) also find old age of household heads to be related to risk aversion or less flexibility in adopting new techniques.

According to Rogers, (2010) complex technologies are less adopted. Households with heads that are more educated are expected to be more efficient in understanding and obtaining new technologies in shorter period of time. Education also enhances the skills and ability to utilize better information, which may reduce the transaction costs of adopting new technologies, and thus make it more profitable to adopt IPM strategy for mango fruit fly control. Studies on adoption of IPM technologies show that education positively affect IPM adoption (Doss *et al*., 1999; Daku, 2002)

In African society, both men and women play different roles in agricultural production according to the cultural set up in a given community. Just like age, studies argue contrary on the effect of gender on adoption of IPM technologies. Mbata (2001), finds that female were better adopters of new technologies than men since men are involved in off farm activities for income generation while women are left at home to work on their farms. The results also agree with Chi (2008) and Erbaugh *et al*. (2010) who argue that women are better IPM adopters than men. However other studies such as Abdullah *et al*. (2013) reported that women are denied access to basic assets hence less likely to adopt new technologies compared with men.

Farming experience refers to the number of years that the famer has been practical in agricultural activities. According to Rahman (2007) longer farming experience enables a farmer to view new ideas in a way that makes them make decisions wisely thus increasing the probability of adopting new innovations. Adebiyi *et al*. (2013) reported that experienced farmers assume lesser risks when making decisions about new technologies, since they are better informed about new innovations.

Household size refers to the number of members in a given household. Some researchers have modified this variable into a new variable called dependency ratio (Baez, 2004 ;Kassie *et al*., 2010; Davis *et al*., 2012; Nalunkuuma, 2013). Dependency ratio refers to the ratio of the net consumers to net producers or ratio of working group to a non-working group in a given household. It is calculated by summing up the number of children aged between (0-14) and person above the age of 65 divided by the economically active person aged between (15-64) years of age (Brody, 1978).

A large household implies availability of labour which may increase probability of technology adoption (Okuthe, 2014). It is equally important to note that a large household do not guarantee availability of skilled labour. However, some researchers have argued that a large household means increased subsistence requirements that reduces income that may be used for IPM adoption (von Braun *et al*., 1994). Shadiadeh *et al*. (2012) found that household size has a positive impact on technology adoption

2.1.3 Institutional Factors

Famers who have access to extension services poses relevant information required for the adoption of new technologies (Adebiyi *et al*.,, 2013) Caswell. (2001) argues that information access reduces uncertainty about a given technology. Extension services creates awareness to famers on the benefits and cost of new farming methods (Adeoti, 2008). Some studies have used this variable based on the number of extension visits while others have used it based on accessibility but in both cases, extension services were reported to foster IPM adoption. Ragasa *et al*. (2013) and Genius, (2014) reported a positive relationship between extension and technology adoption.

2.1.4 Management Factors

Group membership provides a platform for farmers to access credit and information. In some adoption studies, group membership affects adoption of new technologies in a positive way (Adeoti, 2008;Ghimire *et al*., 2014;Mwaura, 2014). According to (Amek, 2011), group membership has a significant role in adoption of new technologies. Credit can help stimulate technology adoption as it allows the farmers to access information, afford investing in new technologies and ability to take risks associated with the adoption of the technologies (Simtowe *et al*., 2006;Liverpool *et al*., 2010).In addition, famers who have access to credit are more likely to purchase protective clothing. Famers who use protective clothes are likely to adopt fruit fly IPM components because they are aware of the harmful effects of pesticides (Korir et al., 2015)

2.2 Impact of Pesticides on Environment and Human Health

2.2.1 Environmental Effects

Pesticides are toxic chemicals substances used in agricultural production to shield crops from pests and diseases. Although pesticides are meant to control pests, they may be harmful to beneficial agricultural organisms and may pollute the environment by entering the air, water, sediments, and even in the food consumed by human beings. Pesticides easily contaminate the air, ground water and surface water bodies especially if they are applied in windy weather or just before rainfall. In addition, pesticide active ingredients are toxic to all living organisms including birds, fish, beneficial insects, non-target plants and even humans (Tiryaki *et al*.,2010). The effects of pesticides on individual environmental components have been discussed as follows.

A large number of transformed products from different types of pesticides have been found in rain, ground water, streams, rivers, lakes and oceans. They can reach the water through drifting outside of the area of where they were sprayed, leaching through the soil, being carried as runoff, or being spilled accidentally. Research shows that pesticide concentrations exceed those allowable for drinking water in some samples of river water and groundwater (Kole *et al*., 2001).The use of pesticides increases soil erosion since it reduces the population of soil organisms necessary for improving soil structure Good soil structure yields higher soil quality which leads to high water retention, necessary for plants to grow (Savonen, 1997)

Nitrifying bacteria responsible for nitrogen fixation which is essential for the growth of crops is affected by pesticides particles that have volatilized in soil which can lead to reduced productivity of crop. In addition, pollinators such as honey bees can be killed by pesticides hence decrease in crop pollination and reproduction (Rice *et al*.,1997).

Pesticide residues may remain on animal feeds after spraying hence poisoning both domestic and wild animals. An application of pesticides in an area can affect the food web by eliminating certain food sources that certain types of animals need. For example, birds can be affected when they eat insects and worms that have consumed pesticides (Freemark *et al*., 1995). Pesticides cause poisoning to small organisms such as earthworms which are a food source to birds hence extending the poisoning to birds. There is also evidence that birds are being harmed by pesticide use due to accumulation of pesticides in their tissues (Tanabe *et al*., 1998)

Pesticides exposure to water bodies leads to contamination of water hence affecting aquatic life. Application of herbicides to bodies of water can cause aquatic plants to die, reducing the water's oxygen and suffocating the fish. Frequent exposure of pesticides on water bodies can cause physiological changes in fish that reduce populations through decreased immunity to disease (Dubrovsky *et al*., 2010).

2.2.2 Health Impacts

Farmers use pesticide in agricultural production to maximize profits (Liu *et al*.,2013). However, misuse or over use of these synthetic pesticides leads to various pesticide related health complications. According to literature, the most common acute illness caused by pesticides exposure to farmers, farm workers and consumers of farm products include: eye irritation, headache, skin irritation, weakness, respiratory problems, excessive sweating, muscle pain, chopped hands, throat discomfort, pain in chest, nausea, blurred vision, lacrimation, vomiting, diarrhoea, dizziness, nose irritation, depression and thirst (Solomon *et al*., 2000; Beard *et al*., 2014). Chronic illness includes cancer, reproductive health problems, liver damage, kidney, lung and neurological problems and developmental disorder in children (Reynolds *et al*., 2002; Houndekon *et* *al*., 2006; Rao, 2008). Pesticide related illness vary from one victim to another and range from mild, moderate to severe effects.

Khan (2010) classified pesticide risks based on toxicity (acute toxicity and chronic toxicity), and carcinogenic potency, volume of pesticide applied and magnitude of workers poisonings. In a study conducted by Huq *et al.* (2005) over 49% of the respondents had experienced more than one symptom with most commonly reported as neurological, eye irritation, vomiting and dermal problems. Pingali *et al.* (2012) gives a classification of pesticides basing on World Health Organization (WHO) classification; slightly hazardous (WHO class IV), moderately hazardous (WHO class III), highly hazardous (WHO class II) and extremely hazardous (WHO class I). According to the Pingali *et al.* (2012), Class I and II are the common categories linked with pesticide related illness to farmers in developing countries. In addition, pesticide residues in air, water and foods have serious health implications for the public. According to WHO (1990) pesticides residues have been found in the air and aquatic sources even after being used long time ago, leading to negative effects to air borne living things, aquatic organisms, humans, wildlife and biodiversity and the entire environment. Farmers and farm workers are the most susceptible group of people to pesticide contact all over the world, because they are directly involved in mixing and spraying dangerous liquids. In addition, people who are neighbours to pesticide treated farms have shown the uppermost level of pesticide exposure (McDuffie, 1994).

Agricultural workers in developing countries have a higher probability of contracting pesticide related illness because of poor and use unsafe farming practices (McDuffie, 1994). The number of pesticide related poisoning cases is higher in developing countries than in developed countries (Kishi *et al.*, 1995). Studies in Zimbabwe have shown that about 50% of workers on the farms are exposed to organophosphates characterized as extremely hazardous. WHO assessments show that pesticide use causes 20,000 deaths annually across the globe. The majority of these cases are reported from developing countries (WHO, 1990). On the other hand the United Nations (UN) has projected that about 2 million poisonings and 10,000 deaths occur annually from pesticide and most of these happening in developing countries (Macharia *et al.*, 2013). However, Roger (1995) reported that farmers who use protective measures have lower incidences of pesticide poisoning. According to Dasgupta *et al.* (2005), most of the pesticide related health difficulties are arising due to lack of awareness, misunderstanding of hazard, insecure attitudes and dangerous practices. According to WHO (2004) the pesticides barred in developed countries (WHO category I and II), are widely used in less developed countries (LDC). World health organization (WHO) has classified all pesticides basing on their effects on health and environment. IA = Extremely hazardous; IB = Highly hazardous; II =Moderately hazardous; III = slightly hazardous; U = Unlikely to present acute hazard in normal use; FM =Fumigant, not classified; O = Obsolete as pesticide, not classified (WHO, 2009).

2.3 Review of previous literature on IPM studies

2.3.1 Theoretical review

In their study, Garming *et al*. (2007) examined whether farmers adopt IPM packages for health reasons. They investigated the impact of farmers' experiences and perceptions of health risks of pesticides on the adoption of IPM practises and pesticide use among small scale farmers in Nicaragua. The authors found out that those farmers who had high off-farm wages, education and access to IPM training had a higher rate of IPM packages. The paper concludes that most farmers adopted IPM packages for health purposes. However, this study was not comprehensive as it did not include environmental benefits of not using pesticides. Our study goes beyond the health impacts to examine the environmental impacts of IPM technologies.

Verghese *et al.* (2004) assessed cost-effectiveness of the Integrated Management of the oriental fruit fly Bactrocera dorsalis in Mango farming in India. The focus of the study was to examine economic returns of using IPM technologies using cost-benefit analysis. The results showed that the infection levels varied significantly between treatments though not between years. The researchers concluded that the IPM package obtained good fly control at many levels of fly attack pressure. The IPM strategy is environmental friendly and residue-free. However, the returns to IPM investment decreases up to a certain level beyond which the returns are negative. Consequently, awareness should be raised among farmers and the IPM package recommended as the best practice in fruit fly control.

In evaluating economic and health consequences of pesticides use in paddy production in the Mekong Delat, Vietnam, Dung *et al.* (1999) reported that the amount of pesticides applied was far higher in cost considering the amount of profits brought about by the use of the pesticides. Insecticides influenced negatively the health of the farmers, thus a tax of 33.4% on pesticides was suggested to reduce use of pesticides in the country.

In an economic analysis of environmental benefits of IPM in Philippines, using a contingent valuation (CV) survey of 176 farmers, Cuyno et al. (2001), found that the aggregate value for environmental benefits of IPM in five villages where the study was conducted had a total population of 4,600 local residents was estimated at US Dollars 150,000 per cropping season . The authors pointed out that health and environmental concerns associated with reliance on pesticide use has motivated development of IPM technologies. While conducting the study, farmers were asked to quote how much they were willing to pay in order to avoid pesticide related complications. Risks to humans, birds, aquatic animals, beneficial insects and other animals were considered.

Wabbi *et al*. (2008) carried out a study in Uganda to determine health and environmental benefits of reduced pesticide use. They used non-market valuation techniques (contingent valuation and choice experiments). The study found positive impact on health and environment. Maumbe *et al*. (2003) estimated pesticide health costs among cotton farmers in Zimbabwe. In agreement with a similar study by Macharia *et al*. (2013) carried out in Kenya , the incidences of pesticide related poisoning were found to have been increasing over years. Both studies adopted cost of illness model and acute symptoms models to achieve their objectives. However, Macharia used a general panel regression model since his study was conducted in the year 2005 with a follow up in 2008.

In his study assessing the factors influencing adoption of IPM technologies, Amek (2006) explored effect of social capital on IPM technology adoption among small scale farmers in Kenya. The author observed that IPM technology is commended because it lowers production cost and it has no health and environmental risks. Amek (2006) utilized Tobit Model to test the hypothesis that social capital influences IPM adoption. The results found that social capital was significant and positively influenced IPM adoption. Other variables that were found to influence adoption include number of community groups a household subscribes to, monetary contribution to the group and informal chats with neighbours and group members.

A socio economic study conducted in Kenya aimed at approximating environmental impacts of pesticide use in the vegetable sub sector, found out that approximately 263 tons of pesticides were applied at an average of 0.82kg/ha. About 35% of the volumes belong to organophosphates, 25% carbamates, 22% pyrethroids, 7% tetranortrirpenoids, and 7% inorganics. Calculated EIQ values were 22, 6, and 82 for farm workers, consumers and the environment respectively with an overall average of 37 (Macharia, 2009).

2.3.2 Empirical Review

Swinton *et al*. (1998) debates that there is no single parameter that can represent either health or environment. However, many researchers have come up with many techniques that can be used to measure environment and health impacts of several pest management techniques which are presented in this section. Kovach *et al*. (1992) for instance developed a method to measure environmental and health effects of pesticides called environmental impact quotient (EIQ). It is an important method on informing policy makers and stakeholders in agriculture on the adverse effects of pesticides and impact assessment of IPM programs (Sande *et al*., 2011). In this method, risks associated with a pesticide use are summed into a single value called EIQ. The model also evaluates both qualitative and quantitative effects of each pesticide use (Praneetvatakul *et al.*, 2006 ; Greitens *et al.*, 2007 ;Biddinger *et al*., 2014). In order to compare several pest management technologies, EIQ field use rating is computed as explained in chapter three of this study. However Bues *et al*. (2004) claimed that EIQ does not determine actual pesticide risks since it only generalizes risks basing on toxicological data, chemical and physical properties of pesticides. Several studies however have applied EIQ Model in assessing adverse effects of pesticides on health and environment and IPM impact assessments studies. For instance Van der , (1996), Pradel *et al*. (2008), and Kromann *et al*. (2011) used EIQ model to establish health and environmental impacts of pesticide use, while Williams (2000) used EIQ to assess impacts of IPM technologies on health and environment.

Contingent valuation (CVM) and choice experiments have also been used in many IPM impact assessment studies (Cuyno *et al.,* 2001). Contingent valuation involves asking respondents openly about their preferences and how much they are willing to pay to forego risks associated with pesticides. The researcher may also estimate a price which the respondents may accept or reject (Kriström, 1990; Mitchell *et al*., 2013). Average willingness to pay is computed and used as a dependent variable in empirical analysis. In some studies health and environmental benefits of IPM technologies has been estimated using CVM (Mullen., *et al* 1997; Cuyno *et al.*, 2001). In distinction with CV method, for choice experiments, individuals are given a set of alternative responses to pick from in a choice set. A choice experiment eases challenges such as information bias, strategic bias, design bias and hypothetical bias associated with CV method (Birol *et al*., 2006). Travisi *et al*. (2008) applied choice experiments to value health and environmental risks in agriculture. These methods have hypothetical limitations, potential sources of errors and are often expensive (Atreya, 2005).

Cost of illness model is used to estimate economic load of diseases caused by pesticide use in agriculture (Olin *et al.*,2008). Since it is difficult to value health effects of pesticides, some authors have approximated health costs using several techniques. For instance, Maumbe *et al.* (2003) estimated health costs by measuring medical treatment costs in a health facility, opportunity costs of days lost due pesticide related illness, cost of home based care such us taking a shower, milk or honey and cost of traditional healing strategies. Multiple regression model is then used to find out factors affecting the magnitude of health costs. Macharia *et al*. (2013) used Tobit model to evaluate factors determining health costs because in some instances heath costs were found to be zero.

Several researchers have also incorporated economic impacts models in determining environmental effects of IPM technologies and pesticide use (Pimentel *et al*., 1992). Common models used include but not limited, partial budgeting, gross margins, cost of pesticides, and cost benefit analysis. To conduct an economic examination of IPM technologies, Musser *et al*. (1981) evaluated the benefits by finding the difference between crop returns and pesticide input costs. In addition Vergara *et al.* (2002); Gajanana, (2006) and Singh *et al*. (2007) used gross margins and/or partial budgets to compare the revenue of participants and non-participants. Cost benefit analysis was applied by Orr *et al*. (2008) while assessing economic, health and social economic impacts of IPM technologies.

