IMPACT OF INTEGRATED PEST MANAGEMENT TECHNOLOGY ON FOOD SECURITY AMONG MANGO FARMERS IN MACHAKOS COUNTY, KENYA

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DECLARATION

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

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DEDICATION

This thesis is dedicated to my late parents Nelson and Hellen and to my late brother Amos whose sincere love has constantly inspired my life.

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ACRONYMS AND ABBREVIATIONS

2SLS	Two-Stage Least Square
AIEI	African Impact Evaluation Initiative
AR	Autoregressive
ASDS	Agricultural Sector Development Strategy
CIDP	County Integrated Development Plan
DD	Difference-in-difference
FAO	Food and Agriculture Organization of the United Nations
FFS	Farmer Field Schools
FSD	Financial Sector Deepening
GOK	Government of Kenya
HCDA	Horticultural Crop Development Authority
HDDI	Household Dietary Diversity Index
ICIPE	International Centre for Insect Physiology and Ecology
IPM	Integrated Pest Management
IV	Instrumental Variable
KES	Kenya Shilling (Currency)
KNBS	Kenya National Bureau of Statistics
MOA	Ministry of Agriculture
OLS	Ordinary Least Square
PCCI	Per Capita Calorie Intake
PSM	Propensity Score Matching
SSA	Sub Saharan Africa
STDF	Standards and Trade Development Facility
USD	United States Dollar (Currency)
VIF	Variance Inflation Factor

ABSTRACT

Mango (*Mangifera indica*) is one of the leading tropical fruits grown in Kenya and is ranked third after banana and pineapples in terms of acreage and total production volume. However, production has fallen below consumption due in part to fruit fly (*Bactrocera invadens*) infestation. About 40 percent of annual mango production in Kenya estimated at US$ 32 million, is lost due to direct damage of fruit flies. In an effort to improve production, the International center for Insect Physiology and Ecology (ICIPE) has developed a set of Integrated Pest Management (IPM) technologies aimed at controlling fruit fly infestation in mangoes. However, the impact of these technologies on the food security are not well understood.

This study evaluated the impact of IPM technology for mango fruit fly control on food availability and accessibilty among 600 mango farmers in Mwala and Kangundo sub-Counties selected using a stratified sampling procedure. A seven-day recall was used to elicit Per Capita Calorie Intake while a 30-day recall was used to measure household dietary diversity. To evaluate the impact of IPM on food security the difference-in-difference method (DD) was used.

The results indicate that 67 percent of IPM participants in Mwala and 75 percent of non-participants in Kangundo were food secure as they had attained the 2,250 Kcal threshold recommended by the Kenya National Bureau of Statistics (KNBS). The OLS regression results show that the IPM technology had a positive impact on per capita calorie intake but not on the quality of food intake (HDDI) estimated by the poison regression. This suggests that farmers using IPM technology benefit from income gains, and higher incomes improve the economic availability to food but not food access. The study recommends that the government should promote IPM technology for the control of mango fruit fly as it is likely to improve the food security of smallholder farmers.

CHAPTER ONE: INTRODUCTION

1.1 Background

Mango production is a major income-generating activity in the country where it is produced by both large- and small-scale farmers for both export and domestic consumption. With regard to production, the fruit is ranked third after banana and pineapple in terms of acreage and quantity produced in Kenya (Korir *et al*., 2015). It is estimated that more than 200,000 small-scale farmers in Kenya derive their livelihood from mango production (ICIPE, 2009). In addition to income-generation opportunities, mango is important in fighting nutritional disorders as it contains almost all the known vitamins and essential minerals (Griesbach, 2003).

Kenya grows 32 mango varieties; however, only seven are grown on commercial scale (Ministry of Agriculture [MoA], 2010). These include Apple, Boribo, Kent, Tommy Atkins, Ngowe, Dodo and Van Dyke (Muthini, 2015). Over the years, mango production has been increasing owing in part to the growing global demand for mangoes which increased by 22 percent from 2007 to 2011 (Financial Sector Deepening [FSD] Kenya, 2015).

Approximately 98 percent of mangoes produced in Kenya are consumed in the domestic market while the rest is exported (Government of Kenya [GOK], 2010). Mangoes account for 26 percent of export earnings from fruits, which is second only to avocados at 62 percent in Kenya. In 2010, mangoes earned Kenya US$70 million and US$10.1 million in the domestic and export markets respectively (GOK, 2012). The major export destinations for Kenyan mangoes in 2010 were United Arab Emirates, Tanzania, and Saudi Arabia with each accounting for 53, 20 and 22 percent respectively (HCDA, 2010).

Voor de Tropen *et al*. (2006) identify several factors constraining mango production and marketing in Kenya. These include high perishability, poor quality planting material, pest and disease infestation, high cost of inputs, limited adoption of improved technologies, seasonal gluts, poor post-harvest handling, and poor market infrastructure. According to Korir *et al*. (2015), pest and diseases constitute the most debilitating constraints in mango production especially among the resource-poor smallholder farmers in Kenya. Ekesi *et al*. (2010) observe that about 40 percent of annual mango production in Kenya, estimated at US$ 32 million, is lost due to direct damage by native fruit fly species such as *Ceratitis cosyra*, *Ceratitis rosa* and *Ceratitis capitate.*

Infestation of mangoes by insect pests limits Kenya's access to profitable export markets where such insects are considered quarantine pests (Korir *et al*., 2015). Thus, mango exporters in Kenya incur huge losses due to rejection and subsequent destruction of the fruit fly-infested mangoes. According to Horticultural News (2010), Kenya's fruit industry losses up to KES 478 million annually from ban of fruits exports to South Africa due to fruit fly infestation. Kenya's mango exports to the United States, Europe, Japan and Middle East must meet stringent phytosanitary standards to access those markets (Mitcham and Yahia, 2010). Locally, Muchiri (2012) reported 56 percent mango yield loss due to fruit fly damage in Embu County.

In order to stem the huge losses in mango production, farmers in Kenyan predominantly use chemical broad-spectrum pesticides to ameliorate the problem (Amata *et al*., 2009). Although chemical pesticides have been employed as the primary pest control strategy by mango farmers, there is increasing evidence of pest resistance to available pesticides (Korir *et al*., 2015). Additionally, the larvae of some insect pests, which is the most destructive stage, develop inside the fruit tissue and are not reached by pesticides applied on the surface of the fruit (*ibid*.).

To address this limitation, farmers tend to increase the frequency of spraying thereby increasing both the production cost and the likelihood of developing pest resistance to available pesticides (Macharia *et al*., 2009). In an effort to enable mango farmers reduce production losses and minimize the incidence of pest resistance, the International Center for Insect Physiology and Ecology (ICIPE) has developed a set of Integrated Pest Management (IPM) technologies for mango fruit fly control in several sub-Saharan countries (ICIPE, 2009).

In Kenya, the strategy has been implemented in the major mango growing areas of eastern and coast counties. Trials on the IPM technology package were conducted at Mwala sub-County in 2015 through a project in which farmers were enrolled and trained on use of the mango fruit fly IPM package components at designated lead mango orchards. After each training session, participants were issued with starter kits of the IPM technology for trial at their orchards. These technologies were based on baiting and male annihilation techniques (MAT), fungal application, orchard sanitation, use of weaver ant (*Oecophylla longinoda*) and biological control using parasitoids (Korir *et al*., 2015; Kibira *et al*., 2015; Muriithi *et al*., 2016).

The mango fruit fly IPM technology uses a combination of interventions that complement each other rather than work as a stand-alone management strategy (Ekesi and Billah, 2007). The spray food bait is a food protein bait (DuduLure®) developed by ICIPE and is combined with an insecticide named spinosad (Muriithi *et al*., 2016). The food bait is applied as localized spots at a rate of 50 ml solution on 1 m^2 of mango canopy. Both adult male and female fruit flies are attracted to the confined area on the canopy of the mango tree where the food bait is sprayed (Ekesi *et al*., 2015). The fruit flies ingest the bait along with the toxicant, which kills them before they infest fruits (Ekesi *et al*., 2014).

The male annihilation technique (MAT) involves deployment of high-density trapping stations consisting of a male attractant (in this case methyl eugenol), combined with a toxicant (malathion) to trap and kill male flies thus reducing their populations to very low levels such that mating does not occur or is greatly reduced (Ekesi and Billah, 2007). The strategy employees 7 Lynfield trap stations per ha recharged after 6 weeks of exposure (Muriithi *et al*., 2016).

The bio-pesticides used in the IPM package are fungus-based formulations that targeted pupariating larval stages of the fruit flies and emerging adults but do not have any effect on beneficial parasitoids (Ekesi *et al*., 2015). Instead they complement the beneficial parasitoids in significantly reducing the fruit fly populations. Orchard sanitation is achieved using an Augmentorium (Klungness *et al*., 2005). This is a tent-like structure that 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 from the structure through a fine mesh at the top of the tent (*ibid*.).

The IPM mango fruit fly control package is aimed at reducing economic losses at the farm level, reducing insecticide use and enhancing the supply of high quality mangoes to the market, raising profit levels for the producers thus improving their livelihood. The current mango fruit fly IPM technology dissemination and promotional activities have shown success with many farmers rapidly taking up the strategy (Korir *et al*., 2015). Kibira *et al*. (2015) and Muriithi *et al*. (2016) have shown that the use of IPM technology can lead to a reduction in magnitude of mango losses due to fruit fly infestation with associated reduction in expenditure on insecticides and increased net farm income.

The expected increase in net income will increase farmers' food purchasing power, which in turn, is hypothesized to increased food security. On the other hand, it is possible that the innovations may be unsuccessful or do not produce immediate result, hence, has negative effect on household income and food security. For example, an increase in income can lead to households' expenditure on food devoted to cereal staples alone such as millet, maize and sorghum. Since the introduction of the IPM package in Machakos County no work has been done to evaluate the intervention in terms of its effects on smallholder household food security. The current study assesses the impact of Mango IPM technologies for controlling fruit fly on household food security.

1.2 Statement of the research problem

The adoption and extensive use of improved agricultural technologies is vital for poverty reduction and improved food security in developing countries (Barrett and Lentz, 2010). Agricultural technologies can boost crop productivity, allowing higher production and lower food prices, directly contributing to alleviate food insecurity. ICIPE has developed and implemented a set of Integrated Pest Management (IPM) technologies aimed at reducing mango losses and the cost of production. This in turn will lead to an increase in marketable produce or save labour for non-farm activities and subsequently increase household income and food security.

Previous studies on the effect of mango fruit-fly IPM technologies have concentrated on pesticide expenditure and income (first order effects). Although these studies have shed some light on IPM adoption, reduced pesticide expenditure and increased farm income, they have not examined the impact of IPM on food security (second order effects) in Machakos County. Consequently, the existing literature is unable to inform policy makers on the impact of IPM on food security. In addition, there is limited knowledge on the factors influencing food security in Machakos County. Since the introduction of the mango fruit fly IPM technology in Kenya, no research has been done to evaluate the intervention in terms of its impact on smallholder household food security.

1.3 Purpose and Objectives

The purpose of this study is to evaluate the impact of IPM technology on food security among smallholder mango farmers in Machakos County.

The specific objectives of this study are;

1. To assess characteristics of smallholder mango growers in Mwala and Kangundo sub-counties.
2. To assess the impact of IPM technology on food availability and accessibility among mango producers in Machakos County.

1.4 Hypotheses tested

1. The IPM technology has no impact on food availability and accessibility of smallholder mango producers in Machakos County.

1.5 Justification

In Kenya, Mango is ranked third among tropical fruits in terms of acreage and total production and accounts for 26 percent of foreign earnings from fruits. However, it is confronted with a major threat of fruit fly infestation that causes reduction of quality and quantity of marketable fruit and hence considerable produce losses. Use of IPM technologies has been shown to reduce magnitude of mango losses due to fruit fly infestation, reduction in insecticide expenditure and increased net farm income.

Understanding the impact of IPM technology is important for generating information to policy makers (National and County governments), mango IPM project funders (ICIPE) and farmers on technology effectiveness for future adjustment and up scaling to other mango producing areas. Knowledge about factors influencing food security points out areas of policy intervention that need to be emphasized in order reduce food insecurity in the country. The information generated by this study will contribute to the growing body of knowledge on impact assessment particularly focusing on other mango producing areas.

1.6 Organization of this thesis

This thesis is organized into five chapters. Chapter one introduces the background of the study, the statement of the research problem, purpose and objectives, hypotheses and justification of the study. In Chapter two, relevant studies are reviewed. These revolve around on impact assessment and the general approaches/methods used to operationalize them. Chapter three presents the methods and data used in this study. This chapter presents the analytical and empirical frameworks as well as the type and sources data used, and sampling procedures. Chapter four presents the results and discussion. Finally, Chapter five presents the summary of major findings, conclusions and policy recommendations.

CHAPTER TWO: LITERATURE REVIEW

2.1 Food security concept

Food security is a broad concept that is generally defined as physical and economic access to adequate, safe and nutritious food by all people at all times for an active and healthy life (FAO, 1996). The broad definition implies that food security is more than food production and accessibility. Generally, this definition has four dimensions that constitute the four pillars of food security: food access, availability, utilization and stability of food supply (Gross *et al*., 1999).

Food access is ensured when all members in a household have enough resources to acquire food to meet their nutritional and dietary requirements. Access reflects the demand side of food security, as manifest in uneven inter- and intrahousehold food distribution and in the sociocultural limits on what foods are consistent with prevailing tastes and values within a community (Barrett, 2010). Availability is achieved when sufficient quantities of food are available to all individuals (Latham, 1997). Food utilization requires a diet that provides sufficient energy and essential nutrients, along with access to potable water and adequate sanitation. Stability, on the other hand, concerns the balance between vulnerability, risk, and insurance to food access and availability, which are often termed as security (Jones *et al*., 2013).

In an effort to reduce the proportion of people suffering from hunger by half, world leaders committed themselves to the Millennium Development Goals (MDGs) aimed at eradicating poverty and hunger. Despite the tremendous progress towards the goal of halving the number of hungry people in the world, food security remains a major risk for 815 million worldwide according to the FAO and WFP report. The food security situation has worsened sharply in parts of sub-Saharan Africa, South-Eastern Asia and Western Asia due to conflict, climate change, drought and increase in population (FAO, 2017).

Studies by Babatunde (2007), Oriola (2009) and Fayeye and Ola (2007), have documented that despite the growing food production globally, malnutrition, hunger and famine are prevalent in many parts of Africa. This is partly due to domestic policies in many countries in sub-Saharan Africa having contributed very marginally to food security. These authors argue that improvement in food production in sub-Saharan Africa will boost per capita GDP, raise purchasing power and access to food. These studies conclude that research is needed on improved technologies that are output-driven, ecologically friendly, acceptable and affordable to the resource-poor farmers. To increase food security especially in developing countries, good governance and stable political governance system are emphasized by these studies.

2.2 Measurement of food security

While food security encompasses the four dimensions, the time and cost involved in collecting data on all the dimensions may be prohibitively high. This is evident from previous studies, where different researchers adopt different measures of food security. In estimating the impact of technology adoption on food security, many authors have often used indirect monetary (income and expenditure) and/or production measures (farm production and yields) of food security (e.g., Mason and Smale, 2013; Shiferaw *et al*., 2008). Other authors have used poverty intensity indexes to measure food security (e.g., Kassie *et al*., 2012; Kabunga *et al*., 2014). The use of monetary and production indicators partially captures the impact of the technology on food availability and food access and assumes a causal relationship with food utilization and stability (Magrini and Vigani, 2016).

Other studies that directly estimate the effects of agricultural technologies on household food security in sub-Saharan Africa (SSA) use subjective indicators based on household surveys with self-assessment questions on own-food security status combined with monetary proxies (e.g., Kabunga *et al*., 2014; Kassie *et al*., 2012; Shiferaw *et al*., 2014). The main problem of the subjective approach is not standard (Magrini and Vigani, 2016). Moreover, the presence or absence of particular strategies is often not a standard indicative of food security status. Subjective indicators are also likely to be influenced by measurement errors due to biased self-perception of the respondents of their food security status (Kabunga *et al*., 2014).

Orewa and Iyangbe (2009) and Bashir *et al*. (2010) used household calorie consumption method to measure food security. Orewa and Iyangbe (2009) used a 48-hour recall method while Bashir *et al*. (2010) used a 7-day recall period in obtaining information on the type and quantity of food each household member consumed over the relevant period. The calorie content in each food item consumed was determined and used in estimating the total food intake of the household members. A minimum level of per capita calorie below which a household was considered food insecure was set.

Other measures or indicators of food security include the Household Dietary Diversity Index (HDDI) and the household food insecurity access indicator (HFIAI). HDDI is calculated by summing data on the consumption of 12 food groups (i.e., cereals, roots and tubers, fish, meat, fruits, eggs, vegetables, dairy products, pulses and nuts, oils and fats, sugar, and condiments). The HFIAI score is a continuous measure of the degree of food insecurity (access) in the household in the past four weeks. HFIAI is based on the idea that the experience of food insecurity (access) causes predictable reactions and responses that can be captured and quantified through a survey and summarized in a scale (Coates *et al*., 2007). These methods are preferred to calorie intake due to the simplicity of survey administration and the fact that they can be used in combination with other measures (Chege *et al*., 2015b; Coates *et al*., 2007).

The current study adopts the calorie intake method with a 7-day recall together with HDDI. Per capita calorie intake is the most widely used method of assessing food availability. However, literature points to the intrinsic limitation of this method in assessing calorie intake indicating that it does underestimate calorie intake in that it does not take into consideration the different age and activity levels of the household members and is thus at fault (Claro *et al*., 2010). However, it is easy and less expensive to calculate thus used in this study.

Food security definition includes food consumption in enough quantity to meet for energy and nutrient requirement which is the main focus of calorie intake. Its error structure is also far well understood than for any other method employed for assessing food security (Chege *et al*., 2015b). It has thus been used in validating other food security measures. However, it is not without shortcomings, which include possibility of underreporting, logistic complexity and prohibitive cost of survey (*ibid*.). HDDI is an attractive proxy indicator of food accessibility because obtaining these data is relatively straightforward.

2.3 Determinants of food security

Literature on factors affecting household food security in various developing countries especially in Africa have been documented. These determinants or factors are most often not location-specific (i.e. different determinants were found to influence food security differently in the study areas with some determinants recurring). The study conducted in Nigeria by Oluwatayo (2008) using probit model found out that age, educational level, sex of household head, and income have positive influence on food security whereas household size has negative influence on household food security.

Orewa and Iyangbe (2009) attempted to identify the factors that have major influence on the level of food calorie intakes of rural and low-income urban households in Nigeria using OLS regression analysis. The result revealed a significant positive relationship between daily per capita calorie intake and age, household size, sex, education level and salaried income earners. On the other hand, dependency ratio and non-engagement in farming had a negative influence on daily per capita calorie intake.

Sikwela (2008) documents that fertilizer application, access to irrigation, per aggregate production and cattle ownership have positive effect on household food security in South Africa. The study on the other hand, showed that household size and farm size have negative effect on household food security. Oni *et al*. (2010) assessed the socio- economic factors affecting smallholder farming and food security in Thulamala, South Africa. The study found out that total income, education level, household own food production, number of people living in a household and spending patterns significantly affected food security.

Babatunde *et al*. (2007) utilized a three-stage random sampling technique to obtain a sample of 94 farm households in Nigeria. Using the recommended calorie required approach; the study revealed that 36 per cent and 64 per cent of the households were food secure and food insecure respectively. A logit regression model estimated showed that household income, household size, educational status of household head and quantity of food obtained from own production were found to determine the food security status of farming households in the study area.

Determinants identified in the above studies are not identical. Different factors were found to influence food security in different areas. The current study adds to this existing literature, by assessing the factors influencing food security in the Mwala and Kangundo sub-Counties, Kenya.

2.4 Approaches to assess the impact of food security interventions

Impact evaluation aims to establish whether or not an intervention produces its intended effects (AIEI, 2010). One of the most enduring challenges in undertaking impact evaluation is the failure by the evaluator to systematically and objectively gauge what would have happened to the beneficiaries of a program, project or policy in the absence of the intervention, or the so-called the counterfactual problem (Khandker *et al.*, 2010). The problem of evaluation is that while the program's impact (independent of other factors) can truly be assessed only by comparing actual and counterfactual outcomes, the counterfactual is not observable (*ibid.*). Therefore, the main challenge in impact assessment is that of finding an appropriate counterfactual.

Two approaches exist to overcome the counterfactual problem in impact assessment. These are the 'before and after' and the 'with and without' approaches (Gittinger, 1984). The 'before and after' approach compares key indicators before and after the intervention (Wainaina *et al*., 2012). A baseline survey of participants and non-participants is done before the intervention and a follow up survey done after. Statistical methods are then used to assess whether there is a significant difference in the essential variables overtime (Gittinger, 1984). According to Gittinger (1984), the 'before and after' comparison fails to account for all the changes that would occur without the intervention and thus leads to an erroneous statement of the benefit attributable to the intervention.

The 'with and without' approach, on the other hand, is more comprehensive in its capture of the changes attributable to the intervention (Gittinger, 1984). It compares the behavior of key variables in a sample of beneficiaries of the intervention (or treatment) with their counterparts in non-intervention (or control) group (Wainaina *et al*., 2012). This approach uses the comparison group as a proxy to gauge what could have happened in the absence of the intervention. It is particularly useful when the baseline is missing (*ibid*.).

The challenge of using this approach is the tendency of beneficiaries to allocate themselves to one intervention group or the other, which leads to self-selection bias (Khandker *et al*., 2010). This problem could also arise due to ethical reasons where the program implementer subjectively allocates potential beneficiaries to one intervention group or the other. That is, programs are designed based on the needs of the communities and individuals, who in turn select themselves according to program design and placement (*ibid.*). Self-selection could be based on observed characteristics, unobserved factors, or both.

In order to overcome the self-selection bias problem, three impact evaluation designs have been proposed in the literature namely experimental, quasi-experimental and non-experimental (Baker, 2000). In experimental or randomized designs, a well-defined sample of beneficiaries is randomly selected into treatment and control groups (*ibid*.). In this case, the only difference is that the treatment group has access to the program ("treatment" or intervention). When it is impossible to construct treatment and control groups through experimental designs, the quasi-experimental designs are used (*ibid*.). In this case, comparison groups are generated that resemble the treatment group based on observed characteristics. Non-experimental designs are used when it is impossible to randomly select a control group (*ibid.*). In such situations, program participants and non-participants are compared using statistical methods.

Depending on the nature of the counterfactual and self-selection bias problems, various econometric techniques are used to undertake impact evaluation. These include reflexive comparison, instrumental variable methods, matching methods and difference-in-difference (DD) methods (Baker, 2000). Reflexive comparison is a quasi-experimental design in which a baseline survey is conducted before and a follow up survey after the intervention.

The counterfactual is constructed on the basis of intervention participants before the intervention. This design is useful in evaluating the full coverage of an intervention where the entire population participates and therefore there is no control group. The major drawback with reflexive comparison method is that the situation of the participants may change due to reasons independent of the intervention (*ibid.*). In such cases, the method may not differentiate between intervention and external effects leading to unreliable results (Morton, 2009).

The instrumental variable (IV) approach involves the use of at least one variable in the treatment equation as instrument of participation. This also serves as its major limitation since finding such instruments remains a difficult task in empirical analyses (Chege *et al*., 2015b). The other two limitations of the IV approach include the fact use of instrumental variables that explain little variation in the endogenous explanatory variables can lead to large inconsistencies in coefficient estimates even if only a weak relationship exists between the instrument and the error term in the structural equation (Bound *et al.*, 1995). Secondly, coefficient estimates are biased in the same direction as those produced through the ordinary least squares (OLS) estimator in finite samples (*ibid*.).

Matching methods include one-to-one matching, radius matching, weighting and sub-classification (Khandker *et al*., 2010). These methods involve the pairing beneficiaries and non-beneficiaries of an intervention with similar observable characteristics believed to affect program participation (*ibid.*). During matching, a statistical comparison group is constructed based on a model of the probability of participating in the treatment using observed characteristics (*ibid.*). The matching only controls for the differences on observed characteristics and there may be some biases resulting from unobserved variables that could affect program participation (*ibid.*).

The DD method is used on panel or longitudinal data. It entails comparing a treatment with a control group before and after an intervention (Baker, 2000). In this case, the "first difference" constitutes of the difference between the treatment and control groups before the intervention while that after the intervention is the "second difference" (*ibid.*). Thus, the total difference is the difference between the first and second differences (*ibid.*). The DD estimator compares program participants and non-participants before and after the intervention (Khandker *et al*., 2010). The difference of observed mean outcomes for the treatment and control groups is then calculated before and after program intervention (*ibid.*).

The main advantage of DD is that it removes biases coming from permanent differences between those groups (Kibira *et al*, 2015). In addition, biases from comparisons over time in the treatment group coming from trends are removed. Thus, the DD method solves the problems arising from non-random selection as well as the non-random placement of program participants (Ravallion, 2005). Time-invariant selection bias has been deemed as the main limitation of DD (Kibira *et al*, 2015). Despite its shortcomings, DD estimator is intuitively appealing, simple and can be used with panel data (Khandker *et al*., 2010) as is the case with the current study.

2.5 Studies on the impact of agricultural innovations on food security

Agricultural technologies have a special role in developing countries, boosting production in the agriculture sector, hence driving the overall growth and lowering food prices. While analyzing the potential impact of improved wheat varieties on household food consumption in South eastern Ethiopia, Mulugeta and Hundie (2012) employed a propensity score matching (PSM) method. The authors used a purposive sampling technique on 200 selected farm households. The results showed that the adoption of improved wheat varieties had a positive impact on households' food availability.

Magrini and Vigani (2016) assessed the impact of new technologies on food security among maize producers in Tanzania. The study selected 543 households were selected using multi-stage, stratified, random sampling. Using matching techniques to estimate impact, the authors found a positive and significant impact on use of improved seeds and inorganic fertilizer on all dimensions of food security. The study reported mixed findings on determinants of food security, for example, household size had positive effect on food security when a household used improved seeds but negative in terms of inorganic fertilizer.

Assessing the impact of improved dairy cow breeds on nutrition in Uganda, Kabunga *et al*. (2014) employed matching techniques on a random sample of 906 households. The study found out that the adoption of improved dairy cows considerably increased milk yield, household's milk market orientation, and expenditure on food. In addition, the adoption of improved cow breeds considerably reduced stunted growth amongst children below five years of age. The study used subjective indicators to assess households' perception of their food security. Despite being cost-effective, subjective indicators are particularly prone to errors especially when long term stability is analyzed.

2.6 Studies on IPM technology

Several studies have been done on adoption and use of integrated pest management strategies. For example, Fernandez-Cornejo *et al.* (1994), Dasgupta *et al*. (2004) and Garming *et al*. (2007) suggest that IPM is a knowledge intensive technology and dissemination of accurate information, to create awareness among farmers, about IPM enhances adoption. Korir *et al*. (2015) found that education, the number of mature mango trees planted, whether or not a farmer kept records of the mango enterprise, use of protective clothing during spraying, and participation in IPM technology training had a positive influence on the intensity of adoption.