Heckman model is common in impact studies including IPM impact assessment studies (Isoto *et al*., 2008; Carrión *et al.*, 2013; Yaguana *et al.*, 2013). The model controls for selection bias that often occurs due to a number of reasons such as: missing data, model specification errors, self-selectivity of the units being investigated or errors emanating from the data analyst (Briggs, 2004). However the model tend to impose a functional form assumption by assuming that adoption has only an intercept shift and not a slope shift in the outcome variables (Tambo 2014). To address this issue, Endogenous Switching Regression (ESR) model can be used. ESR also addresses similar concerns of other methods including Instrument Variable (IV) and Propensity Score Matching (PSM) (Tambo 2014). ESR has been used in various studies to assess the impact of agricultural innovations and technologies. Shiferaw *et al*. (2014) used ESR model to estimate the impacts of improved wheat varieties on household food security in Ethiopia. ESR model has also been used by (Kabunga *et al*., 2011) to determine the yield effects of tissue bananas in Kenya. Based on the context of this study, ESR is adopted to assess the impact of IPM strategy for control of mango fruit flies on health and environment.

2.4 Theoretical Framework

This study is based on both diffusion of innovation theory and consumer theory. An innovation is an idea, practice or technology which is perceived as new by a farmer. Rogers defined the diffusion of Innovation theory (DOI) as the process by which an innovation is communicated through certain channels over time among the members of a social system (Rogers, 2010). It is the process by which the innovation spreads from its source of innovation to its ultimate users or adopters. According to Rogers, diffusion rates determines by four main elements: the characteristics of innovation, the effectiveness of communication channels, time involved in the innovation decision process relative to the innovativeness of the individual or other decision making unit and the surrounding social system.

The first element in the diffusion of innovations theory that determines the adoption rate is the characteristics of the innovation. This is comprised of five components (i.e. Relative advantage, compatibility, observability, trialability, and complexity). (Sahin, 2006) literature proposed that innovations which are perceived by individuals as having greater relative advantage, compatibility, trialability, observability, and less complexity will have a greater adoption rate than other innovations(Lyytinen et al., 2001)

It is important to note that the decision to adopt IPM technologies and pesticide use in mango farming can be made concurrently by a given farmer. This may be caused by unobserved factors such as pest resistance, size of pesticide population, location of the farm and farmers perception of pest control methods which may influence IPM adoption. In addition, farmers may be assigned in the two treatments (control and treated) randomly, but they make adoption decisions themselves. If self-selection problem is not taken into account it may lead to serious bias in the final results. (Heckman, 1990) discussed ways of correcting self-selection problem which has been adopted in this study. Additionally, farmer's decision to accept new farming techniques is a choice decision which can be borrowed from the consumer theory. Consumer theory is concerned with how a rational consumer would make consumption decisions. A consumer has an interest of maximizing utility at the lowest possible cost as illustrated in the equation below:

$$\text{Max } u(x)$$
$$\text{s.t } p.x <= w \qquad (2.1)$$

The idea is that the consumer chooses a vector of goods $x = (x_1 ... x_n)$ to maximize her utility subject to a budget constraint that says she cannot spend more than her total wealth (w). Thus in this case a mango grower is likely to adopt IPM technologies if the technology has more benefits than costs. In the context of this study we refer to benefits as the health and environmental effects associated with the adoption of IPM technologies. Since the benefits are unknown, we will treat them as random variables. Thus in the context of adoption

$$u_{ij} = v_{ij} + e_{ij} \qquad (2.2)$$

Where v_{ij} is the systematic component of IPM adoption (j=1) and the costs of not adopting (j=0) and the error term (e_{ij}) accounts for unobserved variation. Therefore, to examine health and environmental benefits of IPM technologies one needs to have a comparison of the health and environmental effects of other pest control strategies. To achieve this, we adopt EIQ model that was developed by Kovach (1992) in determining the impact of IPM technologies. EIQ is an index based method that assigns a single value to the impacts of individual pesticides to health and environment. Thus, the higher the value of EIQ the higher the magnitude of the negative effects of pesticides on health and environment.

2.5 Conceptual Framework

This study evaluates the environmental and health effects of IPM technologies for suppression of mango fruit flies. These effects can only be experienced after adoption. Figure2.1 below represents a conceptual framework used as a skeleton for this thesis. The arrows show the source of influence and the point the factor that is influenced. Factors that influence adoption of IPM technologies can be classified into economic, social, institutional and managerial.

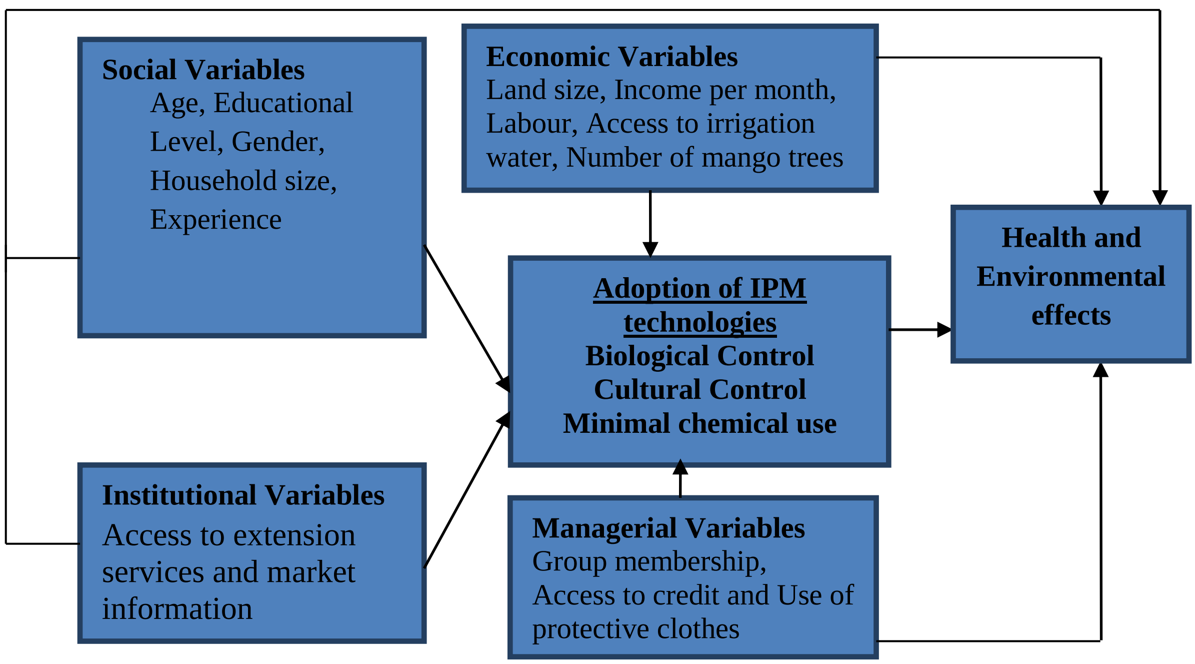

Figure 2. 1: Conceptual Framework

Source: author

Young people are risk takers, energetic and ambitious to try new ideas. Old men are risk averse and are reluctant to try new methods of production Nalunkuuma *et al*. (2013), thus young people are likely to adopt IPM technologies. Highly educated farmer have better opportunities to acquire and process information on the new technologies, ideas and innovations (Chi, 2008). Household size determines subsistence requirements of a given household. Large house hold means pressure on given resource, thus the income earned will be used to supplement subsistence requirements at the expense of purchasing adopting new technologies (Shadiadeh *et al*., 2012). Large farm size affects adoption because some technologies are scale dependant thus investing such technologies on small farms becomes economically inefficient (Abara *et al*.,;1993; Mugisa-Mutetikka *et al*., 2000). Access to market and credit and good external environment such as availability of good infrastructure and access to extension services enables the farmer to access new information on new technologies (Akudugu *et al*., 2012).

CHAPTER THREE
METHODOLOGY

3.0 Introduction

This chapter discusses the research design, the features of the study area where the research was conducted, and the target population. It also presents the sampling method, the sample size, the data collection instruments, and the methods of data analysis and presentation.

3.1 Research Design

This study adopted survey research design to establish the health and environmental effects of IPM technologies in between control and treatment regions in Meru County. The study used the questionnaires as the instruments of data collection. Data on pesticide use and health effects were collected to determine the magnitude of health and environmental effects. Descriptive statistics and analytical models were used to analyse the data. Descriptive statistics involved use of means, frequency tables, percentages, ranges, standard deviation and averages. Stata was used to do regression analysis and other data analysis to generate the statistics.

3.1 Area of Study

This study was conducted in Meru County located in Eastern province of Kenya. Meru County is one of the ICIPE's IPM project sites, purposely selected because it is one of the major mango growing counties in Kenya. It borders Isiolo County to the north and north east, Tharaka County to the south west, Nyeri County to the south west and Laikipia County to the west. Meru County is made up of nine constituencies; Igembe South, Igembe Central, Igembe North, Tigania West, Tigania East, North Imenti, Buuri, Central Imenti and South Imenti. It has an area of 6936km^2 and a population of Meru

County is about 1.4 million people. The climate in Meru is cool and warm (upper highland agro ecological zone). Horticulture and subsistence farming are the main economic activities in the county with mangoes, oranges, avocadoes, bananas, paw paws, and macadamia as main the fruit crops cultivated in the region. Mangoes are preferred since they require less water for growth compared to other crops cultivated in the region. This makes mango an economically viable crop in the county due to frequent water shortage in the area.

3. 2 Sampling Procedure

The study utilized a survey of mango producers that was compiled previously by ICIPE for their study on impact assessment of mango IPM fruit fly control technology. The survey comprised of mango growers from three sub–counties where IPM technology were distributed and one sub-county as a control. The previous icipe survey provided a sampling frame from which IPM participants and non-participants were randomly selected for household interviewers.

3. 3 Sample Size

The sample size was determined using Cochran’s Formulae (Kotrlik *et al.,* 2001) . A 95% confidence level and a p=0.05 were used because of the nature of study. The formula that was used to calculate the sample size was as follows:

$$n_0 = \frac{t^2 \times (p)(q)}{d^2}$$

$$n_0 = \frac{1.96^2 \times (0.5)(0.5)}{0.05^2} \qquad (3.1)$$

$$= 384$$

Where t is the value for selected alpha level of 0.25 in each tail = 1.96, (p) (q) = estimate of variance = 0.25, while d is the acceptable margin of error for proportion being estimated at 0.05. Since the sample size exceeds 5% of the population, we used Cochran's correction formulae:

$$n_1 = \frac{n_0}{1 + \frac{n_0}{Population}} \qquad (3.2)$$

$$n_1 = \frac{384}{1 + \frac{384}{1200}}$$

$$= 290$$

Where population size is 1200 (from previous ICIPE baseline surveys), n_0= required return sample size according to Cochran's formulae = 384, n_1= required return sample size because the sample size exceeds 5% of the population. Assuming a response rate of 80%, a minimum of 364 should be used as shown below.

$$n_2 = \frac{290}{0.8} = 364$$

3.4 Data Types and Sources

The core information for the primary data consisted of a detailed household-level survey. The data collected from respondents includes level of household and farm characteristics, transaction cost variables such as, distance to the nearest market, institutional factors such as access to extension services, access to credit, group membership, and health and environmental pesticides management parameters such as health costs, use of protective clothing. Primary data was carried out in the month of October 2014. The study utilized electronic data collection tool, Open Data Kit (ODK) technology to collect information from the sampled farmers. Secondary data on pesticides active ingredient was obtained from Pest Control Products Board (PCPB). More information on individual pesticide EIQ was collected from online platforms through a desktop literature review, targeting relevant available and accessible documents and reports. Books and journals were also used to complement the information collected from other sources. Published and unpublished ICIPE reports were also reviewed.

3. 5 Data Analysis Techniques

This study adopted descriptive methods and econometric modelling to address the objectives and test the postulated hypothesis concerning impacts of IPM technologies on health and environmental effects. Variables considered for quantitative analysis were as shown in Table 3.1. The choice of the variables is based on literature review discussed in the previous chapter and on theoretical information on the subject matter.

Table 3. 1: Measurement and Description of variables

Variable description	Unit of measurement
Educational level	Years
Years in Mango farming	Years
Household head age	Years
Household size	Count
Agricultural land owned	Acres
Mango production trees	Count
Income per month	Kshs per month
General farming experience	Years
Gender of the household head	Dummy (male=1, 0=female)
Access to extension officers	Dummy (Yes=1, 0=No)
Protective Clothes Usage	Dummy (Yes=1, 0=No)
Group membership	Dummy (Yes=1, 0=No)
Access to credit facilities	Dummy (Yes=1, 0=No)
Access to irrigation water	Dummy (Yes=1, 0=No)
Labor management (man-day) to total labor (man-day)	Ratio
Use of IPM	Dummy (1 if farmer adopted IPM and 0 if other)
Total Mango Revenue – Total variable costs	Kshs per acre per season
Total health costs resulting from pesticide use	Kshs per acre per season
EIQ field use	Rank

3.5.1 Descriptive Methods

Descriptive analysis was used to describe quantitative and qualitative variables collected in this study. Measures of central tendency and dispersion such as the mean, mode, S.D, range and medians of various variables were obtained. T-tests and chi square tests were used to compare selected variables between control and treatment regions.

3.5.2 Environmental Impact Quotient (EIQ)

Environmental Impact Quotient (EIQ) is a mathematical model used to summarize health and environmental effects of pesticides. It combines the pesticide hazard posed to farm workers (applicators and pickers), consumers (consumer and ground water) and the local environment (aquatic and terrestrial) into one numerical value (Pradel *et al*.,2008; Macharia, 2009). The potential risks for each pesticide is based on measures of toxicity such as LD_{50} (dose at which 50% of the treatment group dies within specified time period), or LC_{50} (Concentration at which 50% of the treatment group dies within a specified period of time) and the potential exposure such as the half-life, run off or leaching potential (Swinton *et al., 1998).* The model make use of toxological data which has been standardized to a three point scale of 1, 3, and 5 in accordance to the hazard of various pesticides (1 being the lowest, 5 the highest), (Kovach *et al.*, 1992). The EIQ has three components; farm worker, consumer and ecological components. The farm worker component refers to the effects of pesticide on applicators and pickers such as farm workers and household members. The consumer component is based on pesticide residues on farm products and ground water contamination. Ground water effects are included in the consumer component because contaminated drinking water is a human health concern rather than a wildlife issue (Macharia *et al.*, 2009). The ecological component includes potential effects on aquatic organisms, bees, birds and beneficial arthropods. The value of EIQ for a pesticide is given by the sum of the EIQ farm worker, EIQ consumer and EIQ environment, altogether divided by three as shown in the following EIQ Formula:

$$EIQ = \{C[(DT * 5) + (DT * P)] + [C * ((S + P)/2) * SY) + (L)] + [(F * R) + (D * ((S + P)/2) * 3) + (Z * P * 3) + (B * P * 5)]\}/3 \quad (3.3)$$

Where:

C = chronic toxicity; DT = dermal toxicity

P = plant surface residue half-life S = soil residues half-life

SY = systemicity L = leaching potential

F = fish toxicity R = surface loss

D = bird toxicity Z = bee toxicity

B = beneficial arthropods activity

The first component represents the farm worker component; the second part represent the consumer component while the third section represent the ecological component. Table 3.2 provides definition of parameters discussed above in EIQ formulae.

Table 3. 2: Parameters for Determination of EIQ

Variables	Symbol	Score 1	Score 3	Score 5
Long-term health effects	C	Little-none	Possible	Definite
Dermal toxicity (Rat LD_{50})	DT	>2000 mg/kg	200-2000 mg/kg	0-200 mg/kg
Bird toxicity (8 day LC_{50}	D	>1000 ppm	100-1000 ppm	1-100 ppm
Bee toxicity	Z	Non – toxic	Moderately toxic	Highly toxic
Beneficial Arthropods toxicity	B	Low impact	Moderate	Severe impact
Fish toxicity (96 hr. LC50)	F	>10 ppm	1-10 ppm	<1 ppm
Half-live surface	P	1-2 weeks	2-4 weeks	>4 weeks
Soil residue half-live (T1/2)	S	<30 days	30-100 days	>100 days
Mode of Action	SY	Nonsystematic	Systematic	
Leaching potential	L	Small	Medium	Large
Surface runoff potential	R	Small	Medium	Large

Source: Kovach *et al.*, 1992

The toxicity information in Eqn. (3.3) is available from several sources including extension toxicology network, published journals and individual chemical manufacturers (Macharia *et al.*, 2009). After establishing the EIQ values for the active ingredient of each pesticide, the EIQ field use rating is calculated. The computation requires determining the rate of each pesticide, such that.

$$EIQ\ field\ use\ rating = EIQ * \%active\ ingredient * Rate \quad (3.4)$$

Using the above method, comparisons of environmental impact between pesticides and different pest management programs, for example use of conventional synthetic pesticides and an integrated pest management (IPM) strategy can be made (Kovach *et a.l*, 1992). The EIQ field Use Ratings and number of application during a defined period of time, for instance a season, are determined for each pesticide, and these values are then summed to determine the total environmental impact of that particular strategy. The pest management strategy with a low EIQ Field Use Rating is preferred as it presents less health and environmental effects.