Muchiri (2012) used stratified sampling to select 257 IPM participants and non-participants from the intervention and control areas in Embu County. The study revealed substantial losses in mangoes amounting to KES. 3.2 million per acre due to fruit fly infestation. In addition, 66 percent of respondents were willing to pay KES 1,100 per acre for the IPM mango fruit fly control package. Studies by Isoto *et al*. (2008), Kibira et al. (2015), Muriithi et al. 2015 and Njankoua et al. (2007) have found that IPM use leads to increase in income.

Kibira et al. (2015) also reports that, on average, recipients of the IPM technology recorded a 55 percent reduction in mango rejection relative to non-recipients. In addition, recipients of IPM spent 46 percent less on insecticides per acre compared to their counterparts. Further, the participants received 22 percent more income than non-participants. These findings are consistent with those of Njankoua *et al*. (2007), who reported that IPM training had a reduction in the frequency of spraying fungicides and the number of sprayers applied per treatment by 47 and 17 percent respectively in Cameroon.

2.7 Studies using difference-in-difference method

Feder *et al.* (2004) evaluated the impact of Farmer Field School (FFS) on yields and pesticide use in Indonesia using the DD approach. The data were obtained from a sample of 268 households of which 112 had participated in the training while 156 households had not attended the training. The evaluation considered direct impact on participating farmers and secondary benefits through farmer to farmer diffusion from previous FFS beneficiaries to other farmers. The study found no significant differences in performance between FFS graduates and exposed farmers in terms of pesticide use and yields.

Omilola (2009) estimated the impact of improved agricultural technology on poverty reduction in Nigeria using double difference approach. A multistage random sampling approach was used to select a total of 200 adopters and 200 non adopters for the study. The analysis showed that participants received statistically significant and higher increases in agricultural income than non-participants. Non-adopters had larger changes in other income sources than adopters. The overall findings revealed that the differences between the adopters and non-adopters' poverty status of the new technology were fairly small, demonstrating that the adoption of agricultural technology did not considerably translate to poverty reduction for its adopters.

Yamano and Jayne (2004) used the DD approach to assess the impact of mortality of the working age group on crop production of small-scale farmers in Kenya. The study used a two-year panel of 1,422 randomly selected Kenyan households surveyed in 1997 and 2000. The findings indicated that: the effects of death of an adult on crop production was sensitive to age, gender and position of the deceased; death of a working male household head greatly affected household off-farm income negatively; households coped with the death of a working adult by selling particular types of assets.

2.8 Summary

Based on the reviewed literature, many authors have used different methods to measure food security. The determinants of food security are not location specific which emerges as a gap. On the other hand, many methods have been used to assess impact of IPM technologies including PSM, IV and DD. The DD estimator is intuitively appealing, simple and can be used with panel data. Although a few studies have been undertaken on impact of IPM technologies on food security, none has been done in Machakos County. To fill this gap, the current study assessed the impact of mango fruit fly IPM technology on food security in the county using the DD method.

CHAPTER THREE: METHODOLOGY

3.1 Analytical framework

The effect of a technology on household food security is transmitted through three main linkages; (i) reallocation of farm resources between enterprises as a result of technology adoption, (ii) changes in household income, and (iii) changes in food consumption patterns as a result of changes in the income derived from the proceeds of technology adoption (von Braun, 1988). The technology impacts the profits derived from increasing farmers' knowledge on a technology.

The second link is through possible changes in household income. Kibira *et al*. (2015) and Muriithi *et al*. (2016) have shown that an agricultural technology can cause significant income gains. Higher incomes improve the economic access to food, which may result in higher calorie consumption, especially in previously undernourished households (third link). Moreover, rising incomes may contribute to better dietary quality and higher demand for more nutritious foods, including vegetables, fruits, and animal products. When technological change raises income and income raises food consumption, the positive effects of this change can be identifiable. The relationships are, however, not straight forward (von Braun, 1988).

Following Heckman (1979), the most basic function considered in examining the impact of technology adoption on household food security is a linear function of the explanatory variables (X_i) and a treatment dummy variable (U_i) and an error term, i.e.,

$$Y_i = \alpha X_i + AU_i + \mu_i \quad \text{(3.1)}$$

where Y_i is the household food security indicator, X_i represents household and farm level characteristics, U_i =1 for adopters and 0 for non-adopters and μ_i is the error term that is also assumed to be normally distributed.

The expected treatment effect of IPM adoption or Average Treatment effect on Treatment (ATT) is the difference between the actual food security status and the food security status if they did not adopt. This is given as (Caliendo and Kopeinig, 2008);

$$ATT = E(Y_{1i} - Y_{0i} / P_i = 1) \text{ .... } (3.2)$$

where Y_{1i} denotes food security status when the *i-th* farmer adopts IPM, Y_{0i} is the food security status of *i-th* farmer who does adopt, and P*i* denotes adoption, 1=adopts, 0=otherwise. ATT is also called conditional mean impact (Wainaina *et al.*, 2012). The mean difference between IPM adopters and non adopters is written as (Caliendo and Kopeinig, 2008);

$$D = E(Y_1 / P_i = 1) - E(Y_0 / P_i = 0) = ATT + \varepsilon \text{ .... } (3.3)$$

where ε is the bias, also given by:

$$\varepsilon = E(Y_1 / P_i = 1) - E(Y_0 / P_i = 0) \text{ .... } (3.4)$$

The parameter of ATT is only identified if the outcome of treatment and control under the absence of the intervention are the same. This is written as (Caliendo and Kopeinig, 2008):

$$E(Y_1 / P_i = 1) - E(Y_0 / P_i = 0) \text{ .... } (3.5)$$

In the case of Difference in difference setting which consists of a treatment and control group & a baseline and follow up survey i.e. Group G_i=0,1; time T_i=0,1; $Y_i(0)$ is the, counterfactual, response of farmer *i* in the absence of IPM while $Y_i(1)$ is the response if farmer *i* got the intervention.

The standard DD model is (Omilola, 2009):

$$E(Y_i) = \alpha + \beta T_i + \gamma t_i + \delta T_i * t_i \text{ .... } (3.6)$$

Where Y_i is the outcome of interest for farmer $i = 1\ldots., n$

T_i is a dummy variable with 1 if farmer *i* is in the treatment group (IPM participant) and zero otherwise

t_i is a dummy variable with 1 if the measurement was in the post-treatment period (follow up survey) and zero otherwise

$T_i * t_i$ is an interaction term, i.e., the product of the two dummy variables where 1 represents intervention only in (post- treatment) if farmer *i* applies the control package. It represents the actual treatment variable that indicates the impact of the intervention.

α = constant term.

β = treatment group-specific effect that accounts for average permanent differences between treatment and control groups.

γ = time trend common to control and treatment groups.

δ = true effect of treatment.

In the absence of intervention (counterfactual), the expected outcome (Food availability and accessibility) is:

$$E(Y_i(0)) = \alpha + \beta T_i + \gamma t_i \quad (3.7)$$

In the presence of intervention, the expected outcome (Food availability and accessibility) is:

$$E(Y_i(1)) = E(Y_i(0)) + \delta \quad (3.8)$$

Now, ATT is the expected difference in $Y_i(1)-Y_i(0)$ for those treated by time 1, i.e. with G=1 and T=1. Plugging these values into Equation 3.2 to get (Caliendo and Kopeinig, 2008):

$$ATT = [E(Y_i \mid G_i = 1, T_i = 1) - [E(y_i \mid G_i = 1, T_i = 0)] - [E(Y_i \mid G_i = 0, T_i = 1)] - [E(Y_i, G_i = 0, T_i = 0)] = \delta \quad (3.9)$$

Table 3.1 provides a framework for comparing treatment and control groups before and after the treatment. The columns present information about the treatment [or intervention denoted by I] and control (denoted by C) groups. The rows represent the time difference before (or the baseline situation) and after (treatment situation) intervention, denoted by subscripts 0 and 1 respectively. After implementing the intervention, it is expected that the food security status of the treatment and control groups would be different. Following Ahmed *et al*. (2009), to account for any observable and unobservable differences existing between the two groups a double difference is obtained by subtracting pre-existing differences between the groups, i.e., (I_0 - C_0), from the difference after the intervention has been implemented, (I_1 - C_1). Thus, the DD shown on the right of the last row in Table 3.1 is what this study sought to measure.

Table 3.1: Scheme of DD estimation of average technology adoption effect

Time period	**Intervention (Group I)**	**Control (Group C)**	**Difference across groups**
Follow-up	I_1	C_1	$I_1 - C_1$
Baseline	I_0	C_0	$I_0 - C_0$
Difference across time	**$I_1 - I_0$**	**C_1- C_0**	**DD = [I_1 - C_1] – [I_0 - C_0]**

Source: Ahmed *et al*. (2009)

The unconditional treatment effect of DD expressed in Equation (3.6) assumes that the dependent variable, Y_i, is only affected by the intervention, while other factors do not change across time (Ravallion, 2005). However, this is not realistic as farm and household conditions vary over time, which might affect the outcome of interest (*ibid*.). This calls for the estimation of the conditional treatment effect of DD. Following Omilola (2009), the conditional treatment effect of the intervention, DD, is given by:

$$E(Y_i) = \alpha + \beta T_i + \gamma t_i + \delta T_i * t_i + \lambda_i X_i \quad \text{(3.10)}$$

where X_i is the vector of farmer and household characteristics such as age, education, gender, wealth category, land size, group membership, credit access, farm income, household size, distance to nearest market, experience, extension and livestock units, and λ_i represents the coefficients of the X_i. The sign on δ indicates whether the technology adopters have experienced a bigger or lesser change in the outcome of interest than the control group. A positive sign on δ indicates that technology adopters' food status increased compared to non-adopters and vice versa.

3.2 Empirical framework

3.2.1 Objective 1: Characterizing mango farmers in Mwala and Kangundo sub-Counties

To achieve objective one descriptive statistics is used. Socio-economic characteristic differences between adopters and non adopters are tested using t test for differences of the means.

3.2.2 Objective 2: Assessment of impact of IPM technology on food security

This is achieved in two stages. The first stage measures the food security status of households while in the second stage assesses the impact of IPM on food security. Food security is measured using two methods namely, per capita calorie intake and household dietary diversity index (HDDI). Based on the average dietary energy requirement in Kenya of 2,250 kcal per adult equivalent, households are categorized as either food secure or insecure as used by the Kenya National Bureau of Statistics.

To assess impact of IPM on food security the difference in difference (DD) method is used. The DD estimator for per capita calorie intake (Yi), a continuous covariate, is estimated with ordinary least squares (OLS) (Omilola, 2009). On the hand, a truncated poison regression is estimated to assess the impact of fruit fly IPM on Household Dietary Diversity Index (HDDI) a measure dietary quality. The higher the diversity index so is the quality of diet and vice versa.

3.2.2.1 Measures of food security adopted in this study

Household food security is measured using (i) per capita calorie intake and (ii) Household Dietary Diversity Index (HDDI) following Hoddinott and Yohannes (2002).

a) Per capita calorie intake

The calorie intake is estimated from data collected through a 7-day recall of consumption of all significant sources of calories consumed in the household. The household member that prepared the food or another adult who was present and ate the food in the household during the 7 days is asked how much food she/he prepared/ate over the reference period. Data on what meals are consumed, the ingredients and the quantity in grams were collected. Following Swindale and Bilinsky (2006), the data are converted into calories using standard food composition tables (Appendix 4) and the following formula:

$$C_{ij} = \sum_{1}^{n} W_i B_i \quad (3.11)$$

where

C_{ij} is the total calorie intake from the *i*th food type consumed by the *j*th household

W_i is the weight in grams of intake of food commodity *i*

B_i is the standardized food energy content of the *i*th food commodity (FAO tables).

n is the number of food types consumed by the household

C_{ij} is divided by the household's total adult equivalent to get per capita calorie intake. Based on the average dietary energy requirement in Kenya 2,250kcal (Recommended by KNBS). This study uses a minimum Per Capita Calorie intake of 2,250 kcal per adult equivalent to categorize households below this threshold as food insecure.

b) Household Dietary Diversity Index (HDDI)

Dietary diversity is considered an outcome measure of food security mainly at individual and/or household levels. Dietary diversity index is the sum of the number of food groups consumed by an individual or a household over a reference period (Chege *et al*., 2015b). In this study, the HDDI is obtained by summing up the number of different food group consumed in the household during the 24 hours preceding the survey. The FAO 12 food group system is used in this regard. These food groups included cereals, root and tubers, pulses/legumes, milk and milk products, eggs, vegetables, meat, oil/fats, sugar/honey, fruits, fish and seafood and miscellaneous (Kennedy *et al*., 2011). An increase in the average number of different food groups consumed provides a quantifiable measure of improved household food access (Swindale and Bilinsky, 2006).

3.3.2.2 Justification for inclusion of independent variables

The independent variables chosen for the empirical model are based on previous empirical review on technology adoption and food security interlinkage studies mentioned in Chapter two. Table 3.2 presents the descriptions and expected signs of the variable used in the model.

Household Head Age: The age of household head is expected to impact on his or her labour supply for food production (Babatunde *et al*., 2007). Young and energetic household heads are expected to cultivate larger farms compared to the older and weaker household head. Age is measured by the years of the household head. The square of age is included in the model as result of the nonlinear relationship between age and food security. Age is hypothesized to be positively associated with the quantity and quality of food consumed by households in Machakos County, Kenya.

Household Head Education: The education level determines the number of opportunities available to enhance livelihood strategies, improve food security and reduced poverty levels (Amaza *et al*., 2009). It is hypothesized that the more the years of education of the household head the better the food security situation of the household. This is because education is positively attributed to uptake of improved technology, improved managerial capacity even at the farm level and more probability of off farm employment opportunities either self-employment or otherwise (Pankomera *et al*., 2009). Education is measured by the number of years of formal schooling completed by the household head. The current study hypothesizes education to be positively related with food security.

Table 3.2: Definition of variables hypothesized to influence the impact of IPM on Food Security

Variable	Meaning	Measurement	Expected sign
IPM (Treatment)	Mango IPM control package treatment status	(Dummy) 1=household in treatment group, 0 =household in control group	+
Time (Period)	Time period survey was conducted	(Dummy) 0=before intervention 1=After intervention	+
Interaction of IPM and Time (Effect of IPM)	Actual mango IPM intervention variable	(Dummy) 1= only after intervention if household applies the IPM package, 0= otherwise	+
Age	Age of household head in years	Continuous (Years)	+
Education	Household Head number of formal education	Continuous (Years)	+
Gender	Gender of the household head	(Dummy) 1=male 0=female	+
Household Size	Number of persons in a household	Continuous (Number)	+/-
Experience	Total number of years of experience in mango farming	Continuous (Years)	+
Group Membership	Whether a farmer belongs to a farmer group	(Dummy) 1=yes 0=No.	+
Farm Income	Total income from all farming enterprises	Continuous (KES/Year)	+
Extension	Whether a farmer had any contact with an extension worker over the last one year	(Dummy) 1=Yes 0=No	+
Livestock Units	Number of livestock equivalent units owned by the household	Continuous (TLU)	+
Market Distance	Distance in km to the nearest market	Continuous (KM)	-
Farm size	Farm size under mango cultivation	Continuous (Acres)	+
Credit	Whether a farmer acquired credit for mango production	(Dummy) 1=Yes 0=No	+
Wealth Category	Wealth category classification based on the number of assets owned by a household	(Categorical) 2=Wealthy 1=Moderately wealth 0=Not wealthy	+

Source: Author

Experience. Refers to the number of years the household head has been engaged in mango farming activities. It's expected that an experienced household head to have more insight and ability to diversify his or her production to minimize risk of food shortage. Research findings by Feleke *et al*. (2003) and Oluyole *et al*. (2009) have shown a positive relationship between food security status and farming experience. This variable is measured as number of years that the household head has been practicing mango production. The expected sign for experience on food security is positive.

Gender: Gender of household head looks at the role played by the individuals in providing households' needs including acquisition of food. Kassie *et al*. (2012) have documented an increased food security of male headed households compared to female headed household stating that female headed households are mostly single parented and have limited access to productive resources. Gender of the household head is a dummy variable taking 1 if the household is a man headed and 0 if a woman. In this study, Gender is hypothesized to be positively related to the food security of households

Household size: Household size determines the amount of labor available for farm production, farm produce kept for own consumption, and agricultural marketable surplus of farm harvest (Amaza *et al*., 2009). Households with large family members are mostly associated with a high dependency ratio and more food requirements, depicting a negative effect on food security. However, an increase in a household size could translate to an increase in the number of income earning adults depicting a positive effect on food security (Iyangbe and Orewa, 2009). Therefore, the expected sign for household size can be either positive or negative. This variable is measured as number of people living in the household. Household size is expected to have either a positive or negative effect on household's food security

Group membership: Agricultural groups provide social network platforms within which participants share new information and experiences such as IPM strategies and proper pesticides use. Group membership also increases farmers bargaining power in terms of credit and market access. Belonging to a group also acts as a form of social capital which Martin *et al*. (2004) found to be significantly positively associated with food security. Sseguya (2009) found that households that had membership in one or more groups were more food secure. The dummy variable takes the value of 1 if the respondent is a member of a group and 0 if not a member. Group membership is expected to be positively associated with food security.

Farm income: It improves access to food for those who earn the income. The higher the income, the higher the expected per capita calorie intake and the more diverse a household diet is expected to be. Anderson (2002) found a positive impact between farm income and food security. In this study, annual farm income is hypothesized to be positively associated with household's economic access of food in the Machakos County, Kenya. Farm income is a continuous variable measured in KES.

Access to extension service: Field extension officers are important in dissemination of improved technology. It is important that the contact between extension officers informing on the innovation and farmers occurs before the adoption in order to avoid any reverse causality problem. Kassie *et al*. (2012) and Lewin (2011) found that government investment in agricultural extension has a significant impact in food security status. Lewin (2011) found that at least one visit to each household from an agricultural extension agent during each cropping season would reduce food insecurity by 5.2 percent. The dummy variable takes the value of one if the farmer had accessed formal agricultural extension services and zero if they did not

Tropical Livestock units owned: Livestock play a number of roles which include; income generation, provision of inputs and providing a buffer against environmental and economic shocks (FAO, 2009). Livestock act as a source of food for instance, milk, eggs and meat and can also be considered as assets thus a form of wealth indicator. Animals provide manure and are used as a form of traction hence increasing output. Households with more livestock units are expected to have more per capita calorie intake and diverse diets. The tropical livestock unit is commonly taken to be an animal of 250kg live weight (Jahnke, 1982).

Distance to the Agricultural market: Long distances to the market centre and input shops translate to high transport and fare paid by farmers, most importantly when sourcing important inputs for farming. Longer distances discourage farmers from visiting markets frequently hence less likely in getting market information (Staal *et al*., 2002; Fekele *et al*., 2003; Matchaya and Chilonda, 2012). Hence farmers may sell their produce at times when prices are low and buy when prices are high. It is hypothesized that distance to the market is negatively related to food security. The variable is measured in kilometers (KM) between the respondent's farm and the mango inputs market.

Farm size: This is the logarithm of the household land cultivated under mango. It is hypothesized that as the size of the farm increases, the level of food production increases as well. Mwanaumo *et al*. (2005) and Deininger (2003) establishes a positive relationship between farm size and food security. Larger land sizes are associated with more mango produced. Increase in mango production is hypothesized to increase income available for household to purchase of food. Therefore, the expected effect of farm size on food security is positive. The area under mango production is measured in acres.

Credit availability: Includes the ability of a household to access credit either in cash or in kind for either food consumption or production (KM *et al*., 2013). Mulugeta and Hundie (2012) and Pankomera *et al*. (2009) have documented a positive relationship between credit availability and food security. This is a dummy variable taking the value of 1 if the household head accessed credit in the 2015 mango production season, and 0 if did not access. In this study, Credit availability is hypothesized to have a positive association with food security in Machakos County, Kenya.

Wealth category: Households with greater incomes and resources tend to have more diverse diets (Arimond and Ruel, 2004). Wealth category also determines farmers' decision to adopt a new technology (Kassam, 2014). A study by Holloway *et al*. (2000) has shown that poor households face entry barriers in access to markets due to low levels of physical and financial assets. The wealth category status of household is hypothesized to positively influence food security in Machakos County, Kenya.

A household wealth index is derived using Principal Component analysis (PCA). To compute the principal components, the number of farm and household assets[1] owned by a household is used. Following Irungu *et al*. (2006), the largest component score coefficient for each asset is used it in the following formula to calculate the asset index for each household:

$$A_i = \sum_k f_k \frac{a_{ik} - a_k}{s_k} \quad \text{……………………………………………………………………….. (3.12)}$$

where:

A_i = value of asset index for the *i*th household,

f_k = factor score coefficient for the *k*th asset obtained from PCA,

a_{ik} = value of the *k*th asset for the *i*th household,

[1] The farm and Household assets used to compute PCA are listed in Appendix 1

a_k = the mean of the kth asset over all households.

s_k = the standard deviation of the kth asset over all households.

In order to group the households into different wealth categories, households with a A_i which is less than the mean of all households were classified as "Not wealthy", those with a A_i greater than the mean plus one standard deviation were classified as "Average wealth" while those with A_i greater than the mean plus one standard deviation were classified as "Wealthy".

3.2.2.3 Assessing the impact of IPM on per capita calorie intake (PCCI)

The following OLS model is fitted into the data to assess the unconditional impact of IPM on per capita calorie intake (Omilola, 2009):

$$PCCI = \alpha + \beta(IPM) + \gamma(Time) + \delta(IPM * Time) \text{ .... } (3.13)$$

To account for other factors that influence food security in Machakos County, the model is expanded to (Omilola, 2009);

$$PCCI = \alpha+\beta(IPM)+\gamma(Time)+\delta(IPM*Time)+\lambda_1(AGE)+\lambda_2(EDUCATION)+\lambda_3(GENDER) +\lambda_4(HOUSEHOLDSIZE)+\lambda_5(EXPERIENCE)+\lambda_6(GROUPMEMBERSHIP)+\lambda_7(FARMINCOME) +\lambda_8(EXTENSION)+\lambda_9(LIVESTOCKUNITS)+\lambda_{10}(DISTANCE)+\lambda_{11}(FARMSIZE)+\lambda_{12}(CREDIT) +\lambda_{13}(WEALTH)+\varepsilon_i \text{ .... } (3.14)$$

where α is intercept; β, γ, δ and $\lambda_1 \ldots\ldots \lambda_{13}$ are parameters to be estimated.

3.2.2.4 Assessing the impact of IPM on household dietary diversity

To assess the impact of IPM on HDDI a count variable, Poisson regression model was used. The Poisson regression model expresses the natural logarithm of the event or outcome of interest such as HDDI as a linear function of a set of predictors (Greene, 2007). It is a useful tool for the analysis of count data and derives its name from the Poisson distribution. This is a mathematical distribution used to describe the probability of a household consuming a certain food group, under the assumption that the conditional means of the food groups equal the conditional variances.

Following Greene (2007), let *Yi* denote the number of food groups consumed by the *i*th household. The empirical specification of this "count" variable is assumed to be random and, in a given time interval (24 hours), has a Poisson distribution with probability density:

$$P(Y_i) = \frac{e^{-\mu}\mu^{y}}{y!} \quad \text{…...……………………………………………………………………….. (3.15)}$$

where Y_i denotes what? i= 1, 2, 3…12 and μ = E(Y) expected index (and variance).

Since the log of the expected value of Y is a linear function of explanatory variable(s), and the expected value of Y is a multiplicative function of X. The Model log of μ as a function of X:

$$\mu = e^{\sum_{j=1}^{K} \beta T_i + \gamma t_i + \delta T_i * t_i + \lambda_i X_{ji}} \quad \text{……………... (3.16)}$$

Equation (3.16) can also be written as

$$ln(\mu) = \sum_{j=1}^{K} \beta T_i + \gamma t_i + \delta T_i * t_i + \lambda_i X_{ji} \quad \text{……….…………………………………………………... (3.17)}$$

Or

$$ln(\mu) = \alpha + \beta T_i + \gamma t_i + \delta T_i * t_i + \lambda_i X_i + ... + \lambda_k X_k \quad \text{………..…………………………………... (3.18)}$$

where α is the constant, β ,γ, δ and λ_1…… λ_{13} are parameters to be estimated and X_1….X_{13} are the predictors. Note that Y>0 as the number of food groups consumed by a household over the previous 24 hour period must be strictly positive.

To achieve the second objective and therefore test the hypothesis that IPM technology has no impact on HDDI of mango producers in Machakos County, the following Poison model was fitted into the data (Green, 2007);

$$HDDI = \alpha + \beta(IPM) + \gamma(Time) + \delta(IPM * Time) \quad \text{……………………………..……..…….. (3.19)}$$

The conditional treatment effect of IPM technology on HDDI is presented as (Green, 2007);

$$HDDI = \alpha + \beta(IPM) + \gamma(Time) + \delta(IPM * Time) + \lambda_1(AGE) + \lambda_2(EDUCATION) + \lambda_3(GENDER) + \lambda_4(HOUSEHOLDSIZE) + \lambda_5(EXPERIENCE) + \lambda_6(GROUPMEMBERSHIP) + \lambda_7(FARMINCOME) + \lambda_8(EXTENSION) + \lambda_9(LIVESTOCKUNITS) + \lambda_{10}(DISTANCE) + \lambda_{11}(FARMSIZE) + \lambda_{12}(CREDIT) + \lambda_{13}(WEALTH) \quad \text{……………………………………….….. (3.20)}$$

3.3.3 Econometric Models Diagnostic Tests

A number of tests are conducted on the data before estimating the OLS model.

(a) Multicollinearity

Multicollinearity exists when independent variables have high inter-correlations or inter-associations (Gujarati, 2012). It increases the probability of making type I error which may lead to the rejection of the null hypothesis when it is true (*ibid*.). This leads to imprecise and unreliable parameter estimates. Two approaches are used to test for multicollinearity; symptoms and diagnostic procedure. The current study employed Variance Inflation Factor (VIF), tolerance level and partial correlation technique. VIF is defined as (Gujarati, 2007):

$$VIF(X_i) = \frac{1}{(1 - R_i^2)} \quad \ldots \quad (3.21)$$

where;

Ri^2 is the squared multiple correlation coefficient between X_i and other independent variables. The bigger the value of VIF, the more severe the multicollinearity problem (Gujarati, 2012). The rule of thumb used by many researchers is: a mean VIF value greater than 10 indicates that the variable is highly collinear (Gujarati, 2012).