3.6 Econometric Model

To estimate the impact of IPM technologies for suppression of mango fruit flies on health and environment, the following general model is used;

$$y = \boldsymbol{\beta} V + \sigma IPM + \varepsilon \qquad (3.5)$$

Where y represents Environmental Impact Quotient, V denotes a vector of independent variables; IPM use is a dummy variable for IPM adoption, σ measure the impact of IPM use on health and environmental effects while ε is the error term.

IPM is a dummy variable and potentially endogenous because farmers decide whether to adopt or not (self-selection bias), thus estimating the coefficients with OLS will yield biased results. Heckman selection, instrumental variable (IV) and propensity score matching (PSM) are some of the other models used to handle such biases in literature review. These methods also have some several limitations, for example, both Heckman selection and IV methods tend to impose a functional form assumption by assuming that adoption of IPM has only an intercept shift and not a slope shift in the outcome variables (Alene *et al*.,2007). PSM produces bias result when there are unobservable factors that influence both IPM adoption and the outcome indicators. In order to address these issues, we use the endogenous switching regression (ESR) technique which has been employed in many impact assessment studies (Rao *et al.*, 2011).

The endogenous switching regression model consists of two stages. In the first stage, a selection equation is estimated while an outcome equation is estimated in the second stage. According to Lokshin *et al* (2004) the probability of a farmer adopting IPM technologies is given by the expected benefits I_s^* against the expected costs of not adopting the IPM practises, I_t^*. However I_s^* and I_t^* are latent variables. What is observed is the actual adoption of IPM technologies, I, I=1 if $I_t^* \triangleright I_s^*$ and I=0 if $I_t^* \leq I_s^*$. Adoption of IPM can therefore be denoted as:

$$IPM = Z\alpha - \varpi \quad (3.6)$$

Where *IPM* is the participation dummy, Z is vector of the independent variables affecting adoption of IPM and respective coefficients e α, and ϖ is an error term. The general probit model of adopting IPM technologies is therefore specified as:

$$IPM = \beta_{0j} + \beta_{1j}(gender) + \ln\beta_{2j}(educ) + \ln\beta_{3j}(\exp) + \ln\beta_{4j}(age) + \ln\beta_{5j}(hhsize) + \ln\beta_{6j}(fsize) + \ln\beta_{7j}(mtrees) + \ln\beta_{8j} + \beta_{9j}(exten) + \beta_{10j}(pcloth) + \beta_{11j}(grpmem) + \beta_{12j}(credit) + \ln\beta_{13j}(labmngt) + \beta_{14j}(irrwat) + \mu \quad (3.7)$$

The IPM participation dummy takes a value of 1 if the farmer has adopted IPM practices and 0 otherwise. The explanatory variables are well elaborated in Table 3.1 comprised of both continuous and binary variables. Full Information Maximum Likelihood (FIML) is an efficient method to estimate ESR because it calculates the probit equation and the outcome equation simultaneously to yield consistent standard errors (Alene *et al.*, 2007). These estimates of the parameters of the ESR can be obtained using movestay command in Stata (Asfaw *et al*., 2010). The general representation of the outcome equation used in the second stage is as presented below.

$$EIQ = \beta_{0j} + \beta_{1j}(gender) + \ln\beta_{2j}(educ) + \ln\beta_{3j}(\exp) + \ln\beta_{4j}(age) + \ln\beta_{5j}(hhsize) + \ln\beta_{6j}(fsize) + \ln\beta_{7j}(mtrees) + \ln\beta_{8j} + \beta_{9j}(exten) + \beta_{10j}(pcloth) + \beta_{11j}(grpmem) + \beta_{12j}(credit) + \ln\beta_{13j}(labmngt) + \beta_{14j}(irrwat) + \mu \quad (3.8)$$

The dependent variable here refers to the environmental field use which represents effects of IPM technologies on health and environment. To successfully achieve this we need to estimate the conditional expectation of effects that participants would have without adoption of IPM technologies (Lokshin *et al.*, 2004). The steps carry on as follows: first, for a farmer with characteristics X and who adopt IPM technologies the expected effects can be defined as:

$$E(y_s / I = 1) = X\beta_S - \sigma_{SV}\lambda_S \quad (3.9)$$

Where ($\sigma_{SV}\lambda_S$) denotes sample selectivity, i.e. that a farmer who adopts IPM may be different from an average farmer with characteristics X due to unobserved factors. For the same IPM adopter, the anticipated health/environmental effects would be (Lokshin *et al* 2004)

$$E(y_t / I = 0) = X\beta_t - \sigma_{tv}\lambda_S \quad (3.10)$$

The change in health and environmental effects due to adoption of IPM can then be calculated as (Lokshin *et al.*,2004):

$$E(y_s / I = 1) - E(y_t / I = 1) = X(\beta_s - \beta_t) + (\sigma_{tv} - \sigma_{sv})\lambda_s \tag{3.11}$$

This is the average treatment effect on the treated (ATT) which compares the magnitude of health and environmental effects of adopters with and without IPM technologies while the ATU compares the magnitude of health and environmental effects of the non-adopters with and without IPM technologies. This treatment effect on the treated is due to the differences in the coefficients in Equations (3.9) and (3.10).

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.0 Introduction

This chapter reports the findings of the study based on the methods discussed in the previous chapter. Its purpose is to analyse the variables involved in the study. Data from the respondents was collected and analysed to assess health and environmental effects of IPM technologies in Meru County. The results are presented by use of tables and pie charts as shown below.

4.1 General household characteristics

This section presents the main demographic and socio economic characteristics of the sampled households. Table 4.1 below presents descriptive statistics for selected quantitative variables used in the study. On average, education of the household heads was 9.02 years in the treatment region while in the control region it was 7.86 years, and the difference was statistically significant. Education can enhance the ability to access and synthesize information that may positively influence adoption of a new technology (Wabbi *et al.,* 2002).

The mean years of mango farming experience was 14.78 and11.30 years in the treated and control regions respectively. This shows that farmers in the treatment region planted mango earlier in comparison to those in the control area. The highest number of years of mango farming experience was 57 years in the treated area and 50 years in the control region, implying that mango farming in Meru started as early in the 1950's. Farmers with longer period of farming experience are expected to have tried a number of technologies, hence likely to adopt new technologies. The mean age of heads of households in treated area was 55.93 years while those in the control area was 55.33 years. Young farmers are likely to adopt new technologies such as IPM packages for control of mango fruit fly since young farmers are risk takers, ambitious and energetic. Caswell *et al.* (2001) note that older farmers are reluctant to invest in new technologies especially where previously tried technologies did not perform as expected. Additionally, old farmers may be having other goals other than profit maximization. Wabbi (2002) contends that it is important not to correlate age and experience. A farmer may be old but with a few years in farming. On average, the family size was 2.73 and 2.67 persons per family in treated and control regions respectively. Family size may determine the quantity of labour available for use in Mango production since it is labour intensive. Family labour provides a greater bulk of the farm labour requirement in this area, thus a lager family size could be an incentive to adopt new technologies.

Table 4. 1: Summary of selected household characteristics

Variable	Overall Sample (n=371)	Control farmers (n=165)	Treatment farmers (n=206)	t-test
Educational Level (years)	8.51 ± 0.22	7.86 ± 0.36	9.02 ± 0.27	-2.6557***
Years in Mango farming	13.23 ± 0.91	11.30± 0.68	14.78 ±0.62	-3.7971***
Household head age (years)	55.59 ± 0.66	55.93± 1.03	55.33± 0.87	0.4415
Household size (count)	2.70 ± 0.48	2.67 ± 0.69	2.73 ± 0.07	-0.6204
Agricultural land owned (acres)	5.25 ± 0.28	4.01 ± 0.37	6.26 ± 0.40	-4.0461***
Mango production trees (count)	76.5 ± 5.71	38.16± 5.33	115.40±0.3	-6.3407***
Income per month (Kshs)	33125 ± 0.91	38250±0.87	28000±0.96	-1.4741
Distance to input market (KM)	13.39 ± 1.85	11.02± 1.69	15.75 ±2.01	-1.8151*
Distance to output market (KM)	20.36 ± 4.02	15.30± 1.96	25.41 ±6.08	-1.2441

Note: *** significant at 0.01 level, ** significant at 0.05 level, * significant at 0.10 level
Source: Field survey, 2014

There was great variation on land size among the respondents with the lowest farm size being 0.5 acres and the highest 51 acres. Put together, the mean land size was 5.2 acres. Farmers in treated region had a mean of 6.26 acres while those in control had a mean farm size of 4.01 acres. On average, number of productive mango trees was higher for farmers in the control region. Farmers with bigger farms are likely to have a higher number of mango trees. Results from Cornejo (1998) finds that large farm size have a positive impact on adoption of new technologies. Farmers with large farm size have better access to credit and financial resources. Some farmers were engaged in other activities other than farming. The average off farm income in control region was Kshs. 38,850 while in treated region was Kshs.28, 000 per month.

Sample t-tests (mean comparisons) in Table 4.1 show that on average there was no significant difference between the treatment and control groups in terms of age of household head, household size, distance to output market, off farm income in Kshs and health costs. However, variables such as educational of head of household, farm size, farming experience, number of productive trees, and distance to input market, gross annual mango income and total cost of mango production were statistically significant between the two groups of mango farmers.

As presented in Table 4.2 only two variables; use of protective clothes and access to irrigation to water are statistically significant. Most of the households are headed by males. Overall, 80.5% of the sampled mango farmers had male heads whereas 19.5% had female heads. Further analysis shows that in treatment region 82.04% of the households had male heads while the rest had female heads. The trend is the same for in control where 78.18% of the mango farmers had male heads. These results are similar to those of Muchiri (2012) who find a ratio of 3:1 of male to female-headed households among mango farmers in Embu County. In the treatment area, 53.89% of the farmers had access to irrigation water while a smaller percent of 40% of those in control region. Water shortage was noted as a common challenge in the county especially during dry months since there are limited natural water sources. Although mangoes do not require a lot of water for cultivation, water is essential for other fruits such as paw paws and oranges. Sixty-three percent of farmers in the control region use protective clothes while spraying while only 45.46% of farmers in control region use protective clothes.

Table 4. 2: Comparison of qualitative variables between control and treated regions

Variable	Control (n=165)	Treated (n=206)	Chi-square	P-value
	%	%		
Gender of household head				
Male	78.18	82.04	0.8264	0.353
Female	21.82	17.96		
Access to Extension Officers				
Yes	70.30	76.21	1.6466	0.199
No	29.70	23.79		
Protective Clothes usage				
Yes	45.46	63.11	11.5468***	0.001
No	54.54	36.89		
Group Membership				
Yes	70.33	63.11	2.1237	0.145
No	29.67	36.89		
Access to credit services				
Yes	24.24	26.23	0.1882	0.664
No	75.76	73.77		
Access to irrigation water				
Yes	40	53.89	7.4334***	0.006
No	60	46.11		

Note: *** significant at 0.01 level, ** significant at 0.05 level, * significant at 0.10 level
Source: Field survey, 2014

4.2 Pesticide Intoxication

Mango farmers were also asked if they had experienced any health symptoms ascribed to chemical pesticides during the last mango season. About forty percent of the sampled respondents said they had experienced pesticide related complications for the last one year. According to the Figure 4.1, household heads were the most affected in both regions while children were least affected. Households (mostly men) are usually involved in spraying of pesticides. More farm workers in households in the treatment region were affected than those in the control region. This could be explained by the fact that farmers in treatment region receive higher mango revenue, which enable them to employ more farm workers in mango production than in the control region. Spouses and children were least affected in both regions since they are mostly engaged in other farm duties other than pesticide application.

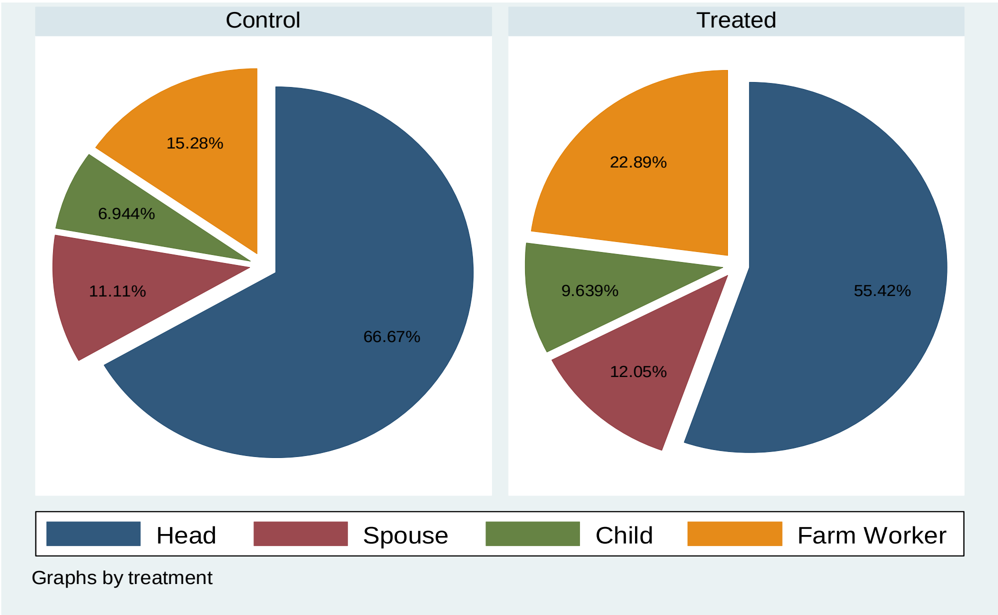

Figure 4. 1: Pesticide Intoxication by household member

Source: Field Survey, 2014

Dolan (2001) notes that in horticultural farming, some farming activities such as planting, weeding and picking are sex typed in a relatively inflexible manner, whereas others (fertilizer and pesticide application, watering) exhibit a cross cutting gender complementary of tasks. Precisely men are involved in laborious tasks such as clearing of fields while women get involved in tasks such as watering and harvesting. According to Dolan (2001), women provide 70% of the pesticide application labour. This finding contrast with the results of this study that finds that pesticide application in mango production is laborious, thus mostly provided by men. This is plausible since Dolan (2001) study focused on vegetables, in contrast to fruits production, where activities such as pesticide application require extra physical exertion.

4.3 Health effects of Pesticides

The most common acute health signs and symptoms of pesticide intoxication reported from the study locale include headache, sneezing, eye irritation, dizziness, shortness of breath, skin irritation, fever, dizziness, and chest and stomach pains. It was found out that, although mango farmers in Meru do not frequently seek medicinal treatment at the hospital; they use home based care and traditional healing strategies such as drinking milk and taking showers using plenty of waters immediately after pesticide application. In the control region about 40% of the interviewed households reported to have experienced headache, 19% reported to have experienced sneezing, 14% reported eye irritation and 11 % shortness of breath while in the treatment region about 34% reported headache, 29% eye irritation, 19 % skin irritation while 7% reported sneezing.

Table 4. 3: Pesticides related health effects among mango growers

	Overall (n=371)		Control(n=165)		Treated(n=206)	
Symptom	Freq.	%	Freq.	%	Freq.	%
Headache	57	15.4	29	40.3	28	33.7
Sneezing	20	5.4	14	19.4	6	7.2
Eye irritation	34	9.2	10	13.9	24	28.9
Dizziness	9	2.4	6	8.3	3	3.6
Vomiting	1	0.3	1	1.4	0	0
Shortness of breath	6	1.6	2	2.9	4	4.8
Skin irritation	24	11.1	8	11.1	16	19
Fever	2	6.5	1	1.4	1	1
Stomach Pains	1	0.3	1	1.4	0	0
Chest Pains	1	0.3	0	0	1	1

Source: Field Survey, 2014

Aiwerasiav (2002) assessed pesticide related health symptoms among crop farmers in Tanzania. He noted that common symptoms experienced by crop farmers were coughing (30.8%), headache (27.1%), general body weakness (25.6%), difficulty in seeing (27.1%), and dizziness (19.5%). In addition, Khan (2009) assessed economic evaluation of health cost of pesticide use in Pakistan and found out that 34% of the farmers experienced multiple effects while 63% believed the symptoms were related to pesticides. Asfaw *eat al*., (2010) investigating the health and environmental impact of EU private sector standards in Kenyan export vegetable growers identified sneezing, skin and eye irritation, dizziness and headache among the most common pesticide related health symptoms among the export vegetable producers.