The inverse of the VIF is called tolerance (TOL). That is,

$$TOL(X_i) = \frac{1}{VIF\left(X_i\right)} \quad \ldots \quad (3.22)$$

$$TOL(X_i) = (1 - R_i^2) \quad \ldots \quad (3.23)$$

When $Ri^2 > 0.8$ i.e. TOL (Xi) < 0.2 multicollinearity exists (Gujarati, 2012).

Partial correlation is the measure of association between two variables while controlling other variables. Multicollinearity is considered a big problem if pair-wise correlation among dependent variables is more than 0.7 (Gujarati, 2012).

(b) Heteroscedasticity

Heteroscedasticity occurs when the variance of the error term is non-constant in which case the OLS estimator, although still unbiased, is inefficient and the hypothesis tests are not valid (Wooldridge, 2002). If present in the data the estimates will not be the Best Linear Unbiased Estimates (Gujarati, 2009). In this study, the Breusch-Pagan/Cook-Weisberg test was used to test for heteroscedasticity under the null hypothesis of a constant variance (homoscedasticity). According to Coenders and Saez (2000), a significant parameter estimate of the Breusch-Pagan/Cook-Weisberg test leads to the rejection of the null hypothesis of homoscedasticity.

(c) Autocorrelation

Autocorrelation occurs when members of series of observations ordered in time are correlated (Gujarati, 2012). It is a violation of the assumption that the size and direction of one error term has no bearing on the size and direction of another. This results to inefficient estimation (Gujarati, 2012). This study used panel data which can be prone to autocorrelation.

3.4 Study Area

The study was conducted in Machakos County, which is ranked fourth in terms of mango production in Kenya. Mwala and Kangundo sub-counties (Figure 3.1) have been specifically selected by the African Fruit Fly Programme in Kenya. In Mwala sub-County, the study was conducted in three wards (Mwala, Mbiuni and Miu) while in Kangundo sub-County four wards were selected (Kangundo North, Kangundo Central, Kangundo South and Kangundo East). Mwala sub-County has a population of 89,211 persons and covers an area of 1017.9 km^2 (Machakos County Intergrated Development Plan [CIDP], 2015). The local climate is semi-arid (average annual rainfall of 500mm with an average altitude of 1400 meters above sea level.

Kangundo sub-County has a total area of 177.2 km^2 and lies at an average altitude of 1555 meters above sea level (Machakos CIDP, 2015). According to 2009 national population and housing census, Kangundo sub-County had 94,367 persons. Temperature in Kangundo ranges between 12^oC and 28^oC annually while the average annual rainfall is 958 mm (*ibid.*). The main economic activities/industries include dairy farming, beekeeping, trade, limited coffee, eco-tourism, businesses and manufacturing. The primary agricultural products in Mwala and Kangundo sub-counties include mangoes, maize, pawpaws, watermelons, beans, cow peas, pigeon peas, lentils and livestock.

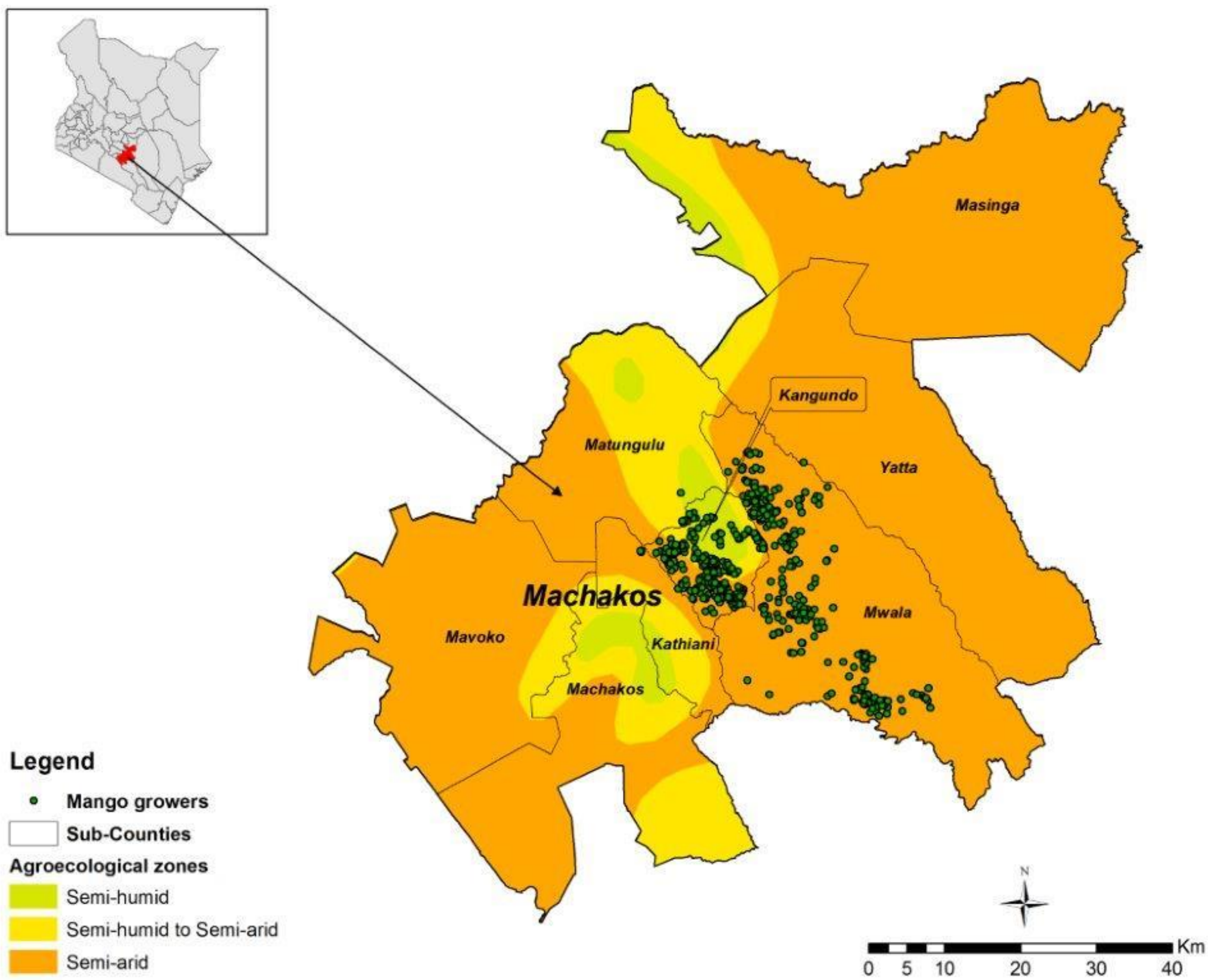

Figure 3.1: Map of Machakos County
Source: *ICIPE* (GIS)

3.5 Data sources and Sampling procedure

The study used primary data collected from mango farmers using semi-structured questionnaire (Appendix 1). Information on farmer demographics, socio-economic characteristics, mango production and marketing and food security indicators was collected. Secondary data were obtained from government data sources such as MoA, HCDA, journals and sessional papers, previous studies and internet sources. Data on the acreage of mango production and the volume of marketing for previous years and volume conversion rates used in the areas were obtained from the sub-county agricultural offices in Mwala and Kangundo, Machakos.

The study used a stratified sampling procedure to select the farmers to be interviewed. All the mango farmers in Machakos County constituted the study population. Mwala and Kangundo sub-counties were purposively selected on the basis of being the leading mango producing areas in Machakos County. Because ICIPE had implemented the mango fruit fly IPM project in Mwala sub-county, it was designated as the treatment site while Kangundo constituted the control area. The sample size each of the two study sites was calculated using the Cochran sample size formula for continuous data (Bartlett *et al*., 2001):

$$n = \frac{t^2 * s^2}{d^2} \quad \text{...} \quad (3.24)$$

$$n = \frac{1.96^2 * 1.856^2}{(7*0.03)^2} = 300 \text{ households} \quad \text{...} \quad (3.25)$$

where *t* is the value for selected alpha level of 0.027 in each tail (1.96), *s* is the estimated population standard deviation assumed to be normally distributed, *d* is the acceptable error margin assumed to be random (Kotrlik and Higgins, 2001). This gave a sample size of 300 households for each site or 600 households for the whole study.

A structured questionnaire (Appendix 1) was administered to 600 sampled mango producers in their farms; 300 IPM control package participants (intervention group) and 300 non-participants (control group), from the selected sub-counties. Prior to questionnaire administration, the enumerators were trained and the tool pre-tested in Embu County. Data were collected in two scenarios; 'before' and 'after' the IPM control package intervention. A baseline survey was undertaken in both study sites in February and March 2015 to collect baseline information on the 600 households on mango production during the 2014 growing season. After the baseline survey, farmers in Mwala sub-County were trained on how to apply the IPM technology on their mango orchards.

They were then given the various components of the IPM. A follow-up survey targeting the same households was undertaken in December 2015 to capture information on IPM technology used during the 2015 mango season. During this follow-up survey, 4 percent of the 600 households were not readily available for interviewing. Hence, the sample size dropped to 566 households of which 289 were in the treatment site (Mwala sub-County) and 277 were in the control site (Kangundo sub-County). A final sample for the analysis was 1147 households including 588 IPM farmers and 559 control farmers.

As is the case in many household surveys, the current study encountered a few problems during the data collection process. In a few cases, the respondents were unwilling to respond to certain questions such as income and asset value. Most households in the small farm sector do not keep written records of their transactions. Hence, most of the answers given were based on recalls. But overall, the survey went on smoothly and without any major problems.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Socio-economic characteristics of mango farmers in Mwala and Kangundo sub-Counties

The socio-economic characteristics of mango farmers in Mwala and Kangundo sub-Counties are presented in Table 4.1. Half of the mango farmers in Mwala were in the 41-60 year age bracket while 45 percent of sampled households in Kangundo were in this age bracket. The IPM participants (Mwala) had significantly a lower average age of 58 years while non-participants (Kangundo) had mean age of 61 years ($p<0.05$).

In Kangundo sub-County, the household heads' average number of years of formal education was 10 years, which was significantly higher than Mwala's 9 years ($p<0.05$). This literacy level would imply that mango farmers are likely to synthesize information and appreciate the new technology. Education enables farmers to interpret and respond to new information faster than those without education (Kibira *et al*, 2015).

Eight seven percent of the households in IPM adopters and non adopters are male headed (Table 4.1). However, there was no significant difference in gender between Mwala and Kangundo sub-Counties ($p>0.05$). The average household size was 5 people among the sampled groups. The average number of years of experience in mango farming in Mwala was 14 years while that in Kangundo was 12 years with significant difference between the two ($p>0.05$). Experienced household heads have more insight and ability to diversify their production to minimize risk (Feleke *et al*., 2003).

Table 4.1: Descriptive statistics of social -economic characteristics of smallholder farmers in and Mwala and Kangundo sub-Counties, Kenya

Variable	IPM participants Mwala sub-County; n=299		Non-IPM participants Kangundo sub-County; n=282		T-test value
	Mean	SD	Mean	SD	
Age (Years)	57.51	12.56	60.50	12.13	2.921***
Education (Years)	8.58	3.94	10.16	3.88	4.881***
Gender (Dummy)	85.62	35.15	88.65	31.77	1.089
Household size (Number)	4.92	2.10	4.63	1.88	-1.783*
Experience (Years)	13.94	10.32	12.25	10.34	-1.963*
Group membership (Dummy)	31.44	46.50	23.76	42.64	-2.071**
Annual farm income (KES)	89,740	104,426	104,744	127,365	1.557
Extension (Dummy)	24.08	42.83	11.35	31.77	-4.051***
Livestock units (TLUs)	2.53	2.21	2.64	3.84	.428
Farm size (Acres)	1.10	1.48	0.75	1.22	-3.113***
Credit (Dummy)	4.68	21.16	1.42	11.85	-2.276**
Distance (KM)	4.96	5.11	10.48	7.56	10.37***

*Significant at 10 percent; **Significant at 5 percent, and *** Significant at 1 percent; SD= Standard deviation

Source: Author's survey

Three quarters of the mango farmers did not personally seek advice or assistance on mango production from extension service providers (Table 4.1). However, they consulted during organized training fora such as field days, demonstrations, seminars and workshops. The number of times participants and non-participants attended such events was 97 percent and 21 percent respectively, with significant difference between the two groups (Table 4.1). Extension officers are important in dissemination of improved agricultural technologies and also provide marketing information (Lewin, 2011).

The average number of Tropical Livestock Units (TLUs)[2] was 2.5 and 2.7 in Mwala and Kangundo sub-counties respectively (Table 4.1). The main livestock species reared in the two counties were cattle, goats, sheep, poultry, donkey, rabbit and pigs. These livestock were used as food and non-food sources such as manure, animal traction and transportation. On average, mango farmers in Kangundo sub-County traveled significantly longer distances (10 km) to the market compared to those in Mwala sub-County (5 km). Access to input and output markets is known to increase the uptake of new agricultural technologies in rural areas of Africa (Asfaw *et al*., 2012).

IPM participants and non-participants had statistically similar acreages of land of 4.21 and 4.29 respectively. However, on average, IPM participants allocated significantly more land to mango production than non-participants at 1.1 and 0.75 acres respectively ($p<0.05$). At KES 46,533 in Mwala and KES 28,640 in Kangundo, the average annual farm income between IPM participants and non-participants was not significantly different ($p>0.05$). Farm income enables farmers to procure farm inputs necessary for mango production.

[2] See computation in Appendix 3.

Overall, most (97 percent) of the respondents had no access to credit specifically targeted to mango production. However, significantly more IPM participants (5 percent) than non-participants (1 percent) had access to credit. Majority of those who did not access credit expressed fear of default due to unreliable and unstreamlined mango marketing system as the reason for their unwillingness to go for credit. Access to credit has been shown to increase farmers' purchasing power thus enabling them to procure farm inputs and cover operating costs (Guirkinger and Boucher, 2005; Eswaran and Kotwal, 1990; Komicha and Öhlmer, 2007).

4.2 Food security situation in the study sites

Table 4.2 presents the average per capita food intake and the household dietary diversity indices for the two study sites during the baseline and follow-up survey. On average, the per capita food intake was higher in Kangundo at 3,007 Kcal/day than in Mwala at Kcal 2,840/day during the baseline survey. This shows that they were above the standard average dietary energy requirement for Kenya cutoff of 2250 Kcal (as used by the (Kenya National Bureau of Statistics)). This suggests that households in the two study areas were food secure.

Based on the means presented in Table 4.2, 72 and 67 percent of survey respondents in Mwala sub-County were food secure during the baseline and follow up surveys respectively as they exceeded recommended per capita calorie intake of 2250 kcal. In Kangundo sub-County, 81 percent and 75 percent of the respondents were food secure during the baseline and follow up respectively. With regard to HDDI, households in Mwala sub-County had almost similar averages between the baseline and follow-up surveys (Table 4.2). A similar pattern is repeated in Kangundo sub-County. Overall, there was no difference in the dietary diversity scores between IPM participants and non-participants.

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Table 4.2: Average per capita calorie intake and dietary diversity indices among survey households during baseline and follow-up survey in Mwala and Kangundo sub-Counties, Kenya

Food security measure	Baseline survey		Follow up survey		Change	
	IPM participants Mwala sub-County; n=299	Non-IPM participants Kangundo sub-County; n=282	IPM participants Mwala sub-County; n=299	Non-IPM participants Kangundo sub-County; n=282	IPM participants Mwala sub-County; n=299	Non-IPM participants Kangundo sub-County; n=282
Per capita calorie intake (Kilocalories)	2,839.52	3,006.52	2,731.48	2,843.22	-97.56	-159.41
Household dietary diversity index (HDDI)	9.81	9.80	9.71	9.70	-.10	-.10

Source: Author’s survey

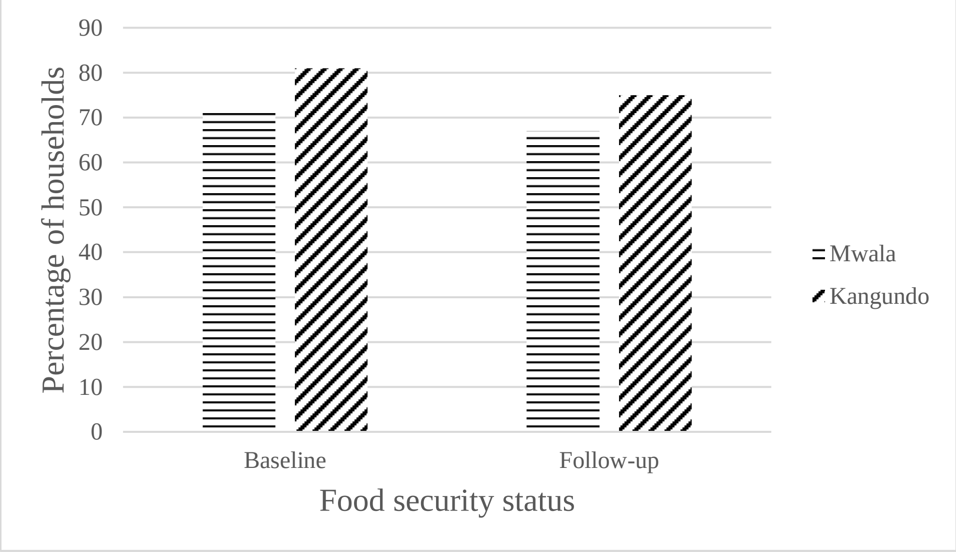

Figure 4.1 Food security status among fruit fly IPM participants (Mwala sub-county) and Non-participants (Kangundo sub-county).

4.3 Impact of mango fruity fly IPM technology on food security

4.3.1 Model Diagnostic Tests

Before estimating the factors influencing food security situation by use of regression analysis, preliminary tests were carried out on the data. The tests included; multicollinearity, heteroscedasticity and autocorrelation. To check for the presence of multicollinearity problem among the independent variables the Variance Inflation Factor (VIF) was computed. The results of the VIF for the variables included in all the models were less than 10 (Appendix 3) and the pairwise correlations were less than 0.7 (Appendix 4), hence no independent variables were dropped from the estimated model.

To test for heteroscedasticty, the Breusch-Pagan was used. As shown by the results in Appendix 8, the Breusch-Pagan/Cook-Weisberg test was not statistically significant (p=0.512), implying that heteroscedasticity was not a problem in the dataset. Autocorrelation test (actest) in Stata presented in Appendix 5 detected the presence of autocorrelation in the data ($p<0.00$). Iterative Prais-winsten method was used to correct for autocorrelation. The Prais-Winsten estimation procedure takes into account serial correlation of type Autoregressive (1) in a linear model (Prais and Winsten, 1954). The procedure is an iterative method that recursively estimates the beta coefficients and the error autocorrelation of the specified model until convergence of rho, i.e. the AR(1) coefficient, is attained (Wooldridge, 2013).

4.3.2 Impact of IPM on per capita calorie intake

Table 4.3 presents the estimate of the difference-in-difference per capita calorie intake in the two study areas derived from equation (3.6). As shown, the average difference in per capita calorie intake was negative in each group of respondents for baseline and subsequent survey; i.e., -109 and -164 Kcal/person/day in Mwala and Kangundo sub-counties respectively (Table 4.3). The difference in per capita calorie intake was negative among the two groups of respondents during baseline and follow-up surveys; i.e., -112 and -167 Kcal/person/day in Mwala and Kangundo sub-counties respectively (Table 4.3). The reduction in per capita calorie intake in follow up period can be attributed to dry spell in the area during the study period leading to decreased food availability.

Table 4.3: Average IPM technology effect on per capita calorie intake among mango farmers in Mwala and Kangundo sub-Counties, Kenya

Survey period	Per capita calorie intake (Kcal/person/day)		
	IPM participants Mwala	**IPM non-participants Kangundo**	**Total difference between Mwala and Kangundo**
Follow up (2015)	2731	2843	-112
Baseline (2014)	2840	3007	-167
Difference between 2014 and 2015	-109	-164	55

Source: Author's survey

The difference in per capita calorie intake between IPM participants and non-participants during baseline and follow up survey was positive 55 Kcal/person/day. This total difference (or DD) indicates that, on average, IPM participants received only 1.93 percent more per capita calorie intake than their counterparts. This suggests that the mango fruit fly IPM technology contributed a small but positive increase in per capita calorie intake among IPM participants in Mwala sub-County.

4.3.2.1 Unconditional treatment effect of IPM technology on per capita calorie intake

Table 4.4 presents the results of unconditional treatment effect of adopting the mango fruit fly IPM technology by fitting equation (3.13) into the data using OLS. The unconditional treatment effect was evaluated for the sole purpose of assessing the impact of IPM on a strong assumption that the IPM users and nonusers have no other differences apart from the fact that the former adopted the new technology. The coefficient of the unconditional treatment effect of IPM (Time*IPM) was positive but not statistically significant ($p>0.05$) (Table 4.4).

Table 4.4: OLS parameter estimates of unconditional effect of IPM technology on per capita calorie intake among mango farmers in Mwala and Kangundo sub-Counties, Kenya

Variable	Regression coefficient	Semi-robust standard error	t-statistics
IPM	-165.693	64.754	-2.56**
Time	-157.821	46.758	-3.38***
IPM*Time	57.457	64.457	0.89
Constant Term	3005.213	45.638	65.85***
R^2 =52	**n=1147**		

*significant at 10 percent **significant at 5 percent and *** significant at 1 percent.

Source: Author's survey

4.3.2.2 Conditional treatment effect of IPM technology on per capita calorie intake

Table 4.5 present the OLS parameter estimates of the conditional effect of IPM technology on per capita calorie intake using equation (3.14). The coefficient of the conditional treatment effect of IPM (IPM*Time) is positive and statistically significant implying that adoption of IPM technology led to an increase in per capita calorie intake among survey households. Hence, the second hypothesis that IPM had no impact on per capita calorie intake in Mwala and Kangundo sub-counties was rejected. Suggesting that the technologies lead to an increase in food availability.

Table 4.5: OLS parameter estimates of the conditional effect of IPM technology on per capita calorie intake among mango farmers in Mwala and Kangundo sub-Counties, Kenya

Variable	Coefficient	Semi-robust standard errors	t-statistic
IPM	-162.855	62.04	-1.94*
Time	-190.000	46.76	-4.22***
IPM*Time	105.192	63.92	1.69*
Age	-11.972	16.89	-0.73
Age squared	0.119	0.14	0.85
Gender	13.953	81.75	0.16
Household size	-171.195	13.20	-12.87***
Experience	-1.917	2.28	-0.88
Farm income	0.000	0.00	1.71*
Group membership	-48.567	53.79	-0.90
Extension	164.157	59.52	2.30**
Livestock units	3.668	4.74	0.80
Farm size	24.132	32.94	0.74
Credit	-141.021	131.59	-1.08
Moderately wealth	166.342	75.29	2.24**
Wealthy	188.124	105.18	1.85*
Distance	14.225	0.57	2.95***
Constant	3864.890	506.46	7.78***
R^2 =57	**n=1147**		

*significant at 10 percent, ** at 5 percent and *** at 1 percent level

Source: Author's survey

Farm income, access to extension services, wealth category and distance to agricultural input market had a positive and significant impact on per capita calorie intake. On the other hand, household size had a negative effect. An additional household member was associated with a 171 Kcal decline in per capita intake. This could be due to the fact that households with many members are mostly associated with a high dependency ratio and more food requirements, depicting a negative effect on food security, *ceteris paribus*. This finding is consistent with Goshu *et al*. (2013)'s who observed that family size was negatively related to food security in rural Ethiopia.

Contrary to the *a priori* expectation, an additional kilometer in distance to agricultural input markets increased the per capita calorie intake by 14 Kcal, *ceteris paribus*. This can be a case that households that travelled long distances to agricultural input market consumed more calories from own production and gifts as compared to purchases (Tembo and Simtowe, 2009). This finding is however inconsistent with available literature (see e.g., Staal *et al*., 2002; Fekele *et al*., 2005; Matchaya and Chilonda, 2012), that suggests long distances to input markets reduces the amount of food consumed.

Access to agricultural extension had a positive impact on per capita calorie intake. Thus, holding other factors constant, a shift from no access to agricultural extension increased the per capita food intake by 164 Kcal. This finding corroborates those of Kassie *et al*. (2012) and Lewin (2011) who reported that government investment in agricultural extension has a significant impact in food production and subsequently food security. Agricultural extension services provide farmers with important information, such as patterns in food prices, new technologies, crop management, and marketing. Such information is intended to increase households' ability to increase food production or increased income which in turn increase consumption levels (per capita calorie intake).

Ceteris paribus, a shift from not wealthy to a moderate wealth category had a positive and significant effect on per capita calorie intake. Thus, a shift from not wealthy to a moderate wealth category led to a 166 Kcal increase in the household per capita calorie intake. Additionally, a movement from not wealthy to a wealthy category increased the per capita calorie intake by 188 Kcal, all else being equal. Wealthy households do not face entry barriers in access to markets and subsequently food access due to high levels of physical and financial assets (Holloway *et al*., 2001).

4.3.3 Impact of IPM technology uptake on household dietary diversity index

The HDDI was lower during the follow-up survey than during the baseline (Table 4.6). The country experienced a dry spell during the reference period which affected the different varieties of food accessible in the market. Accordingly, the difference in HDDI during the two periods was negative for both IPM participating and non-participating households. Across time, the difference was small but positive. Hence, the total difference in HDDI between IPM participants and non-participants was only 0.001 (or 0.01 percent)[3] across time (Table 4.6).

Table 4.6: Difference in Difference (DD) estimate of average IPM technology effect on HDDI among mango farmers in Mwala and Kangundo sub-Counties, Kenya

Survey period	IPM participants(Mwala)	IPM Non-participants (Kangundo)	Difference across (Mwala & Kangundo)
Follow up (2015)	9.709	9.700	0.009
Baseline (2014)	9.806	9.798	0.008
Difference between 2014 and 2015	-0.097	-0.098	0.001

Source: Author's survey

4.3.3.1 Unconditional treatment effect of IPM technology on household dietary diversity index

The coefficient of the unconditional treatment effect of IPM technology (IPM*Time) on HDDI not statistically significant ($p>0.05$) (Table 4.8). This could be explained by the fact that the household dietary diversity behavior adjusted only slightly because income was subjected to temporal variability (Chege *et al*., 2015a). This slight income increments leads to households diversifying food within groups and not between groups.

[3] 0.001/9.806*100=0.01percent

Table 4.7: Marginal effects of unconditional effect of IPM technology uptake on HDDI among mango farmers in Mwala and Kangundo sub-Counties, Kenya

Variable	Marginal effects	Robust standard errors	Z-statistics
IPM	0.001	0.005	0.16
Time	-0.010	0.006	-1.71
IPM*Time	0.000	0.009	0.01
Constant Term	2.282	0.004	631.58
Pseudo-R^2 =0.01	**n=1,147**		

*significant at 10 percent **significant at 5 percent and *** significant at 1 percent.