4.4 Pesticide Management Practices

Despite the fact that farmers understand pesticides are poisons, 26.1% of the respondents in the control region and 21.4% in treated region store pesticides in their houses. A study by Mutuku *et al.* (2013) which assessed current patterns and practices of pesticides use in Tomato based agro system in Kathaini Constituency, Kenya reported that majority of the farmers do not have knowledge on how to store pesticides. He found out that 20.8% of the respondents store pesticides in the farm, bathroom, toilet and granary.

Table 4. 4: Pest management practices

		Overall (n=371)		Control (n=165)		Treated (n=206)	
Variable		Freq.	%	Freq.	%	Freq.	%
Storage	Homes	87	26.1	43	26.06	44	21.36
	Granary		3.0	5	3.03	1	0.49
	Field	4	1.2	2	1.21	2	0.97
	Others	274	69.7	115	69.69	159	71.18
Use of protective clothes	Yes	205	45.4	75	45.45	130	63.11
Training on pesticide	Yes	169	33.9	56	33.94	111	53.88
First aid training	Yes	113	30.9	51	30.91	62	30.10

Source: Field survey, 2014

From the Table 4.4 above, 45.5% and 63% of the farmer respondents in control region and treatment areas use protective clothing’s respectively. About 34% and 54% of the farmers in control and treated region respectively had received some training on pesticide application. In addition, about 31% and 30% of the respondents in control and treated regions respectively had received training on first aid. Mutuku *et al.* (2013) found out that 41.6% of the respondents did not use apron while 45.8% had never worn nose mask while spraying pesticides. These can cause infection to human body hence poor human health due to disease from chemicals resulting into reduced labour for agricultural production.

4.5 Perception on impacts of pesticides on health and Environment

Farmers were asked to rank the risk associated with pesticide use to health and environmental indicators. Five categories were presented to the farmers, from "no risk at all" risk to "large" risk. Majority of the farmers in both regions reported that pesticides have a large risk on their health and environment.

Table 4. 5: Farmers perceptions on pesticide risks

Perception	Overall (n=371)		Control (n=165)		Treated (n=206)	
Health	Freq.	%	Freq.	%	Freq.	%
Large Risk	150	39.4	65	39.4	85	41.3
Medium Risk	98	22.4	37	22.4	61	29.6
Small Risk	57	17.6	29	17.6	28	13.6
Very Toxic	42	13.9	23	13.9	19	9.2
No risk at all	24	6.7	11	6.7	13	6.3
E**nvironment**	Freq.	%	Freq.	%	Freq.	%
Large Risk	106	25.5	42	25.5	64	31.1
Medium Risk	95	26.1	43	26.1	52	25.2
Small Risk	97	23.1	38	23.1	59	28.6
Very Toxic	12	4.9	8	4.9	4	1.9
No risk at all	61	20.6	34	20.6	27	13.1

Source: Field survey, 2014

Awareness of pesticides' on health and environmental risk is of importance as this may influence farmers' decision to adopt IPM. In the control region, 39.4% of the respondents reported large risk of pesticides on health, 22.4% medium risk, 17.6%

small risk, 13.9% very toxic while 6.7% no risk at all. In the treatment region 41.3% reported large risk of pesticides on health, 29.6% reported medium risk, 13.6% reported small risk, 9.2% reported very toxic while 6.3% reported no risk at all. According a study conducted in Pakistan by Khan (2009), 88% of the farmer respondents believed that use of pesticides imposed a higher health risk to humans. On the perception of the impacts of pesticides on health, 54% of the surveyed households in this study reported small risk, 23% medium risk, 10% believed the risk is large, 3% believed its very toxic, while 12% believed there is no risk at all. Mutuku *et al*. (2013) reported that 59.7% of the respondents were aware that pesticides have effect on environment while 40.3% are not.

4.6 Environmental Impact Quotient (EIQ) for commonly used pesticides for control Mango fruit flies in Meru County

This study has adopted an Environmental Impact Quotient (EIQ) approach to evaluate the health and environmental effects among mango farmers in Meru County (Kovach *et al.*, 1992). A total of 65 pesticides comprising of 41 active ingredients were used in Mango production in the County. Bayleton and Bulldock were the most used pesticides in mango production representing 34.50% and 33.96% of the total pesticide used respectively. They recorded a percentage of 15.43% and 24.47% of the total pesticide usage in the control region and a percentage of 22.78% and 22.42% of the total pesticide usage in the treatment region respectively. Mean EIQ values for farm workers, consumers and environmental component in the control region were 24, 10 and 75, respectively while in the treatment region the mean components were 25, 10, and 73, respectively (Appendix 8).

To obtain the volume of individual pesticides applied per acre, we first computed the treated area which was arrived at by multiplying the percentage of farmers using pesticides in mango production with the total area under mango trees. The obtained treated area was then multiplied with the rate of the pesticide applied per acre so as to find the estimated amount of chemical used. From literature, we listed all pesticides applied to the mangoes and their recommended application rates. We also interviewed key agricultural experts and pesticide venders to obtain information on recommended pesticide dosages which was counterchecked by information from PCPB's website and product labels. With the aid of Kovach *et al.* (1992) procedure, EIQ values for each active ingredient of a pesticide used were calculated based on the pesticide active ingredient and physical properties while others were obtained from internet sources and published journals (Macharia, 2009).

Basing on EIQ Classification rule (Macharia, 2009), values for all the mango pesticides used in mango production showed that 30%, 25% and 45% of those pesticides were rated as low (EIQ = 0 to 20), medium (EIQ = 21 to 40) and high (EIQ $\geq$ 41), respectively. Pesticides that had EIQ field use below 40 were decis, orthene, actara, karate, rodazim, cyclone, thunder, antracol, topsin, thiovit. Methomyl, danadim, bayleton, agrinate, tata alpha, dithane, copper, bulldock and dimethoate had an EIQ field use of greater than 40. Generally, results show that the environmental component of the EIQ is high in both control and treatment regions but there is a significant difference observable in the EIQ field use between the two regions. Of the total pesticides used in Meru County for mango production, none could be classified in category 1a (extremely hazardous), 10% are in category 1b (highly hazardous), 40% are in category II (moderately hazardous), 25% are in category III (slightly hazardous), 25% are in category U (unlikely to present acute hazard in normal use). The remaining two categories FM (fumigant, not classified) and O (obsolete as pesticide, not classified) were not used in mango production. The total EIQ field use in Meru County was 4049.67, out of which 84% was obtained from the control region. The total field-use EIQ rating per individual pesticide ranged from 0.58 to 946.16, being lowest for Deltamethrin (0.58) and highest for Dimethoate (946.16).

4.7 Correlation Analysis

Correlation analysis was conducted for the following variables: educational level, years in mango farming, household head age, household size, Agricultural land owned, mango production trees, income per month, general farming experience, gender of the household head, access to extension officers, protective clothes usage, group membership, access to credit facilities and access to irrigation water. The pair wise correlation showed that no variable(s) had a correlation above 0.8, which could result in multi-collinearity problems. The correlation matrix is attached in this report as appendix 3. Variance Inflation Factor (VIF) was also conducted after regression to detect the problem of multi-collinearity. The results show that there is no strong correlation among the variables since the values of VIF are far less than 10 (Appendix 6).

4.8 Econometric Results

This section presents the results of model estimation and inferential statistics. The null hypothesis was that IPM technologies do not have any effect on health and environmental. The F-ratio was used to test the joint hypothesis to show whether the included variables exerted any significant influence on the dependent variable. It tested the null hypothesis that all the estimated coefficients are zero.

Before conducting the Endogenous Switching Regression analysis, the following preliminary tests were carried out to establish linearity, normality, homogeneity of the variance, independence and multi-collinearity. The results indicated that the relationships between the predictors and the outcome variables were linear, the errors were normally distributed, the error variance was found to be constant, the errors associated with one observation were not correlated with the errors of any other observation and, predictors were not highly collinear, that is linearly related. Goodness of fit was verified using Hosmer-Lemeshow tests. With a p-value of 0.29, we can say that Hosmer and Lemeshow's goodness-of-fit test indicates that our model fits the data well.

4.8.1 Determinants of adoption of IPM technologies

The first stage of the Endogenous switching regression model is a probit model that evaluated factors that influence adoption of IPM technologies in Meru County. The results of the probit model are presented in Table 4.8. The first two columns present results from a normal probit model, estimated independently, while the last two columns show the probit model that is jointly estimated alongside the outcome equation using FIML method as outlined in section 3.6. Adoption of IPM technologies significantly depends on number of productive mango trees, access to irrigation water, membership to farmer groups, size of agricultural land, age of the household head and years in mango production. Farmers with more number of productive mango trees are likely to adopt IPM strategy for control of fruit flies. This is reasonable, because more number of productive trees implies high production and thus higher revenue from mango production, which may trigger adoption of new technologies due to certain necessary capital investments. This finding is in agreement with Korir *et al.* (2015) who find that farmers with more mango trees are likely to adopt more IPM components, thus a positive significant impact on the level of IPM adoption. Access to irrigation water was significant at 5% with a coefficient of 0.326.

Table 4. 6: Probit models for determinants of IPM adoption

	Independent probit		Joint estimated probit	
Variables	Coefficient	SE	Coefficient	SE
Household size (count)	-0.236	0.152	-0.128	0.148
Years in Mango farming (years)	0.214***	0.075	0.131*	0.068
Age of the household head (years)	-0.000**	0.000	-0.002***	0.000
Agricultural land owned (acres)	0.226**	0.104	0.064	0,122
Gender of the household head (dummy)	0.050	0.207	-0.022	0.182
Access to extension officers (dummy)	-0.071	0.156	-0.070	0.163
Protective clothe usage (dummy)	0.179	0.241	0.167	0.142
Group membership (dummy)	-0.479***	0.169	-0.486**	0.156
Access to credit services (dummy)	0.001	0.177-	0.043	0.161
Access to irrigation water (dummy)	0.326**	0.153	0.143	0.138
Labour management (ratio)	0.002	0.005	0.001	0.005
Mango production trees (count)	0.505***	0.741`	0.516***	0.738
Income per month (Kshs)	-0.010	0.018	-0.000	0.016
Educational level (school years)	-0.004	0.019	0.003	0.014
Constant	-1.067	0.609	-1.167**	0.574
Number of observations		370		370

NB: Statistical significance at 0.01(***), 0.05(**) and 0.1 (*)
Source: field survey data 2014

Access to water for irrigation enables farmers to diversify production and to produce different farm products throughout the year, which increases farm revenue enabling the farmer to adopt IPM technologies. This variable is rarely analysed in many adoption studies, however Rahman (2007) elaborated on the importance of irrigation on IPM adoption, highlighting it as one of the cultural methods of controlling pests and diseases in agricultural production. The above analysis shows that farmers who are members of a farmer group are less likely to adopt IPM technologies. This is unexpected as farmers who are members of a mango group are likely to access new information and likely to adopt new farming ideas. However, as noted by Amek (2006), famers in a group may be limited by group dynamics from adopting new technologies while individual farmers have the freedom to make their decisions independently. On the other hand, Ghimire *et* *al.* (2014) observed a positive and statistically significant relationship between group membership and IPM adoption in their study on determinants of IPM adoption.

Farmers who have larger farm sizes are likely to adopt IPM technologies. This could be due the collateral value of land that could be used to access credit and higher farm revenue due to economies of scale, which are necessary to fund necessary capital investments. According to Wabbi (2002), farm size affects adoption costs, risks perceptions, human capital, credit constraints and labour requirements. The author argues that households with small farms, face large high fixed costs involved in adoption of new technologies. Mugisha *et al.* (2005) in their study on adoption of IPM by ground nuts farmers in Uganda also agree with our findings that adoption of IPM is positively influenced by size of cultivable agricultural land. As expected, age of household heads is negatively related to adoption of IPM. Older farmers may have already invested in older technologies which could hinder them from adopting new technologies. The results are in harmony with Kabir *et al.* (2014) who found that age was negatively correlated with IPM adoption of IPM vegetable farming in Bangladesh. The number of years in mango production has a significantly positive impact on adoption of IPM technologies. Obviously, farmers with more years in mango production have better knowledge on methods of pest and disease control and their impact on health and environment. In harmony with this study, Zyoud (2014) finds positive correlation between age and farming experience and adoption of IPM techniques by greenhouse vegetable farmers in Jordan.

4.8.2 Determinants of health and environmental effects

The second stage estimates of the Full Information Maximum Likelihood (FIML) ESR models for the health and environmental effects are presented in Table 4.8 below. We used FIML because it provides more efficient and reliable estimates. At the bottom of the Table 4.8, the estimates of the coefficient of correlation between the error terms in the adoption and outcome equation are provided ($\rho_{1,}\rho_0$)The estimated coefficient of correlation between the systems of equations, ρ_1 , is positive and significant. Thus, the adoption and outcome regression results together suggest that the observed and unobserved factors influence adoption decision. The significance between the two systems of equations suggests that self-selection occurred in the adoption of ICIPE's IPM technologies.

Table 4. 7: Full information maximum likelihood parameter estimates for health and environmental effects

	Treatment		Control	
Variable	Coefficient	S.E	Coefficient	S.E
Household size (count)	0.389	0.264	-0.435*	0.254
Years in mango farming (years)	-0.019	0.125	0.012	0.105
Household head age (years)	0.000***	0.000	-0.000	0.000
Agricultural land owned (acres)	-0.182	0.233	0.135	0.194
Gender of household head(dummy)	0.435	0.327	-0.319	0.288
Access to extension officers (dummy)	0.177	0.299	0.286	0.267
Protective cloth usage (dummy)	0.009	0.262	-0.379	0.239
Group Membership (dummy)	0.562**	0.269	0.083	0.291
Access to credit services (dummy)	0.070	0.278	0.244	0.265
Access to irrigation water(dummy)	-0.411	0.258	0.206	0.243
Labour Management(ratio)	-0.021*	0.012	0.002	0.005
Mango production trees (count)	-0.730**	0.131	-0.378**	0.167
Constant	2.717	0.972	4.995	0.937
$\ln\sigma_{1,}$ $\ln\sigma_0$	0.693(0.059)***	0.355(0.061)***		
$\rho_1\rho_0$	-1.89(0.45)***	-0.179(0.268)		
LR test of independent questions		35.25**		
Number of observations		371		
Log likelihood		-335.287		

***, **, * mean values are significant at 1%, 5% and 10% respectively
Source: Field Survey, 2014

The estimated coefficient of correlation between the adoption equation and the non-adopters outcome equation, ρ_0, is also significant implying that the adopters and non-adopters would not have the same magnitude of health and environmental effects using the old technology of fruit fly control. In addition, the likelihood ratio test for selection and outcome equations is significant pointing out dependence between the two equations. The estimation results show we have a structural difference between the two groups in the county because most of the variables that influence health and environmental effects in the two regions are distinct. Results from the treated region show that labour management is significant and reduces environmental effects. From the results if the labour management ratio reduces by 1% the value of EIQ field use will reduce by 2.1 % implying a positive impact on the environment. In addition, the number of production trees significantly reduces environmental effects. An increase in the number of mango trees by 1% will reduce environmental impact by 73% in the treatment region. This could be due to the fact that farmers who have a larger orchards are more experienced and have better access to information on pesticide use, thus they spray the recommended rate which has a lower impact on health and environment. The above analysis shows that farm groups have a positive effect on EIQ field use. This is unexpected as farmers who are members of a mango group are likely to access new information and likely to adopt new farming ideas. However, as noted by Amek (2006), famers in a group may be limited by group dynamics from adopting new technologies while individual farmers have the freedom to make their decisions independently. On the other hand, Ghimire *et al.* (2014) observed a positive and statistically significant relationship between group membership and IPM adoption in their study on determinants of IPM adoption. Household head age is also significant by increasing the negative health and environmental effects of pesticide use. As discussed in the descriptive section older farmers are less innovative thus less likely to adopt IPM technologies which would have led to reduced EIQ field use. Results for farmers in control region indicate that household size and number of productive trees are significant in determining the magnitude of EIQ filed use. However positive health and environmental impact of number of mango trees is higher in the treatment region than in control region.