Source: Author's survey

4.3.3.2 Conditional treatment effect of mango fruit fly IPM technology on household dietary diversity index

Controlling for possible influences in the conditional effects model did not improve the results (Table 4.9). Hence, the coefficient of the conditional treatment effect of IPM technology (IPM*Time) was not statistically significant (p>0.05). This suggests that the income benefits of IPM technologies do not necessarily translate into nutritious diets. Thus, the increased food consumption reported earlier is related to availability, and not diversity of food. In fact, the focused group discussions indicated that a large share of the expenditure on food was devoted to cereal staples such as maize, wheat and rice.

Table 4.8: Marginal effects of conditional effect of IPM technology on HDDI among mango farmers in Mwala and Kangundo sub-Counties, Kenya

Variable	Marginal effects	Robust standard errors	Z-statistic
IPM	-0.024	0.06	-0.40
Time	-0.100	0.06	-1.81*
IPM*Time	0.021	0.08	0.25
Age	0.014	0.01	1.04
Age squared	-0.000	0.00	-1.06
Education	0.023	0.01	3.35***
Gender	-0.035	0.07	-0.47
Experience	-0.006	0.00	-3.28***
Farm income	0.001	0.00	1.89*
Group membership	-0.013	0.05	-0.28
Livestock units	0.017	0.01	3.16***
Farm size	0.066	0.03	2.56**
Credit	-0.053	0.18	-0.29
Moderately wealth	0.049	0.53	0.71
Wealthy	0.150	0.70	1.86*
Distance	-0.004	0.00	-1.34
Constant	9.754	0.02	54.11***
Pseudo-R^2=0.12	**n=1147**		

*significant at 10 percent, ** at 5 percent and *** at 1 percent level.

Source: Author's survey

Because of lack of effect of IPM technology uptake on HDDI (the outcome of interest), all the other regressors, some of which were statistically significant, were not relevant to this study and warrant further discussion.

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

Mango production is a major source of income for both medium and small-scale farmers in Kenya. However, it is confronted with a major threat of fruit fly infestation that causes reduction of quality and quantity of marketable fruit and hence considerable produce losses. As a result, the country's horticultural industry loses out on huge revenues that could be derived from higher trade volumes in local urban and export markets. In addition, the increased use of pesticides in the effort to reduce fruit losses has led to a rise in production costs. Use of Insecticides has been shown to be ineffective in controlling the fruit flies.

This study evaluated the impact of integrated pest management (IPM) technology for mango fruit fly control on food security among smallholder mango producers in Machakos County using a difference-in-difference (DD) method. The study found both IPM participants and non-participants to be food secure with per capita calorie intake above the 2250 Kcal threshold for Kenya. In Mwala sub-County, 72 and 67 percent of survey respondents in were food secure during the baseline and follow up surveys respectively while, 81 percent and 75 percent of the respondents were food secure in Kangundo sub-County during the baseline and follow up respectively

Although there were disproportionately more food insecure households among the participants than the non-participants both before and after technology adoption, the participants fared slightly better than the non-participants in terms of food insecurity reduction. The DD method shows that IPM had a positive impact on per capita calorie intake. Farm income, access to extension services, wealth category and distance to agricultural input markets positively influenced the per capita calorie intake. On the other hand, household size had a negative effect. The Poisson model found that IPM had no impact on HDDI, implying IPM does not lead to increased food diversification.

5.2 Conclusion

This study found that uptake of mango fruit fly IPM technology control has a positive influence on household food security and therefore, it concludes that scaling up the mango fruit fly IPM technology could be an option to improve the welfare of rural communities constrained by mango fruit fly infestation. However, the uptake of mango fruit fly IPM technology does not improve household dietary diversity. This could be as a result that an increase in income from mango marketing wasn’t enough for households to diversify their food. The per capita calorie intake a measure of food availability could be improved by increasing farm income and wealth category and also access to extension services.

5.3 Recommendations

1. The study found out that high farm income and wealth status improve households’ food consumption. Hence, policies promoting income and wealth generation such as value addition and group marketing among mango producers should be emphasized.

2. Improving access to extension services may enhance adoption of IPM. The current extension services are faced with many challenges which include: inadequacy and instability of funding, poor logistic support for field staff, use of poorly trained personnel at local level, ineffective agricultural research extension linkages, insufficient and inappropriate agricultural technologies for farmers, disproportionate Extension Agent: Farm Family ratio. Hence, policies addressing the above-mentioned challenges should be encouraged.

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APPENDICES

Appendix 1: Survey questionnaire used for data collection

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African Insect Science for Food and Health

IMPACT ASSESSMENT OF MANGO IPM FRUIT FLY CONTROL TECHNOLOGY PACKAGE -F

Section A: Personal Details and household information

1.0 Household information

01. Questionnaire ID	
02. Date of the interview (dd.mm.yy)	
03. Start time	
04. Enumerator name***:***	
05. Household head Name (*three names*):	
06. Gender of the household head (1=Male 0=female)	
07. Respondent Name (*three names*):	
08. Phone number (*of household head*)	
09. County	
10. Sub- County	
011.Location	
012. Village	

1.1 Household's consent obtained [________] 1=YES 0=NO

1.2 If No (1.1),why?____ **(End Survey)**

1.3 Give details **of all household members (including the household head-HHH)** living permanently on the compound and their primary activities and/or occupations (on and off farm): **include children and infants**

Name (first name only)	Age (yrs)	Relationship with HHH (code **(b)**	Sex **1 = M, 0 = F**	Primary (main) Activity Occupation (code **(a)**	Secondary activity (if applicable) (code**(a)**	Physiological status of women 14-60 years only (**code (c)**	Years of schooling
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							

Activity codes (code (a)		**Codes (c):** Physiological status of women	
0 = None **1** = Mango production **2**=Cereal production **3**= Livestock production **4**=Artisan	**5**=Casual labourer **6**=Salaried employee **7=Business** **8** = In school/college **9** = Pre-school age **10**= Other(specify)______	1= Not pregnant or lactating 2= Pregnant 3=Breastfeeding child <6months 4=Breastfeeding child>6months	5= Pregnant & breastfeeding child<6months' 6=Pregnant & breastfeeding child>6months

Codes for relationship with household head (code (b)				
1=head **2**=spouse; **3**=son/daughter;	4=step child; 5=Father/mother; 6=brother/sister;	7=nephew/niece; 8=son/daughter-in-law; 9=grandchild;	10=unrelated; 11=brother/sister-in-law; 12=Father/Mother-in-law:	13=worker 14=other relative (specify)____

2.0 Household dwelling

2.1. Ownership of household's house [________] 1=YES 0=NO

2.2. Material of the house's wall (code) ___________

0=concrete **1**=timber	**2**=clay **3=**Other(specify)__________

2.3. Material of the house's roof: [______] 1=Slab 2=corrugated iron or tile 3=Other (specify)________________________

2.4. Electricity at home [________] 1=YES 0=NO

2.5. Tap water [________] 1=YES 0=NO

2.6. Type of toilet: [______] 0=No toilet 1=Pit latrine 2=Flush toilet

3.0 Assets owned
3.1. Livestock

3.1.1 Do you own livestock? [_________] 1=YES 0=NO

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

Livestock type	**Total number**	**Who owns (codes a)**	**Estimated value (KES)**
a) Cattle adult			
b) Calve			
c) Goat			
d) Sheep			
e) Pig			
f) Donkey			
g) Camel			
h) Horse			
i) Poultry			
j) Rabbit			
k) Fish			
l) Bee hives			

Who owns codes: 1=Head 2=Spouse	3=Household(all) 4=Head's father	5=Head's mother 6= Spouse's mother	7= Spouse's father 8= son 9=Daughter	10= Other joint (specify codes)__ 11= Other (specify)______

3.1.3 What percent of annual household income is generated from animals and animal products?______percent

Season **1)Rainy** **2)Dry** **3)All**	Plot (no.)	Crop code **(a)**	Area (acres)	Grown for 1=Home use 2=For sale 3=Both give percent of each)	Who owns the plot (codes) **(b)**	Who manages the plot (codes) **(b)**	Total labour time allocated		Land quality (codes) (c)	Was the land irrigated 1=Yes, 2=No	If YES, percentage of land irrigated	Did you use fertilizer 1=**Yes** **2=No**	Did you use manure (any type) 1=**Yes** **2=No**	Crop output 1			Market price (per unit)	Crop output 2			Market price (per unit)	Who receives the money **(b)** if sold
							Hrs per day	Number of days /month						Quantity	Units (codes d)	Cash income (Appx)		Quantity	Units (codes d)	Cash income (Appx)		
		Mango																				

Crop code (a)

Arrow roots =28
African indigenous vegetables=40
Avocado=54
Baby corns =5
Bananas=53
Barley=18
Beans=24
Beetroots=41
Black night shade(managu)=11
brinjals /biriganya=44
Bracoli=51

Butternuts=39
Cabbages =6
Capscum=47
Carrots=52
Cassava =25
Chick pea=12
Coffee =17
Cotton=26
Cow peas =13
Cucumbers=42
Garden peas=45

Godgets=43
Green grams=55
Flowers=14
Fodder=37
French beans=2
Irish potatoes=23
Lemons=60
Lettuce=49
Linseed =15
Lintels =16
Macadamia nuts =29

Mango=56
Maize=1
Melons=34
Miraa=38
Napier grass=36
Ndania=50
Onions=9
Oranges=59
Pawpaw=58
Pigeon peas=46
Pumpkins=35

Pyrethrum=30
Rice=31
Snow peas=3
Sorghum=21
Soya beans=62
Spinach=10
Sugar snaps=4
Sugar cane=48
Sukuma wiki =7
Sun flower=32

Sweet potatoes=22
Tangerines=57
Tea=33
Tobacco=27
Tomatoes=8
Wheat=19
Yam =20
(Other specify)__________=63

Who own/manage (b)

1=Head
2=Spouse
3=Household (all)
4=Head's father
5=Head's mother
6=Spouse's mother
7=Spouse's father
8=Son
9=Daughter
10= Other joint (specify codes)
11= Other (specify)

Land quality (c)

1=Fertile
2=Moderately fertile
3=Infertile

Units (code d)

1=Kgs
2=50Kgs bag
3=90kgs bag
4= numbers/ pieces
5=Wheelbarrow
6=gorogoro
7=debe
8=ox-cart
9=bale
10=pickup
11=bunches
12=crate
13=120 kg bag
14=6 kgs carton
15=4 kgs carton
16=20litres bucket
17=17kgs bucket
18=Lorry
19=Tones
20=grams
21=litre
22=milliliter
23=Other(specify

3.2 Land

3.2.1 Please provide the following information about the land used by the household in the last 12 months (also include rented land, and fallow/ grazing land)

	Total agricultural cultivated land			Own land left fallow	Land given to other family members		Grazing land			Home stead land
	Own land	Gift land	Rented-in		Rented out	Gift	Own	Rented-in	Obtained as gift	
Acres										
If you rented out land, how much did you earn in the last 12 months? KES______________]										

3.2.2 Give details about the plots of land cultivated (including the rented in land) for the last 12 months (2013) in Rainy and dry season, permanent crops (for example coffee) to be recorded in the rainy season crop. For a plot that has **been intercropped/ mixed cropped,** for example with 2 crops, divide the size of plot by two. Also provide estimated ***total labour time*** in hours per day and ***number of days per months*** allocated to each crop

3.2.3 How long have you been cultivating this farm? __________years/ months (own farm)
3.2.4 Is the land under mango rented or owned? [_________]0 = Rented 1 = owned
3.2.5 If land is rented for mango production, what is the rental rate per year ______/KES/acre?