4.8.3 Health and Environmental effects of IPM Adoption

The estimates of the treatment effects of IPM adoption on health and environmental effects are presented in Table 4.9. As explained in chapter 3, the average treatment effect (ATT) is computed on the treated based on results from Table 4.8. The predicted health and environmental effects are compared for the sub-sample who have adopted IPM technologies with and without IPM holding other factors constant. The ATU is also computed, which indicates the difference between the mean health and environmental effects if they had adopted or not adopted IPM technologies. As shown in last columns of Table 4.8, IPM non-adopters would have a positive environmental impact from adoption. Households who actually adopted the IPM strategy have reduced EIQ field use by 6.81% after adopting the strategy.

The lower part of the table shows additional treatment effects for imaginary situations. In the first scenario, the disaggregated findings indicate that IPM strategy has reduced health and environmental effects for all IPM adopters. For small holder mango farmers who owns less than 1 acre of land have benefited more from ICIPE's pest management strategy. Small scale farmers who are mostly poor have limited information on pesticide use and safety precautions unlike the large scale farmers.

Table 4. 8: Treatment effects of IPM technologies

	No.of obs	Adopters EIQ Field use	Non-Adopters EIQ Field use	Net change (%)
All mango farmers	371	5.65	47.12	-6.81***
By land holding				
Mango farmers<1 acre of land	18	0.10	74.17	-160.45***
Mango farmers 1-2 acres of land	100	11.64	45.39	-14.17***
Mango farmers>2 acres of land	253	5.21	43.09	-31.65***
Use of Protective Clothes				
Yes	205	6.06	44.16	-27.21***
No	165	5.23	49.62	-31.53***
Access to credit Facilities				
Yes	95	5.81	57.19	-28.38***
No	276	5.75	43.92	-28.67***
Attend ICIPE's Training				
Yes	234	5.27	0	-31.29***
No	137	7.36	35.244	-22.40***

***, **, * mean values are significant at 1%, 5% and 10% respectively
Source: Field Survey, 2014

In the second scenario, we assume that all farmers have access to credit, which would reduce the value of EIQ field use by 28.38% among the adopters who have access to credit facilities. The results show that access to credit does have an impact on health and environmental effects since all adopters all gained from ICIPE's fruit fly control strategy whether they had access to credit or not. On the other hand, use of protective clothes reduces health and environment effects for IPM adopters by about 27.21% .This is plausible since proper use of protective equipment’s reduces exposure to chemicals and hence the environmental and health effects (Oluwole *et al*., 2009). Adopters who had undergone ICIPE’s IPM training reduced EIQ field use by 31.29%. It is important to note reduced EIQ field use for all the imaginary scenarios.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.0 Introduction

The researcher, after having established health and environmental effects, made conclusions and recommendations and measures to be put in place to ensure that sustainable and environmentally friendly agriculture is promoted in Meru County.

5.1 Summary

The study was conducted in Meru County to assess the effects of an integrated pest management (IPM) strategy for suppression of mango fruit flies on human and environment health. The strategy has been developed and disseminated by ICIPE and partners, to reduce the negative impacts of pesticides on human and environment health and thus improve the socio-economic welfare of mango growers in Africa. The specific objectives of this study were to characterize and determine the magnitude of human and environmental health effects of IPM technology and to assess their impacts on human and environment health. The study utilized a census of mango producers complied previously by ICIPE from their study on impact assessment of mango IPM technology. A total 371 mango growers were randomly selected for the interviews, 165 from control region and 206 from treatment area. Data was collected using Open Data Kit (ODK) programme. Both descriptive and empirical analysis were utilized to analyse the collected household-level data. Environmental Impact Quotient (EIQ) was applied to assess the magnitude of human and environment health effects associated with use of pesticides, while Endogenous Switching Regression (ESR) model was used to analyse the effect of IPM on human and environment health. The results of the first stage show that number of production trees, access to irrigation water, and size of agricultural land have positive and significant influence on adoption of IPM, where years of mango production, membership to farmers group and age of the household age are negatively related to IPM adoption. The results from ESR model number of mango trees has a positive impact on health and environment, however the magnitude is higher in the treatment region. Households who adopted IPM technologies have reduced EIQ Field use by 6.81%.

5.2 Conclusion

The need for sustainable and environmental friendly agriculture has promoted invention of new techniques in organic agriculture which enables farmers to increase production and access lucrative markets for their mangoes in the international market. While few studies have focussed on economic benefits of IPM technologies, there is no study that has estimated health and environmental effects of IPM technologies. In this we bridge this gap by estimating health and environmental effects of IPM technologies. The findings showed statistical significance in the means in socio economic characteristics between the IPM adopters and non-adopters at baseline. Descriptive results shows that years in mango production, number of years in school, size of land, number of productive mango trees, distance to input market, protective clothes usage and access to irrigation water were statistically significant between IPM participants and non-participants. Age of the household head, household size, off -farm income, distance to output market, gender of the household head, access to extension services and credit had no statistical significance. The household heads in both regions were the most affected with negative pesticide effects. At least over 30% of the respondents in the treatment and control regions reported that pesticides had a large risk on both human and environment health. Of importance were the differences in gross margin net health costs and EIQ field use between the two regions. The regression results showed that adoption of IPM leads to positive effects on health and environment.

5.3 Recommendations

Based on the findings, the following recommendations are made:

1) There is need therefore for the Government to increase information access on the impact of various pest management techniques on health and environment.
2) There is need for farmers to be trained on use of protective clothes and pesticides that have a lower EIQ value.
3) Further research should consider using panel data to assess long-term adoption and impacts of IPM technologies on health and environment.
4) Further research on determinants of health costs in Meru County could also be valuable.

REFERENCES

Abara, I. O., & Singh, S. (1993). Ethics and biases in technology adoption: The small-firm argument. *Technological Forecasting and Social Change*, *43*(3), 289–300.

Abdullah, F. A., & Samah, B. A. (2013). Factors impinging farmers' use of agriculture technology. *Asian Social Science*, *9*(3), p120.

Adebiyi, S., & Okunlola, J. (2013). Factors Affecting Adoption of Cocoa Farm Rehabilitation Techniques in Oyo State of Nigeria. *World Journal of Agricultural Sciences*, *9*(3), 258–265.

Adeoti, A. I. (2008). Factors influencing irrigation technology adoption and its impact on household poverty in Ghana. *Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS)*, *109*(1), 51–63.

Adesina, A. A., & Baidu-Forson, J. (1995). Farmers' perceptions and adoption of new agricultural technology: evidence from analysis in Burkina Faso and Guinea, West Africa. *Agricultural Economics*, *13*(1), 1–9.

Aiwerasia, V. N. (2002). *Health impact of exposure to pesticides in agriculture in Tanzania*. Tampere University Press. Academic dissertation, Tampere University.

Aktar, W., Sengupta, D., & Chowdhury, A. (2009). Impact of pesticides use in agriculture: their benefits and hazards. *Interdisciplinary Toxicology*, *2*(1), 1–12.

Akudugu, M. A., Guo, E., & Dadzie, S. K. (2012a). Adoption of modern agricultural production technologies by farm households in Ghana: What factors influence their decisions. *Journal of Biology, Agriculture and Healthcare*, *2*(3).

Akudugu, M. A., Guo, E., & Dadzie, S. K. (2012b). Adoption of Modern Agricultural Production Technologies by Farm Households in Ghana: What Factors Influence their Decisions? *Journal of Biology, Agriculture and Healthcare*, *2*(3), 1–13.

Alene, A. D., & Manyong, V. (2007). The effects of education on agricultural productivity under traditional and improved technology in northern Nigeria: an endogenous switching regression analysis. *Empirical Economics*, *32*(1), 141–159.

Al-Shadiadeh, A. N., Al-Mohammady, F. M., & Abu-Zahrah, T. R. (2012). Factors Influencing Adoption of Protected Tomato Farming Practices Among Farmers in Jordan Valley. *World Applied Sciences Journal*, *17*(5), 572–578.

Al-Zyoud, F. (2014). Adoption Range of Integrated Pest Management (IPM) Techniques by Greenhouse Vegetable Growers in Jordan. Jordan Journal of Agricultural Sciences, Volume 10, No.3 2014

Amek, T. (2011). The effect of social capital on integrated pest management technology adoption: a case of small scale rural farmers in Kenya. (Master's thesis KDI School of public policy and management)

Asfaw, S. (2008). Global Agrifood Supply Chain, EU Food-safety Standards and African Small-scale Producers–The Case of High-value Horticultural Export from Kenya. *Pesticide Policy Project, Leibniz Universitaet Hannover*.

Atreya, K. (2005). Health costs of pesticide use in a vegetable growing area, central mid-hills, Nepal. *Himalayan Journal of Sciences*, *3*(5), 81–83.

Atreya, K. (2007). Pesticide use knowledge and practices: A gender differences in Nepal. *Environmental Research, 104*(2), 305–311.

Baez, C. (2004). Potential Economic Benefits from Plantain Integrated Pest Management Adoption: The Case of Coastal Rural Households in Ecuador.

Beard, J. D., Umbach, D. M., Hoppin, J. A., Richards, M., Alavanja, M. C., Blair, A., … Kamel, F. (2014). Pesticide exposure and depression among male private pesticide applicators in the agricultural health study. *Environmental Health Perspectives*, *122*(9), 984.

Beddow, J. M. (2000). Protocols for the assessment of economic and environmental effects of integrated pest management programs.

Birol, E., Karousakis, K., & Koundouri, P. (2006). Using a choice experiment to account for preference heterogeneity in wetland attributes: the case of Cheimaditida wetland in Greece. *Ecological Economics*, *60*(1), 145–156.

Blessing, A. (2001). Pesticides and Water Quality Principles, Policies, and Programs. *Purdue Pesticide Programs. Purdue University Cooperative Extension Service*.

Boahene, K., Snijders, T. A., & Folmer, H. (1999). An integrated socioeconomic analysis of innovation adoption: the case of hybrid cocoa in Ghana. *Journal of Policy Modeling*, *21*(2), 167–184.

Bonabana-Wabbi, J. (2002). Assessing factors affecting adoption of agricultural technologies: The case of integrated pest management (IPM) in Kumi district, Eastern Uganda. Assessing factors affecting adoption of agricultural technologies: The case of integrated pest management (IPM) in Kumi district, Eastern Uganda.

Bonabana-Wabbi, J., & Taylor, D. B. (2008, July). Health and environmental benefits of reduced pesticide use in Uganda: An experimental economics analysis. In Annual meeting of the American Agricultural Economics Association and the American Council on Consumer Interests. American Agricultural Economics Association, Orlando.

Braun, von J., & Kennedy, E. (1994). *Agricultural Commercialization, Economic Development, and Nutrition*. Washington, D.C.: IFPRI.

Briggs, D. C. (2004). Causal inference and the Heckman model. *Journal of Educational and Behavioral Statistics*, *29*(4), 397–420.

Brody, E. M. (1978). The aging of the family. *The Annals of the American Academy of Political and Social Science*, *438*(1), 13–27.

Bues, R., Bussieres, P., Dadomo, M., Dumas, Y., Garcia-Pomar, M., & Lyannaz, J. (2004). Assessing the environmental impacts of pesticides used on processing tomato crops. *Agriculture, Ecosystems & Environment*, *102*(2), 155–162.

Carrión, V. D., Norton, G. W., Alwang, J., & Barrera, V. (2013). Adoption Analysis and Impact Evaluation of Potato IPM in Ecuador. Presented at the 2013 Annual Meeting, August 4-6, 2013, Washington, DC, Agricultural and Applied Economics Association.

Caswell, M., Fuglie, K. O., Ingram, C., Jans, S., & Kascak, C. (2001). *Adoption of agricultural production practices: lessons learned from the US Department of Agriculture Area Studies Project*. United States Department of Agriculture, Economic Research Service. Agriculture Economic Report No.792. January 2001.

Chi, T. T. N. (2008). Factors affecting technology adoption among rice farmers in the Mekong Delta through the lens of the local authorial Managers: an analysis of qualitative data. *Omonrice*, *16*, 107–112.

Curtiss, J., & Jelinek, L. (2012). Cost efficiency and farm self-selection in precision farming: The case of Czech wheat production. Presented at the 131st EAAE Seminar'Innovation for Agricultural Competitiveness and Sustainability of Rural Areas', Prague, Czech Republic.

Cuyno, L., Norton, G. W., & Rola, A. (2001). Economic analysis of environmental benefits of integrated pest management: a Philippine case study. *Agricultural Economics*, *25*(2-3), 227–233.

Daku, L. S. (2002). Assessing farm-level and aggregate economic impacts of olive integrated pest management programs in Albania: an ex-ante analysis. Dissertation. Agricultural and Applied Economics Virginal Tech University

Damalas, C. A., & Eleftherohorinos, I. G. (2011). Pesticide exposure, safety issues, and risk assessment indicators. *International Journal of Environmental Research and Public Health*, *8*(5), 1402–1419.

Dasgupta, S., Meisner, C. M., Wheeler, D., Lam, N. T., & Xuyen, K. (2005). Pesticide poisoning of farm workers: implications of blood test results from Vietnam. *World Bank Policy Research Working Paper*, (3624).

Davis, K., Nkonya, E., Kato, E., Mekonnen, D. A., Odendo, M., Miiro, R., & Nkuba, J. (2012). Impact of farmer field schools on agricultural productivity and poverty in East Africa. *World Development*, *40*(2), 402–413.

Dolan, C. (2001). The'good wife': struggles over resources in the Kenyan horticultural sector. *Journal of Development Studies*, *37*(3), 39–70.

Dubrovsky, N. M., Burow, K. R., Clark, G. M., Gronberg, J., Hamilton, P. A., Hitt, K. J., … Puckett, L. J. (2010). *The quality of our Nation's waters-Nutrients in the Nation's streams and groundwater, 1992-2004* (No. 2330-5703). US Geological Survey.

Dung, N. H., & Dung, T. T. T. (1999). *Economic and health consequences of pesticide use in paddy production in the Mekong Delta, Vietnam*. Economy and environment program for Southeast Asia (EEPSEA).

Ekesi, S., Billah, M. K., Nderitu, P. W., Lux, S. A., & Rwomushana, I. (2009). Evidence for competitive displacement of Ceratitis cosyra by the invasive fruit fly Bactrocera invadens (Diptera: Tephritidae) on mango and mechanisms contributing to the displacement. *Journal of Economic Entomology*, *102*(3), 981–991.

Ekesi, S., Maniania, N., & Lux, S. (2002). Mortality in three African tephritid fruit fly puparia and adults caused by the entomopathogenic fungi, Metarhizium anisopliae and Beauveria bassiana. *Biocontrol Science and Technology*, *12*(1), 7–17.

Ekesi, S., Mohamed, S., & Hanna, R. (2010). Rid fruits and vegetables in Africa of notorious fruit flies. *CGIAR SP-IPM Technical Innovation Brief*, *4*(2).

Ole Martin Eklo., Ole Henriksen., Trond Rafoss. (2003) Experiences with applying the EIQ-model to assess the environmental impact of IPM farmer training in Vietnam

Erbaugh, J. M., Donnermeyer, J., Amujal, M., & Kidoido, M. (2010). Assessing the impact of farmer field school participation on IPM adoption in Uganda. *Journal of International Agricultural and Extension Education*, *17*(3), 5–17.

Fernandez-Cornejo, J. (1998). Environmental and economic consequences of technology adoption: IPM in viticulture. *Agricultural Economics*, *18*(2), 145–155.

Foti, R., & Chikuvire, T. (2005). Farm level pesticide use and productivity in smallholder cotton production in Zimbabwe: The case of Gokwe Communal Area Farmers. *Journal of Sustainable Development in Africa*, *7*(2).

Freemark, K., & Boutin, C. (1995). Impacts of agricultural herbicide use on terrestrial wildlife in temperate landscapes: a review with special reference to North America. *Agriculture, Ecosystems & Environment*, *52*(2), 67–91.

Gabre-Madhin, E. Z., & Haggblade, S. (2004). Successes in African agriculture: results of an expert survey. *World Development*, *32*(5), 745–766.

Gajanana, T., Krishna Moorthy, P., Anupama, H., Raghunatha, R., & Kumar, G. (2006). Integrated pest and disease management in tomato: An economic analysis. *Agric Econ Res Rev*, *19*, 269–280.

Garming, H., & Waibel, H. (2007). Do farmers adopt IPM for health reasons?–The case of Nicaraguan vegetable growers (pp. 9–11). Presented at the Proceedings of the Tropentag Conference Utilisation of Diversity in Land Use Systems: Sustainable and Organic Approaches to Meet Human Needs.

Genius, M., Koundouri, P., Nauges, C., & Tzouvelekas, V. (2014). Information transmission in irrigation technology adoption and diffusion: social learning, extension services, and spatial effects. *American Journal of Agricultural Economics*, *96*(1), 328–344.

Ghimire, B., & Kafle, N. (2014). Integrated Pest Management Practice and its Adoption Determinants among Apple Farmers in Mustang District of Nepal. Sch J Agric Vet Sci 2014; 1(2):83-89

Gilbert, M. L. (2013). Gilbert, M. L. (2013). Factors influencing adoption of conservation agriculture in south Uluguru Mountains in Morogoro region, Tanzania (Doctoral dissertation, Sokoine University of Agriculture).

Greitens, T. J., & Day, E. (2007). An alternative way to evaluate the environmental effects of integrated pest management: Pesticide risk indicators. *Renewable Agriculture and Food Systems*, *22*(03), 213–222.

Heckman, J. J. (1990). Selection bias and self-selection. In *Econometrics* (pp. 201–224). Springer.

Houndekon, V. A., De Groote, H., & Lomer, C. (2006). Health costs and externalities of pesticide use in the Sahel. *Outlook on AGRICULTURE*, *35*(1), 25–31.

Huq, M., Meisner, C., & Dasgupta, S. (2005). Health effects and pesticide perception as determinants of pesticide use: evidence from Bangladesh. World Bank Policy Research Working Paper 3776.

ICIPE. (2009). *Biennial report highlights, 2008-2009*.

Inter-Organization Programme for the Sound Management of Chemicals, & World Health Organization. (2010). *WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification 2009*. World Health Organization.

Isoto, R. E., Kraybill, D. S., & Erbaugh, M. J. (2008). Impact of integrated pest management technologies on farm revenues of rural households: The case of smallholder Arabica coffee farmers. *African Journal of Agricultural and Resource Economics Volume*, *9*(2), 119–131.

JO, A. (2008). Adoption of Improved Cassava Varieties and Its Welfare Effect on Producing Households in Osogbo Adp Zone of Osun State. *Gene Conserve*, *7*(29).

Kabir, M. H., & Rainis, R. (2015). Adoption and intensity of integrated pest management (IPM) vegetable farming in Bangladesh: an approach to sustainable agricultural development. *Environment, Development and Sustainability*, 1–17.

Kabunga, N. S., Dubois, T., & Qaim, M. (2012). Yield effects of tissue culture bananas in Kenya: accounting for selection bias and the role of complementary inputs. *Journal of Agricultural Economics*, *63*(2), 444–464.

Kassie, M., Shiferaw, B., & Muricho, G. (2010). *Adoption and impact of improved groundnut varieties on rural poverty: Evidence from rural Uganda*. Discussion Paper Series May 2010 EFD DP 10-11

Khan, D. A., Hashmi, I., Mahjabeen, W., & Naqvi, T. A. (2010). Monitoring health implications of pesticide exposure in factory workers in Pakistan. *Environmental Monitoring and Assessment*, *168*(1-4), 231–240.

Khan, M. (2009). Economic evaluation of health cost of pesticide use: willingness to pay method. *The Pakistan Development Review*, 459–470.

Kibira, M., Affognon, H., Njehia, B., Muriithi, B., Mohamed, S., & Ekesi, S. (2015). Economic evaluation of integrated management of fruit fly in mango production in Embu County, Kenya. *African Journal of Agricultural and Resource Economics Volume*, *10*(4), 343–353.

Kishi, M., Hirschhorn, N., Djajadisastra, M., Satterlee, L. N., Strowman, S., & Dilts, R. (1995). Relationship of pesticide spraying to signs and symptoms in Indonesian farmers. *Scandinavian Journal of Work, Environment & Health*, 124–133.

Klungness, L., Jang, E. B., Mau, R. F., Vargas, R. I., Sugano, J. S., & Fujitani, E. (2005). New sanitation techniques for controlling tephritid fruit flies (Diptera: Tephritidae) in Hawaii.

Kole, R., Banerjee, H., & Bhattacharyya, A. (2001). Monitoring of market fish samples for Endosulfan and Hexachlorocyclohexane residues in and around Calcutta. *Bulletin of Environmental Contamination and Toxicology*, *67*(4), 554–559.

Korir, J., Affognon, H., Ritho, C., Kingori, W., Irungu, P., Mohamed, S., & Ekesi, S. (n.d.). Grower adoption of an integrated pest management package for management of mango-infesting fruit flies (Diptera: Tephritidae) in Embu, Kenya. *International Journal of Tropical Insect Science*, 1–10.

Kotrlik, J., & Higgins, C. (2001). Organizational research: Determining appropriate sample size in survey research appropriate sample size in survey research. *Information Technology, Learning, and Performance Journal*, *19*(1), 43.

Kouser, S., & Qaim, M. (2013). Valuing financial, health, and environmental benefits of Bt cotton in Pakistan. *Agricultural Economics*, *44*(3), 323–335.

Kovach, J., Petzoldt, C., Degni, J., & Tette, J. (1992). A method to measure the environmental impact of pesticides. New York's food and life sciences bulletin. Number 139, 1992

Kriström, B. (1990). Valuing environmental benefits using the contingent valuation method. *Umeå Economic Studies, 219*.

Kromann, P., Pradel, W., Cole, D., Taipe, A., & Forbes, G. A. (2011). Use of the environmental impact quotient to estimate health and environmental impacts of pesticide usage in Peruvian and Ecuadorian potato production. *Journal of Environmental Protection*, *2*(05), 581.

Lawrence, J., Tolin, S., Edwards, C., Fleischer, S., Jackson, D. M., Clarke-Harris, D., Chung, P. (2005). Developing IPM packages in the Caribbean. *flJBlackwell*, 95.

Liu, E. M., & Huang, J. (2013). Risk preferences and pesticide use by cotton farmers in China. *Journal of Development Economics, 103,* 202–215.

Liverpool, L. S. O., & Winter-Nelson, A. (2010). *Poverty status and the impact of social networks on smallholder technology adoption in rural Ethiopia*. International Food Policy Research Institute (IFPRI).

Lokshin, M., & Sajaia, Z. (2004). Maximum likelihood estimation of endogenous switching regression models. *Stata Journal*, *4,* 282–289.

Lyytinen, K., & Damsgaard, J. (2001). Lyytinen, K., & Damsgaard, J. (2001). *What's wrong with the diffusion of innovation theory?* (pp. 173-190). Springer US.

Macharia, I., Mithöfer, D., & Waibel, H. (2013). Health Effects of Pesticide Use among Vegetable farmer in Kenya. Invited paper presented at the 4th International Conference of the African Association of Agricultural Economists, September 22-25, 2013, Hammamet, Tunisia

Macharia, I. N., Mithöfer, M., & Waibel, H. (2009). Potential environmental impacts of pesticides use in the vegetable sub-sector in Kenya. *African Journal of Horticultural Science*, *2*.

Marshall, A. (2009). *Principles of economics: unabridged eighth edition*. Cosimo, Inc.

Maumbe, B. M., & Swinton, S. M. (2003). Hidden health costs of pesticide use in Zimbabwe's smallholder cotton growers. *Social Science & Medicine*, *57*(9), 1559–1571.

Mbata, J. N. (2001). Determinants of animal traction adoption in traditional agriculture: an application of the multivariate probit procedure to the case of Lesotho. *Development Southern Africa*, *18*(3), 309–325.

McDuffie, H. H. (1994). Women at work: agriculture and pesticides. *Journal Of Occupational And Environmental Medicine*, *36*(11), 1240–1246.

Mitchell, R. C., & Carson, R. T. (2013). *Using surveys to value public goods: the contingent valuation method*. Routledge.

Morris, M. L., & Doss, C. R. (1999). How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana (pp. 8–11). Presented at the annual meeting of the American Agricultural Economics Association, Nashville, and August.

Mourato, S., Ozdemiroglu, E., & Foster, V. (2000). Evaluating health and environmental impacts of pesticide use: Implications for the design of ecolabels and pesticide taxes. *Environmental Science & Technology*, *34*(8), 1456–1461.

Muchiri, C. M. (2012). Economic assessment of losses due to fruit fly infestation in mango and the willingness to pay for an integrated pest management package in Embu district, Kenya. (Master's thesis, university of Nairobi)

Mugisa-Mutetikka, M., Opio, A., Ugen, M., Tukamuhabwa, P., Kayiwa, B., Niringiye, C., & Kikoba, E. (2000). Logistic regression analysis of adoption of new bean varieties in Uganda. *Unpublished Manuscript*.

Mugisha, J., Ogwal-o, R., Ekere, W., & Ekiyar, V. (2005). Adoption of IPM groundnut production technologies in Eastern Uganda. *African Crop Science Journal*, *12*(4), 383–391.

Mullen, J. D., Norton, G. W., & Reaves, D. W. (1997). Economic analysis of environmental benefits of integrated pest management. *Journal of Agricultural and Applied Economics*, *29*, 243–254.

Muriithi, B. W., Affognon, H. D., Diiro, G. M., Kingori, S. W., Tanga, C. M., Nderitu, P. W., Ekesi, S. (2016). Impact assessment of Integrated Pest Management (IPM) strategy for suppression of mango-infesting fruit flies in Kenya. *Crop Protection*, *81*, 20–29.

Muriithi, B. W., & Matz, J. A. (2014). Smallholder Participation in the Commercialisation of Vegetables: Evidence from Kenyan Panel Data. *Quarterly Journal of International Agriculture*, *53*(2), 141–168.

Musser, W. N., Tew, B. V., & Epperson, J. E. (1981). An economic examination of an integrated pest management production system with a contrast between EV and stochastic dominance analysis. *Southern Journal of Agricultural Economics*, *13*(01).

Mutandwa, E., & Mpangwa, J. (2004). An assessment of the impact of Farmer Field Schools on integrated pest management dissemination and use: Evidence from smallholder cotton farmers in the lowveld area of Zimbabwe. *Journal of Sustainable Development in Africa*, *6*(2), 24–31.

Mutuku, M., Njogu, P., & Nyagah, G. (n.d.). Assessment of the Current Patterns and Practices of use of Pesticides in Tomato Based Agrosystem in Kaliluni, Kathiani Constituency, Kenya. International Journal of Soil, Plant, and Environmental Sciences (IJSPES) 1 (1), 10-15.

Mwaura, F. (2014). Effect of farmer group membership on agricultural technology adoption and crop productivity in Uganda. *African Crop Science Journal*, *22*, 917–927.

Nalunkuuma. J., Affognon, G., Kingori, S., Salifu, D., & Njonge, F. (2013). Adoption of zero grazing and impact on livestock keepers' knowledge of cattle reproductive parameters in Western Kenya (Vol. 11, pp. 599–604). Presented at the African Crop Science Conference Proceedings.

Nyikal, R. A., & Kosura, W. O. (2005). Risk preference and optimal enterprise combinations in Kahuro division of Murang'a district, Kenya. *Agricultural Economics*, *32*(2), 131–140.

Okello, J. J. (2005). Compliance with international food safety standards: The case of green bean production in Kenyan family farms.

Okuthe, I. K. (2014). The Influence of Institutional Factors on the Adoption of Integrated Natural Resource Management Technologies by Small Scale Farmers in South Western Kenya. *Asian Journal of Agricultural Sciences*, *6*(1), 16–32.

Olin, G., Machlin, S. R., & Rhoades, J. A. (2008). *Estimating the cost of illness: the case of diabetes*. Agency for Healthcare Research and Quality. Working Paper No. 08001

Oluwole, O., & Cheke, R. A. (2009). Health and environmental impacts of pesticide use practices: a case study of farmers in Ekiti State, Nigeria. *International Journal of Agricultural Sustainability*, *7*(3), 153–163.

Orornje, M.-L., Nyamasyo, G., & Nderitu, J. (2007). Effects of Insecticide Applications on Sunflower (Helianthus annuus L.) Pollination in Eastern Kenya. Master's thesis)

Orr, L. M., McDougall, S., Mullen, J. D., & Wales, N. S. (2008). *An Evaluation of the Economic, Environmental and Social Impacts of NSW DPI Investments in IPM Research in Lettuce*. NSW DPI.

Padovani, L., Trevisan, M., & Capri, E. (2004). A calculation procedure to assess potential environmental risk of pesticides at the farm level. *Ecological Indicators*, *4*(2), 111–123.

Pimentel, D., Acquay, H., Biltonen, M., Rice, P., Silva, M., Nelson, J. … D'amore, M. (1992). Environmental and economic costs of pesticide use. *BioScience*, 750–760.

Pingali, P. L., & Roger, P. A. (2012). *Impact of pesticides on farmer health and the rice environment* (Vol. 7). Springer Science & Business Media.

Poliquit, L. Y. (2006). Accessibility of rural credit among small farmers in the Philippines: a thesis presented in partial fulfilment of the requirements for the degree of Master of Applied Science in Rural Development, Institute of Natural Resources, Massey University, Palmerston North, New Zealand.

Pradel, W., Forbes, G., Ortiz, O., Cole, D., Wanigarantne, S., & Maldonado, L. (2008). Use of the Environmental Impact Quotient to estimate impacts of pesticide usage in three Peruvian potato production areas. *Sin Publicar*, *32*.

Praneetvatakul, S., & Waibel, H. (2006). The impact of farmer field schools on pesticide use and environment in Thailand. *42 Schriften Der Gesellschaft Für Wirtschafts-Und Sozialwissenschaften Des Landbaues E. V. Band 42*, 261.

Ragasa, C., Berhane, G., Tadesse, F., & Taffesse, A. S. (2013). *Effects of extension services on technology adoption and productivity among female and male farmers: Summary of ESSP working paper 49*. International Food Policy Research Institute (IFPRI).

Rahman, S. (2007). Adoption of improved technologies by the pig farmers of Aizawl district of Mizoram, India. *Livestock Research for Rural Development*, *19*(1), 1–5.

Rao, C. R., Rao, M. S., Srinivas, K., & Ramakrishna, Y. (n.d.). Adoption and Impact of Integrated Pest Management in Cotton, Groundnut and Pigeonpea. Research Bulletin /AgEcon/2/2007

Reus, J., Leendertse, P., & Bockstaller, C. (1999). *Comparing environmental risk indicators for pesticides: results of the European CAPER project*. Centre for Agriculture and Environment.

Reynolds, P., Von Behren, J., Gunier, R. B., Goldberg, D. E., Hertz, A., & Harnly, M. E. (2002). Childhood cancer and agricultural pesticide use: an ecologic study in California. *Environmental Health Perspectives*, *110*(3), 319.

Rice, C. P., & Chernyak, S. M. (1997). Marine arctic fog: An accumulator of currently used pesticide. *Chemosphere*, *35*(4), 867–878.

Roger, P.-A. (1995). Annotated bibliography on the effects of pesticides on nonphototrophic microorganisms of ricefields. *Impact of Pesticides on Farmer Health and the Rice Environment*, *7*, 274.

Rogers, E. M. (2010). *Diffusion of innovations*. Simon and Schuster.

Sachs, J. D. (2012). From millennium development goals to sustainable development goals. *The Lancet*, *379*(9832), 2206–2211.

Sahin, I. (2006). Detailed review of Rogers' diffusion of innovations theory and educational technology-related studies based on Rogers' theory. *TOJET: The Turkish Online Journal of Educational Technology*, *5*(2).

Sande, D., Mullen, J., Wetzstein, M., & Houston, J. (2011). Environmental impacts from pesticide use: a case study of soil fumigation in Florida tomato production. *International Journal of Environmental Research and Public Health*, *8*(12), 4649–4661.

Savonen, C. (1997). Soil microorganisms object of new OSU service. *Good Fruit Grower. Http://www. Goodfruit. com/archive/1995/6other. Html*.

Shiferaw, B., Kassie, M., Jaleta, M., & Yirga, C. (2014). Adoption of improved wheat varieties and impacts on household food security in Ethiopia. *Food Policy*, *44*, 272–284.

Simtowe, F., & Zeller, M. (2006). The Impact of Access to Credit on the Adoption of hybrid maize in Malawi: An Empirical test of an Agricultural Household Model under credit market failure. MPRA Paper No. 45, posted 1. October 2006

Singh, S., & Singh, S. (2007). Economic Evaluation of Pest Management Technologies for Sustainable Cotton Production in Punjab*. *Agricultural Economics Researh Review, 20*(1), 77–86.

Solomon, G., Ogunseitan, O., & Kirsch, J. (2000). Pesticides and Human Health, Physicians for Social Responsibility and Californians for Pesticide Reform. *San Francisco, CA.*

Swinton, S. M., & Williams, M. B. (1998). *Assessing the economic impacts of integrated pest management: lessons from the past, directions for the future*. Department of Agricultural Economics, Michigan State University.

Tambo, J. A., & Wünscher, T. (2014). More than adopters: the welfare impacts of farmer innovation in rural Ghana. Presented at the 2014 Annual Meeting, July 27-29, 2014, Minneapolis, Minnesota, Agricultural and Applied Economics Association.

Tanabe, S., Senthilkumar, K., Kannan, K., & Subramanian, A. (1998). Accumulation features of polychlorinated biphenyls and organochlorine pesticides in resident and migratory birds from South India. *Archives of Environmental Contamination and Toxicology*, *34*(4), 387–397.

Tiryaki, O., & Temur, C. (2010). The fate of pesticide in the environment. *J. Biol. Environ. Sci*, *4*(10), 29–38.

Travisi, C. M., & Nijkamp, P. (2008). Valuing environmental and health risk in agriculture: A choice experiment approach to pesticides in Italy. *Ecological Economics*, *67*(4), 598–607.

Van der Werf, H. M. (1996). Assessing the impact of pesticides on the environment. *Agriculture, Ecosystems & Environment*, *60*(2), 81–96.

Vergara, O., Pitre, H., & Parvin, D. (2002). Economic evaluation methods for integrated pest management in intercropped maize and sorghum production systems in southern Honduras.

Verghese, A., Tandon, P., & Stonehouse, J. M. (2004). Economic evaluation of the integrated management of the oriental fruit fly< i> Bactrocera dorsalis (Diptera: Tephritidae) in mango in India. *Crop Protection, 23*(1), 61–63.

Williams, M. Б. (2000). Methodology of an IPM impact assessment: Development and application of a protocol in Michigan tart cherries.

Wilson, C. (2005). Exposure to pesticides, ill-health and averting behaviour: costs and determining the relationships. *International Journal of Social Economics*, *32*(12), 1020–1034.

World Health Organization. (1990). Public health impact of pesticides used in agriculture.

Yaguana, C., & Del Rocio, V. (2013). Adoption Analysis and Impact Evaluation of Potato IPM in Ecuador.

APPENDICES

APPENDIX 1: QUESTIONNAIRE

AGRICULTURAL INNOVATION SPILL OVER EFFECTS OF FARM PRODUCTIVITY AND ENVIRONMENT: AN ANALYSIS OF MANGO INTEGRATED PEST MANAGEMENT (IPM) FRUIT FLY CONTROL TECHNOLOGY IN KENYA.

International Centre for Insects Physiology and Ecology (ICIPE) in collaboration with Moi University is conducting a survey on Spill over effects of mango Integrated Pest Management (IPM) fruit fly control technologies for in Meru County. Information collected is specifically for research and academic purposes. Your participation is voluntary and can refuse to answer any question at any time. The information you provide will be **CONFIDENTIAL** and findings reported as an aggregate along with those of other farmers. We are kindly asking for your consent to be part of the study.

00. Household consent obtained (Tick) **[__] Yes** **[__] No** **thank you.**

00a. If No, why____

Identifying Variables

01. Questionnaire ID		07.Sub- County	
02.Date of the interview (dd.mm.yy)		08.Division:	
03. Start time		09.Location:	
04.Enumerator:		010.Sub-location:	
05.Household head Name (three names):		011.Village:	
06.Respondent Name (three names):			

SECTION 1: HOUSEHOLD DEMOGRAPHICS

1.0 Gender of the household head: [______] [1=Male, 0=Female]

1.1 Age of the household head (years)_______

1.2 Education level of the household head (**code)** [______]

0=None 1=Primary	2=High school 3=University	4=College or polytechnic 5=Other(specify)

1.3 Number of years the household spent in school (years)____

1.4 What is the highest education level attained by adult persons in the household (use codes in 1.3) [____]

1.5 How many household members are currently living with you? [_________]

1.6 Provide the following description of the composition of your household in terms of age, gender for household members (*i.e. people who live in the same compound and eat from the same pot in the last 12 months*).

Age (years)	Male	Female
0-14		
15-64		
64+		

1.7 Marital status of the head of the household (code) /_____/

(1) Married	(2) Married	(3) Single
(4) Divorced	(5) Widowed	(6) Separated
		7. Other(specify)

1.8 What is the household head major (**a)** and minor occupation/activity **(b)**: (**a**)[___] (**b**) [____]

0 = None	**4**=Mango production
1 = Farming	**5**=Casual labourer
2=Cereal production	**6**=Civil servant
3= Livestock production	**7**=Other (specify)

SECTION 2: OFF-FARM INCOME

2.1 Off-farm income (income from other sources other than farming in his/her own farm) (anyone in the household who was involved in work other than farming in the last 12 months?

(a) Household member (**Codes, a)**	(b)Type of work (**code b**)	(c) how many months	(d) Income per month (Kshs)	(e)Annual income

Code (a)	**Code (b)**	
1. Head 2.Spouse 3. Son 4.Daughter 5. Other (specify)………	1= Running a business (small or big) 2= Permanent farm worker 3=Agricultural casual labour in other farms 4=Non-agricultural casual labour	5=Salaried employee (e.g. by government) 6=Any other source (specify) ____

2.2 Did your household receive any kind of remittances (gifts from relatives, food aid etc.), transfers (e.g. pension) and other source of income during the last 12 months?/___/ 0=No 1=Yes

2.3 If yes, how much income did you get from these sources? (Kshs)___________

SECTION 3: HOUSEHOLD ASSETS, LAND USE AND OUTPUT

3.1 How many acres of **agricultural cultivatable** land do you own? (acres)___________

3.2 How many acres have you rented in:/___________/Rented out___________

3.3 For how long have you been cultivating this farm? __________years/ months

3.4 What crops do you grow on your farm and what size of your farm is allocated to each crop? (*If the land is inter-cropped then the total area should be divided by the number of crops grown on the plot. If 2 crops, by 2; if 3 crops, by 3 e.t.c.)*

Crop	**Area owned (acres) TEXT**	**Area leased in (acres) TEXT**

3.5 If renting in land, how much do you pay (Kshs/year)______

3.6 Do you have access to irrigation water? /____/ (1=Yes, 0==No)

3.7 If yes, what percent of your cultivated land is irrigated? ______%

3.8 **Livestock ownership:** Do you own livestock? /_____/ 0=No, 1=Yes

3.9 If **Yes,** tell us about the herd of livestock you owned for the last 12 months

Livestock type	**Total number**	**Livestock type**	**Total number**
Cattle adult		Donkey	
Calve		Camel	
Goat		Horse	
Sheep		Poultry	
Pig		Rabbit	

3.10 What percent of annual household income is generated from animals and animal products? ______%

3.11 At present, do you own the following assets?

	0=No 1=Yes		**0=No 1=Yes**
Tractor		TV	
Car/van		Radio	
Motorbike/		Telephone/mobile phone	
Bicycle			
Other transport facility (specify)___________			

3.12 Please tell us whether you have access to the following:

Facility	Available in this village? (0=No 1=Yes)	If available does your household have access to it (0=No 1=Yes)	If not available here		
			Distance to the nearest (Km)	(b)Means of travel **(Code a)**	Cost of travel (two& from) (Kshs
1.Electricity					
2.Piped water					
3.Tarmac road					
4.Public transport system					
5.Agri. Extension Agent					
6.Agricultural input market					
7.Agricultural product market					

Code (a) Means of Transport

1= Walking	3= Matatu/bus	5=Other (specify) ______
2= Bicycle	4= Motorbike	

SECTION 4: ICIPE FRUIT-FLY PROJECT

4.1 Are you applying the mango IPM fruit fly control technologies? /____/ 0=No 1=Yes

4.2 If yes in 4.2, answer the table below on the main enterprises the IPM package applied and from whom you received the IPM technology (*This may be direct IPM package application or an enterprise adjacent to the mango plot, that was previously being affected by fruit fly but now benefiting the same way as mangoes where the IPM technology is applied)*

	What is the number of mature trees (producing) on this parcel?	What is the number of young trees not in production on this parcel	Cropping system 1=intercrop 2=pure stand	If intercrop, what is the other enterprise (s)	What IPM technologies have you applied on this parcel: **(Codes a)**[1]	Where did you acquire it? **(Codesb)**
1=Mangoes						

Codes a: ICIPE fruit-fly control package components
1= Parasitoid(p), Orchard Sanitation(OS), Male annihilation Technique (MAT)
2= Parasitoid(p), OS, Food bait (FB)
3= Parasitoid(p), OS, Bio pesticide (Biop)
4=Parasitoid(p), OS, MAT,FB
5= Parasitoid(p), OS, FB, Biop
6= Parasitoid(p), OS, MAT,Biop
7= Parasitoid(p), OS, MAT, FB, Biop
8= Other (specify)………

Code b:where IPM was acquired
1=ICIPE
2= MoA
3= Farmer
4= Exporter
5= NGO
6= Agro-vet
7=Other (specify)

4.3 Are you applying the mango IPM fruit fly control technology on other farm enterprises other than the ones listed in 4.2? /____/ 0=No 1=Yes

4.4 If **YES,** provide the following information regarding these other farm enterprises

Crop (type)	Size of the plot (acres)	What IPM technologies have you applied on this parcel: (**Codes a, in question 4.2**)	Where did you acquire it? (**Codes b in Qn 4.2**)
[1]*Note: If the farmer applies only one of the listed ICIPE fruit fly control component, type the specific component.*			

4.5 What is your general perception on the benefit of mango IPM fruit fly technology on other farm enterprises other than mango?

SECTION 6: ACCESS TO AGRICULTURE INFORMATION GROUP MEMBERSHIP, EXTENSION SUPPORT AND CREDIT

6.1 For the last 12 months, have you attended a farmer field day, training or seminar? /___/ 0=No 1=Yes

6.2 **If Yes**, how many times did you attend? _____

6.3 **If yes,** from whom did you receive the training/seminar? (*code/s*) /________/

1= MoA staff 2=*ICIPE* staff	3=Agro-chemical Company 4=trained farmer	5=produce buyer 6=NGO	7=other……………

6.4 How many times did an agricultural officer visit you in your farm during the last 12 months ____

6.5 How many times did you go to visit/consult an agricultural officer during the last 12 months ____

6.6 Are you a member of any farmers' group /____/ 0=No, 1==Yes

6.7 If **yes, w**hat farmer's organizations are you a member of (production, marketing etc)? _________________________

6.8 Did you or your spouse get any form of credit/ loan (monetary or non-monetary) during the last 12 months?

6.9 If **Yes**, provide the following information regarding the credit you received

Sources *(Code a)*	**Form***(Code b)*	**Purpose of credit***(Code c)*	**% credit used on mango**

Source	**Form**	**Purpose of credit**	
1= Farmer group; 2= other self-help group; 3= Friends/Relatives; 4= Bank; 5=Microfinance;	1= in kind e.g. inputs, 2=money, 3=other (specify)____________	1- To purchase seedlings 2- To purchase fertilizer 3- To purchase pesticides 4- To expand crop area 5- To invest in business	7- To purchase livestock 8- To Improve water system 9-To pay school fees 10-To purchase basic items like food, clothing

6=Other (specify)		6- To buy construction materials	11-Other (specify)____________

SECTION 7: Health Effects of Pesticides

7.1. Have you or your family members or farm worker experienced intoxication from pesticide for the past season (or last 12 months)? /____/ 0=No, 1==Yes)

7.2. If yes in 7.1, fill the table (Use the codes below)

7.21.Who experienced (**codes a**)	7.22. Symptoms suffered from (**Code b**)	7.23.How severe were the symptoms 1.Mild 2.Severe 3.Very Severe	7.24.How long did the symptom prevail	7.24b. Unit period (e.g. hours, days, months, years)	7.25.Which medical treatment did you use (**Code c**)	How much did you spend on transport (to & from)	If you walked, no hrs spent	7.26.Did the treatment work 0=No, 1=Yes	7.27.How much did the treatment cost (in Kshs)	7.28.Were you able to work during this time 0=No 1=Yes	7.29.If No, how many days, you did not work

Code (a)		Code (b)			Code (c)		
1. Head 2.Spouse 3. Child	3.Farm worker 4.Other (specify) ___	1) Headache 2) Sneezing 3)Eye irritation	4) Dizziness 5) Vomiting 6) Shortness of breath	7)Skin irritation 8)Fever 9)other specify _____	1) Clinic 2) Used tablets from shop or chemist	3) Hospital 4) Home based care	5) Traditional healing strategy 6) other (specify) ____

7.3. How far is the nearest health facility from your farm? (Kms)____

7.4. List the type of pesticides you used in Mangoes to control pests or diseases?

Product name (code a)	Target pest or disease	Source (code a)	Total number of applications in the previous season
	Code a		
	1=old stock (bought in previous season), **2**=other farmers, **3**=purchased from agrovet	**4**= farmer group **5**= produce buyer **6**=other (specify)…………	

7.5. Do household members or workers wear protective clothing in accordance with label instructions when handling and applying chemicals? /____/ (0=No, 1==Yes)

7.6. If No, what are the reasons for not using protective clothing (three important reasons)?

a) ____

b) ____

c) ____

7.7. If Yes in 7.4, list the protective clothes and their estimated cost (Kshs)

	Protective cloth	**Estimated cost (Kshs)**		**Protective cloth**	**Estimated cost**
1.			4.		
2			5.		
3.			6.		
e.g. gloves, masks, boots, overalls, head gear, goggles,					

7.8. Have you or your household member or worker who handles and apply crop protection products trained on application? /____/ (0=No, 1=Yes)

7.9. Who makes decision about pesticide use on your farm ?(*code)/*_________/

1=Head	3=Both head & spouse	3=Daughter	5=Extension staff
2=Spouse	4=Eldest son	4=Produce buyer	6=Other (specify)____

7.10. Do you have a separate storage place for chemicals and its equipment? /____/ (0=No, 1=Yes)

7.11. If NO, where do you store your pesticides? (Code)? /_______________/

1=Field	3=House
2=Granary	4=Others (specify)

7.12. Have you or any person in your household trained in First aid? /____/ (0=No, 1==Yes)

7.13. Does the person who applies pesticides take alcohol regularly? (0=No, 1==Yes) /____/

7.14. If yes, how often (code) /______/

1=Daily	2=Weekly	3=Monthly	4=After two months	5=Others (specify)_______

7.15. Does the person who applies pesticides smoke regularly? /____/ (0=No, 1=Yes)

7.16. If yes, how often (code) /______/

1=Daily	2=Weekly	3=Monthly	4=After two months	5=Others (specify)_______

7.17. From your experience, what is your opinion on the risks associated with pesticides use on your health (code) /_______/

0= no risk at all;	1= small risk;	2=medium risk	3= Large risk	4=very toxic

7.18. From your experience, what is your opinion on the risks associated with pesticides use on your environment (code) /_______/

0= no risk at	1= small	2=medium risk	3= Large risk	4=very toxic

all;	risk;			

7.19. How do you evaluate the total rainfall from planting until harvesting? /________/

1=Excess	2=Good	3=shortage

7.20. Have you experienced natural hazard/shock such as hail, storm and floods that damage your crop? /__________/ 0=No, 1=Yes

7.21. If yes, how do you evaluate the degree of the hazard? __________

1=low	2=medium	3=high

APPENDIX 2: Probit Regression Results

```
Probit regression                               Number of obs   =        368
                                                LR chi2(15)     =     130.92
                                                Prob > chi2     =     0.0000
Log likelihood = -186.98252                     Pseudo R2       =     0.2593
```

ipm_use	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
yearschool	-.0041212	.0190198	-0.22	0.828	-.0413994	.033157
hhsizesqrt	-.2362649	.1516808	-1.56	0.119	-.5335538	.061024
sqrtq56a_yrsmango	.2139522	.075049	2.85	0.004	.0668589	.3610454
hhagesq	-.0001815	.0000761	-2.39	0.017	-.0003306	-.0000324
lnq31_agrland	.2257771	.1041916	2.17	0.030	.0215653	.429989
lnq21e_monthlyincome	-.0090263	.0182201	-0.50	0.620	-.0447371	.0266845
gender	.0498556	.206938	0.24	0.810	-.3557355	.4554466
q312_agriexte	.0713548	.1766746	0.40	0.686	-.274921	.4176306
q75_protectivecloth	.1794135	.1564167	1.15	0.251	-.1271577	.4859847
q66_farmgroup	-.4787566	.1694465	-2.83	0.005	-.8108657	-.1466475
q69_accesstocredt	.0012999	.1767117	0.01	0.994	-.3450487	.3476486
q36_irrigation	.3256139	.1531756	2.13	0.034	.0253953	.6258326
q521labour_mngt	.001503	.0050981	0.29	0.768	-.0084891	.0114951
sqq33_farmingexp	-.0816264	.0730927	-1.12	0.264	-.2248856	.0616327
ln_prdtrees	.5046807	.0741181	6.81	0.000	.3594118	.6499495
_cons	-1.066616	.6093254	-1.75	0.080	-2.260872	.1276399

Marginal Effects of probit Model

	dy/dx	Delta-method Std. Err.	z	P>|z|	[95% Conf.	Interval]
yearschool	-.0016119	.0074388	-0.22	0.828	-.0161916	.0129678
hhsizesqrt	-.0924078	.0593402	-1.56	0.119	-.2087125	.0238969
sqrtq56a_yrsmango	.0836809	.0293333	2.85	0.004	.0261887	.1411731
hhagesq	-.000071	.0000298	-2.39	0.017	-.0001293	-.0000127
lnq31_agrland	.0883059	.0408007	2.16	0.030	.0083379	.1682738
lnq21e_monthlyincome	-.0035304	.0071273	-0.50	0.620	-.0174996	.0104389
gender	.0194995	.0809252	0.24	0.810	-.139111	.1781099
q312_agriexte	.0279083	.0691055	0.40	0.686	-.1075359	.1633525
q75_protectivecloth	.0701721	.0611758	1.15	0.251	-.0497302	.1900745
q66_farmgroup	-.1872511	.0662251	-2.83	0.005	-.3170499	-.0574523
q69_accesstocredt	.0005084	.0691154	0.01	0.994	-.1349553	.1359721
q36_irrigation	.127354	.0599097	2.13	0.034	.009933	.2447749
q521labour_mngt	.0005878	.0019938	0.29	0.768	-.0033199	.0044956
sqq33_farmingexp	-.0319257	.0285901	-1.12	0.264	-.0879612	.0241099
ln_prdtrees	.1973905	.0288606	6.84	0.000	.1408248	.2539562

APPENDIX 3: Endogenous Switching Regression Results

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ln_EIQperfarmer_1						
hhsizesqrt	.3893298	.263934	1.48	0.140	-.1279714	.9066311
sqrtq56a_yrsmango	-.019459	.1253377	-0.16	0.877	-.2651162	.2261983
hhagesq	.0003428	.0001071	3.20	0.001	.0001329	.0005528
lnq31_agrland	-.1820928	.2330488	-0.78	0.435	-.63886	.2746745
lnq21e_monthlyincome	-.0019029	.0300157	-0.06	0.949	-.0607327	.0569269
gender	.4350121	.3268772	1.33	0.183	-.2056554	1.07568
q312_agriexte	.1768478	.2995792	0.59	0.555	-.4103167	.7640123
q75_protectivecloth	.0090596	.2621892	0.03	0.972	-.5048219	.5229411
q66_farmgroup	.5621895	.2689213	2.09	0.037	.0351134	1.089266
q69_accesstocredt	.0703876	.2898374	0.24	0.808	-.4976833	.6384585
q36_irrigation	-.4107065	.2582847	-1.59	0.112	-.9169352	.0955222
q521labour_mngt	-.0213766	.0122085	-1.75	0.080	-.0453048	.0025517
prdtrees	-.7303943	.1305449	-5.59	0.000	-.9862576	-.474531
_cons	2.717459	.9724246	2.79	0.005	.8115415	4.623376
ln_EIQperfarmer_0						
hhsizesqrt	-.4354645	.2538927	-1.72	0.086	-.9330851	.0621561
sqrtq56a_yrsmango	.0118397	.1051106	0.11	0.910	-.1941733	.2178527
hhagesq	-.0000322	.0000996	-0.32	0.747	-.0002274	.0001631
lnq31_agrland	.1345118	.1936453	0.69	0.487	-.2450261	.5140497
lnq21e_monthlyincome	.0328092	.0281041	1.17	0.243	-.0222739	.0878923
gender	-.3194899	.2876224	-1.11	0.267	-.8832193	.2442396
q312_agriexte	.2864662	.2673805	1.07	0.284	-.2375899	.8105224
q75_protectivecloth	-.378806	.2388685	-1.59	0.113	-.8469796	.0893677
q66_farmgroup	.0826512	.2912954	0.28	0.777	-.4882773	.6535796
q69_accesstocredt	.243773	.2652699	0.92	0.358	-.2761464	.7636924
q36_irrigation	.206459	.2434989	0.85	0.397	-.2707901	.6837081
q521labour_mngt	.0015258	.0048629	0.31	0.754	-.0080053	.0110568
prdtrees	-.3778877	.1671915	-2.26	0.024	-.705577	-.0501984
_cons	4.995643	.9368092	5.33	0.000	3.159531	6.831756
ipm_use						
sqrtq56a_yrsmango	.1312837	.067558	1.94	0.052	-.0011276	.263695
hhagesq	-.0002031	.0000578	-3.51	0.000	-.0003165	-.0000898
lnq21e_monthlyincome	-.0007623	.0162925	-0.05	0.963	-.0326951	.0311704
gender	-.0219662	.1820736	-0.12	0.904	-.378824	.3348915
q312_agriexte	-.070076	.163215	-0.43	0.668	-.3899716	.2498196
q75_protectivecloth	.167129	.1417268	1.18	0.238	-.1106504	.4449084
q69_accesstocredt	.0425012	.1608496	0.26	0.792	-.2727583	.3577607
q36_irrigation	.1439302	.1380827	1.04	0.297	-.1267069	.4145673
q521labour_mngt	.0005043	.0050664	0.10	0.921	-.0094256	.0104342
prdtrees	.5163319	.0738263	6.99	0.000	.371635	.6610287
hhsizesqrt	-.127582	.1476321	-0.86	0.387	-.4169356	.1617717
lnq31_agrland	.0642747	.1217458	0.53	0.598	-.1743426	.302892
q66_farmgroup	-.4857809	.1557642	-3.12	0.002	-.7910731	-.1804887
yearschool	.0030687	.0135604	0.23	0.821	-.0235092	.0296467
_cons	-1.166708	.57394	-2.03	0.042	-2.29161	-.0418062

/lns1	.6932284	.0587453	11.80	0.000	.5780898	.808367
/lns2	.3554412	.061272	5.80	0.000	.2353502	.4755321
/r1	-1.898771	.1802911	-10.53	0.000	-2.252135	-1.545407
/r2	-.1792969	.2681724	-0.67	0.504	-.7049051	.3463114
sigma_1	2.000162	.1175001			1.78263	2.24424
sigma_2	1.42681	.0874235			1.265352	1.60887
rho_1	-.9561321	.015471			-.9781187	-.9130245
rho_2	-.1773999	.2597328			-.607472	.3331003

LR test of indep. eqns. : chi2(1) = 35.25 Prob > chi2 = 0.0000

APPENDIX 4: Treatment Effects

```
. mspredict Y, yc1_1

. mspredict N, yc2_1

. ttest Y==N

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
       Y |     205    .8776048    .0313384    .4486981    .8158161    .9393936
       N |     205    2.526547     .035632    .5101727    2.456293    2.596802
---------+--------------------------------------------------------------------
    diff |     205   -1.648943    .0439244     .628902   -1.735547   -1.562339
------------------------------------------------------------------------------
     mean(diff) = mean(Y - N)                                      t = -37.5405
 Ho: mean(diff) = 0                               degrees of freedom =      204

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

. mspredict B, yc1_2

. mspredict C, yc2_2

. ttest B==C

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
       B |     165    4.301975    .0475347    .6105941    4.208116    4.395834
       C |     165    3.205181    .0424024    .5446691    3.121456    3.288906
---------+--------------------------------------------------------------------
    diff |     165    1.096794    .0669992    .8606205    .9645015    1.229086
------------------------------------------------------------------------------
     mean(diff) = mean(B - C)                                      t =  16.3702
 Ho: mean(diff) = 0                               degrees of freedom =      164

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000
```

APPENDIX 5: Pair Wise Correlation Results

	q421d_~1	prdtrees	sqq33_~p	q521la~t	q36_ir~n	q69_ac~t	q66_fa~p
q421d_crop~1	1.0000						
prdtrees	0.0955	1.0000					
sqq33_farm~p	-0.0447	0.1954	1.0000				
q521labour~t	-0.0644	-0.0157	-0.0417	1.0000			
q36_irriga~n	-0.0982	0.0735	-0.0335	-0.0258	1.0000		
q69_access~t	-0.0165	-0.0187	-0.0838	-0.0350	0.0844	1.0000	
q66_farmgr~p	0.0680	0.0963	0.1422	0.0099	0.0854	0.0393	1.0000
q75_protec~h	0.1283	0.2446	0.0750	-0.0312	0.0597	0.0063	0.0926
q312_agrie~e	-0.0776	-0.0035	0.0013	0.0036	0.1179	0.0433	-0.1425
gender	0.0202	-0.0915	-0.0675	-0.0247	-0.0099	0.0162	-0.0010
lnq21e_mon~e	0.1318	0.1060	-0.1165	0.0093	0.0395	0.1355	-0.0417
lnq31_agrl~d	0.1322	0.5219	0.1810	-0.0454	0.0932	0.0483	0.1559
hhagesq	0.0028	0.1913	0.6080	0.0362	-0.1189	-0.1499	0.0585
sqrtq56a_y~o	0.0500	0.3076	0.4331	-0.1109	0.0549	0.0419	0.1282
hhsizesqrt	0.1367	0.0431	-0.0901	0.0137	0.1021	0.0546	0.0627
yearschool	0.1987	0.1891	-0.1589	-0.0087	0.0330	0.0674	0.0716
q31_agrland	0.1767	0.4080	0.1654	-0.0281	0.0749	0.0067	0.1211

	q75_pr~h	q312_a~e	gender	lnq21e~e	lnq31_~d	hhagesq	sqrtq5~o
q75_protec~h	1.0000						
q312_agrie~e	0.0879	1.0000					
gender	-0.0799	-0.0069	1.0000				
lnq21e_mon~e	0.1374	0.1685	0.0428	1.0000			
lnq31_agrl~d	0.2434	0.0291	-0.0861	0.1242	1.0000		
hhagesq	0.0563	0.0487	-0.2617	-0.0850	0.2377	1.0000	
sqrtq56a_y~o	0.0848	0.0628	-0.0822	0.0978	0.3354	0.3032	1.0000
hhsizesqrt	-0.0030	-0.0805	-0.0286	-0.0300	-0.0219	-0.1513	-0.0428
yearschool	0.1177	-0.0096	-0.0164	0.2185	0.1363	-0.2339	0.0313
q31_agrland	0.1944	0.0269	-0.0650	0.1190	0.8503	0.2742	0.2793

	hhsize~t	yearsc~l	q31_ag~d
hhsizesqrt	1.0000		
yearschool	0.0782	1.0000	
q31_agrland	-0.0541	0.1127	1.0000

APPENDIX 6: Goodness of fit – Hosmer – Lemeshow test

```
. lfit, group (12)

Logistic model for ipm_use, goodness-of-fit test

  (Table collapsed on quantiles of estimated probabilities)

       number of observations =      368
             number of groups =       12
      Hosmer-Lemeshow chi2(10) =       11.98
                  Prob > chi2 =        0.2864
```

With a p-value of 0.29, we can say that Hosmer and Lemeshow's goodness-of-fit test indicates that our model fits the data well

APPENDIX 7: Variance Inflation Factors (VIF) Results

```
. vif
```

Variable	VIF	1/VIF
hhagesq	1.99	0.502037
sqq33_farm~p	1.88	0.533292
lnq31_agrl~d	1.54	0.651462
logprdtrees	1.49	0.669275
sqrtq56a_y~o	1.41	0.708611
yearschool	1.19	0.837520
lnq21e_mon~e	1.16	0.861591
q75_protec~h	1.12	0.893463
gender	1.11	0.898947
q312_agrie~e	1.09	0.915598
q66_farmgr~p	1.09	0.916606
q36_irriga~n	1.08	0.927629
q69_access~t	1.06	0.943550
hhsizesqrt	1.06	0.945431
q521labour~t	1.03	0.974877
Mean VIF	1.29	

The above test was conducted to detect the problem of multicollinearity. The results show that there is no strong correlation among the variables since the values of VIF are far less than 10

Appendix 8: Environmental Impact Quotient Field Use

Active Ingredient	Trade Name	EIQ F	EIQ C	EIQ E	EIQ T	Rate (kg/acre)	EIQ Field use overall	EIQ Field use control	EIQ Field use treatment	T value	P value	% of farmers using	Vol.kg
Thiamethoxam (U)	Actara	10.35	12.03	77.52	33.3	0.12	5.75	3.55	2.19	0.7891	0.2341	0.81	1.14
Methomyl (IB)	Agrinate	6	11	75	31	0.28	277.38	221.12	56.27	0.2389	0.8805	6.20	452.31
Propineb (1II)	Antracol	6	5.78	14	18.34	0.27	30.93	0.10	30.82	1.2615	0.5807	6.20	534.42
Triadimefon (III)	Bayleton	12.15	15.15	53.57	33.3	0.25	277.31	105.04	172.27	-2.9994***	0.0033	34.50	134040.8
Beta-Cyfluthrin (II)	Bulldock	9	4	69	27	0.21	634.28	550.42	83.86	2.6674***	0.0087	33.96	69418.38
Copper Oxychloride (III)	Copper	108	19	76	67.7	0.20	557.61	512.49	45.12	3.0990***	0.0035	12.12	9444.32
Cypermethrin (II)	Cyclone	9	4	69	27	0.14	22.75	12.14	10.61	-1.5302	0.1482	4.58	173.3091
Dimethoate (II)	Danadim	72	9	141	74	0.22	76.91	46.79	30.11	-0.5301	0.6104	2.67	35.25
Deltamethrin (II)	Decis	6	3	68	26	0.26	0.58	0.21	0.37	0.2350	0.4325	2.43	101.10
Dimethoate (II)	Twigathoate	72	9	141	74	0.21	946.16	794.15	152.01	1.3425	0.7856	8.63	2855.765
Mancozeb (U)	Dithane	12	3	29	44	0.40	532.53	515.95	16.56	0.0955	0.92566	2.43	90.54
Lambda Cyhalothrin (II)	Karate	21	3	106	44.17	0.09	7.96	7.12	0.84	0.1144	0.9100	6.20	84.38
Methomyl (IB)	Weiling	6	11	75	31	0.31	56.45	38.27	18.18	-1.9925*	0.0866	2.42	69.92
Propineb (III)	Milraz	6	6	14	9	0.17	1.54	0.00	1.54	0.8745*	0.0534	1.35	5.07
Acephate (III)	Orthene	15	12.5	47.15	24.88	0.19	16.81	12.59	4.22	0.7131	0.4875	4.58	230.25
Carbendazim (U)	Rodazim	25	40.5	86	50.5	0.26	490.33	485.54	4.79	-0.7419	0.4752	3.23	28.57
Alpha-cypermethrin (II)	Tata alpha	21	3	106	44	0.30	39.62	39.62	0.00	0.1451	0.8862	5.39	34.38
Sulphur (U)	Thiovit	10	6	120	45.5	0.32	24.09	14.12	9.97	0.7117	0.4835	7.00	1427.01
Imidacloprid (II)	Thunder	6.9	10.35	92.88	36.71	0.21	36.36	35.51	0.85	-1.1227	0.2722	7.27	435.39
Thiophanate-Methyl (U)	Topsin	16.2	15.3	39.95	23.83	0.10	14.32	11.30	3.02	-0.58546	0.5796	2.16	2.87
	Total						4049.67	3410.27	639.40	-7.7660***	0.000	100	219465.20

NB: Statistical significance at 0.01(***), 0.05(**) and 0.1 (*)

Source: Field survey, 2014