3.3 **Household assets**

3.3.1 At present, do you own the following assets?

Assets	No. owned now	Current Total Value (KES)	Who owns (codes)	Asset	No. owned now	Current Total Value (KES)	Who owns (codes)
Farm assets				23= ploughs for tractor/animal			
1= spray pump				24= tractor			
2= water pump				25= harrow/tiller			
3= Sprinkler				26= combine harvesters			
4= water tanks				27= planter			
5= stores(chemical/grain store etc)				28= generator			
6= grinder				29= green house			
7= weighing machine				**Household assets**			
8= power saw				30= radio			
9= wheel barrow				31= TV			
10= animal traction plough				32= telephone/ mobile phones			
11= zero-grazing units				33= solar panels			
12= milking equipment/shed				34= sewing/knitting machine			
13= Motorized/ hand thresher				35= posho mill			
14= chaff cutter				36= battery (car)			
15= cattle dip				37= gas cooker			
16= water trough				38= bicycle			
17= pig-stys				40= motorcycle			
18= poultry houses				41= car			
19= borehole or well				42= truck			
20= dam				43= trailer			
21= pestle and mortar				44= Refrigerator			
22= cart				45= Computer			

Who owns codes: 1=Head 2=Spouse 3=Household(all) 4=Head's father 5=Head's mother 6= Spouse's mother 7= Spouse's father 8= son 9=Daughter 10= Other joint (specify codes)__ 11= Other (specify)______

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

Facility			Distance to the nearest (Km)	(b)Means of travel (Code a)	Cost of travel (two & from) (KES)
1. Tarmac road					
2. Public transport system					
3. Agri. Extension Agent					
4. Agricultural input market					
5. Agricultural product market					

Code (a) Means of Transport
1= Walking 2=Bicycle 3=Matatu/bus 4=Motorbike 5=other(specify)

SECTION B: Mango Production

4.1. How many years have you been producing mangoes? (years)[_________]
4.2. Did you attend mango production training over the last 12 months [_________] 1=YES 0=NO
4.3. If YES, how many training sessions have you attended? [_________]

1=Between 1 and 5 2= 5 and 10
3 = 10 and20 4= over 20

4.4 From whom did you receive training? (list codes) [____________]

1- Government officer **2**= ICIPE staff **3**= Techno serve
4= HCDA **5**= GIZ **6**=Other (specify)

4.5. Did you have contact with an extension agent on mango production? [_________] 1=YES 0=NO
4.6. If YES, how many times in the last mango season? _________________________
4.7. Are you a member of any mango growers' group [_____ ____] 1=YES 0=NO

4.8. If **yes, w**hat is the name of the mango growers' group are you a member of ()? ________________________

4.9 If Yes, what are the functions of the mango growers' group that you are a member of? (List 2 major)

a)____

b)____

c)____

4.10. Do you have access to credit for mango production activities? [_________] 1= YES. 0= NO

4.11 If YES, how much credit did you receive in the last mango season (year)? ________________

4.12 Which mango varieties/cultivars do you have on your orchard?

Variety	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)
Improved				
1. Apple				
2. Tommy atkins				
3. Ngowe				
4. Kent				
5. Van dyke				
6. Keitt				
7. Sensation				
8. Haden				
9. Sabine				
10)Other specify1				
11) Other specify2				
12) Other specify3				
13) **Local varieties1**				
14) **Local varieties2**				
15) **Local varieties3**				

4.13 Have you heard about fruit fly IPM control packages? [_________] 1= YES. 0= NO.

4.14 If yes, from who did you first hear about it? (*codes*) [_________] and when ____________year

1- Government Extension officer	**2**= ICIPE staff	**3**= Buyer
4= Other farmers	5=Agro chemical company)	6= Other (specify

4.15 Did you apply pesticides on mango trees during the last mango season? [_________] 1= YES. 0= NO.

4.16 If **yes**, please fill in the details in the table below: (name of pesticides- Chris)

Pesticides name	No. of times applied	Amount used each time	Unit	Total amount used	Product price per unit	Total cost (KES)
a)						
b)						
c)						
d)						
e)						

Units (code d)

1=Kgs	5=Wheelbarrow	10=pickup	15=4 kgs carton	20=grams
2=50Kgs bag	6=gorogoro	11=bunches	16=20litres bucket	21=litre
3=90kgs bag	7=debe	12=crate	17=17kgs bucket	22=milliliter
4= numbers/pieces	8=ox-cart	13=120 kg bag	18=Lorry	23=Other(specify
	9=bale	14=6 kgs carton	19=Tones	

4.17 Provide the following information on other inputs that were applied on mango in the last season

Input	**No. of times applied**	**Amount used each time**	**Unit**	**Total amount used**	**Product price per unit**	**Total cost (KES)**
a)Own Organic matter/manure/ farmyard manure						
b)Purchased Organic matter/manure/ farmyard manure						
c)Fertilizers (list) below:						

c1)							
c2)							
c3)							
c4)							
d)Herbicides							
d1)							
d2)							
d3)							
d4)							
e)Electricity/fuel for irrigation							
f)Other inputs(specify)							

Units (code d)				
1=Kgs 2=50Kgs bag 3=90kgs bag 4= numbers/pieces	5=Wheelbarrow 6=gorogoro 7=debe 8=ox-cart 9=bale	10=pickup 11=bunches 12=crate 13=120 kg bag 14=6 kgs carton	15=4 kgs carton 16=20litres bucket 17=17kgs bucket 18=Lorry 19=Tones	20=grams 21=litre 22=milliliter 23=Other(specify

4.18. Provide the following information on labor costs for mango production in the last mango season (Please fill in the table below) (first five columns record both family and hired labour, the rest only hired labour)

Activity	**Number of times?**	**No. of persons involved**		**No. of days each time**	**No. of hours per day**	**How many of those were hired laborers**		**Total cost paid (KES)**
		Male	**Female**			**Male**	**Female**	
a)Digging up								
b)Weeding								
c)Irrigating								
d)Fertilizer application								
e)Manure application								
f)Pesticide application								
gHerbicide application								
h)Pruning of dead twigs								
i)Orchard sanitation								
j)Top working								
k)Harvesting								
l)Grading								
m)Transport to market								
n) other specify								

4.19 What is the cost of hiring casual laborer (KES/day)_____

4.20 Was a tractor, an ox-plough or hand plough hired **from the beginning of the season** for land preparation (ploughing and harrowing)**?** [_________]
0=No, 1=Yes

4.21 Please fill the following information for the total produce harvested during the last season for that particular mango variety

Varieties	**Total quantity sold**			**Total consumed at home**		**Total quantity damaged**		**Total quantity produced(not in tab)**	
	Qty	**Unit**	**Price per unit**	**Qty**	**Unit**	**Qty**	**Unit**	**Qty**	**Unit**
Improved									
1. Apple									
2. Tommy atkins									
3. Ngowe									
4. Kent									
5. Van dyke									
6. Keitt									
7. Sensation									
8. Haden									

9. Sabine									
10) Other (specify1									
11) Other (specify2									
12) Other (specify3									
Local varieties									
13) **Local varieties1**									
14) **Local varieties2**									
15) **Local varieties3**									

Units (code d)				
1=Kgs 2=50Kgs bag 3=90kgs bag 4= numbers/pieces	5=Wheelbarrow 6=gorogoro 7=debe 8=ox-cart 9=bale	10=pickup 11=bunches 12=crate 13=120 kg bag 14=6 kgs carton	15=4 kgs carton 16=20litres bucket 17=17kgs bucket 18=Lorry 19=Tones	20=grams 21=litre 22=milliliter 23=Other(specify

4.22 Who make decisions on the following activities regarding mango production and harvesting (use table)

Activity	Decision	Who make the decision **(code (a)**
4.20a) Labour	1)How much labour to be hired	
	2)Distribution of labour among different plots	
4.20b)Inputs	1)Where to acquire inputs and	
	2) how much to purchase	
	3)How much to use in a particular mango plot	
4.20c) Training	1) Who to attend mango training and other related gatherings?	
4.20d) Credit	1) Where and when to take credit?	
	2) what to do with the credit	
4.20e) Group participation	1)who will be registered with mango growers group	
	2)who should attend growers group meetings	
4.20f) Market	1)marketing channel to sell produce	
	2)who to receive money from mango sales	
	3) how to use money received from mango sales	

Codes (a)				
1=Head	2=Spouse 3=Household(all)	4=Head's father 5=Head's mother	6= Spouse's mother 7= Spouse's father	8=son 9=Daughter 10= Other joint (specify codes) 11= Other (specify)

4.23 What are the main constraints or challenges you experience in mango production?

1)……………………………………………………………………………………………………
2)……………………………………………………………………………………………………
3)……………………………………………………………………………………………………….
4)………………………………………………………………………………………………………

4.24 In your opinion how is the mango production this **last season** compared to the **previous season**? (code)[_________]

1=Much worse now	3=No change	5=Much better now
2=Little worse now	4=Little better now	

4.25 Is there a market for your mango produce? [_________] 1= YES 0= NO

4.26 If yes, where do you sell your mangoes (code)[_________]

1=Neighbours	3=Urban markets*(farmer takes Mangoes to markets further than Machakos town)*	5=Brokers
2=Export markets	4=Local markets*(farmer takes Mangoes to Machakos town)*	

4.27 How would you rate the market you have for your mango produce? [_________]

1=Very poor	2=fair	3=poor	4=Good	5=Very good

4.28 What are the main constraints or challenges you experience in mango marketing?

1)………………………………………………………………………………………………………
2)……………………………………………………………………………………………………….
3)……………………………………………………………………………………………………….
4)……………………………………………………………………………………………………….

SECTION C: Gender Empowerment

5.1 Provide the following information regarding ownership of mango trees and distribution of income from Mango sales: ***(Use column B for ownership of trees. If different household members own particular type of mango tree variety, use Columns C and D. Ensure the type of mango variety given (or number of trees) are the same as those given in question 4.10)***

a. Mango Variety	b. Who owns the **trees**/ **plot** (**code a**)	c. Number of trees owned by a male household member	d. Number of trees owned by a Female household member	e. Who receive the money from mango sales (**code a**)	Management of income from mango sales		
Improved					f. percent by Man	g.percent by woman	h.percentboth
1. Apple							
2. Tommy atkins							
3. Ngowe							
4. Kent							
5. Van dyke							
6. Keitt							
7. Sensation							
8. Haden							
9. Sabine							
10)Other specify1							
11) Other specify2							
12) Other specify3							
Local varieties							
13) **Local varieties1**							
14) **Local varieties2**							
15) **Local varieties3**							

Code a					
1=Head **2**=Spouse	**3**=Household(all) **4**=Head's father	**5**=Head's mother **6**= Spouse's mother	**7**= Spouse's father **8**=Son	**9**= Daughter **10**= Other joint (specify codes)	**11**=Other (specify) ______

5.2 How is income from mango commonly spent in the households (use table below)?

	Item spent	**percent of the mango income spent on this item**		**Item spent**	**percent of the mango income spent on this item**
1	Food		5.	Entertainment	
2	Clothing		6.	Investment (specify)	
3	School fees		7.	Insurance (specify)	
4.	Health care		8.	Other expenses(specify)	

SECTION D: Household distribution of income, consumption and wealth

6.1 Household expenditure on school fees

6.1.1 Are there any household members that were attending school in the last 12 month? [__] 1=Yes 0=No

6.1.2 If **YES**, what was the TOTAL SCHOOL FEES paid in the last 12 months (or approximate per year)?KES____

6.2 Household expenditure on food

6.2.1 Approximate how much money did you use on food in the last 12 months (year estimate)? KES_________ (*NB: if respondent cannot recall annual expenditure, ask for monthly expenditure, then multiply by 12*)

6.3 Household Expenditure on training

1 Are there any household members who attended **TRAINING** during the last 12 months? [__] 1=Yes 0=No

2 If **YES**, what kind of training? _______________________________________

3 If **YES**, where was the training undertaken? _________________________________

4 What was the total amount paid in those 12 months? KES ____________________

6.4 Household savings

1 Was any member of the household **SAVING** during the last 12 months? [__] 1=Yes 0=No

2 If **YES,** how many household members were saving during that period? ________________

3 If **YES**, where did the member/s save? (code)_____________________________ 1

1)=Commercial Bank	3)SMEs	5) mobile banking
2) ROSCA groups	4) SACCOs	6)Other specify_______________________

4 What was the **average monthly** household **savings** (in a **normal month)**? KES_________________

6.5 Expenditure on entertainment

6.5.1 Does any household member spend on **entertainment and relaxation**? [__] 1=Yes 0=No

6.5.2 If YES, what is the total **average monthly** expenditure on **entertainment and relaxation**? (E.g. beer, holidays etc.) KES._________________

6.6 What is the **average annual** expenditure on **clothing**? KES__________________________________

6.7 Expenditure on health

1 Did any of the household member fall sick in the last 12 months? [__] 1=Yes 0=No

2 If **YES,** how many household members fell sick during this period?______________

3 What were the annual medicare expenses during this period? KES._________________

4 Do you think the last 12 months was a normal year? [__] 1=Yes 0=No

5 If **No**, what are the **average annual Medicare expenses** in a normal year? _________

6.8 Expenditure on energy and fuel

6.8.1 What is the **monthly** expenditure on **energy for lighting?** KES____________________

6.8.2 What is the average monthly expenditure on fuel/ energy for cooking? KES________________

6.8.3 What is the monthly expenditure on **fuel/ energy for other uses**?(SPECIFY) KES________________

6.9 Household's investments

1 Did any household member **INVEST** in the last 12 months? [__] 1=Yes 0=No

2 If **YES**, what was the annual investment for the following:

1. Land **(KES.)**_______	2. Shares **(KES)**_______
3. Business (capital) **KES**._______	4. Other investments (**specify**)……………………… …………………. **(KES)**_____

6.9.3 Do you think the last 12 months was a normal year? [__] 1=Yes 0=No

6.9.4 If **No**, what is the **annual household expenditure on investment** in a normal year? KES______________

6.10 Expenditure on donations

6.10.1 Does any member of the household contribute donations? [__] 1=Yes 0=No

6.10.2 If **YES**, what was the total household expenditure on donations in the last 12 months? KES______

6.11 Did you purchase any major assets such as n farm working implements electronic, the last 12 months? [__] 1=Yes 0=No

6.12 If Yes, state the asset you bought and the amount spent: Item___________ KES ______

6.13 Expenditure on furniture

6.13.1 Was there any **FURNITURE** bought in the household during the last 12 months? [__] 1=Yes 0=No

6.13.2 If **YES,** what was bought? _____________, ________________,__________________

6.13.3 What was the total expenditure on furniture for the 12 months period? **KES.**_____________

6.13.4 Do you think the last 12 months was a normal period? [__] 1=Yes 0=No

6.13.5 If **No,** what is the **annual household expenditure on furniture** in a normal year? **KES.**_____________

6.14 Expenditure on transport

6.14.1 Does any member of the household spend money on **transport** to work or to perform other household activities? [__] 1=Yes 0=No

6.14.2 If **YES,** what is the **average monthly** expenditure on transport? ________________

6.15 Expenditure on insurance

6.15.1 Does any member of the household spend money on **insurance?** [__] 1=Yes 0=No

6.15.2 If **YES,** what kind of insurance? (code)_____________________________________

1=Private health insurance	3=Crop insurance (specify crop)____	5=Other (specify)__________
2=Public health insurance (NHIF)	4=Livestock insurance	

6.15.3 What was the **annual expenditure on insurance** in the last 12 months? KES______

6.16 Other household expenses

6.16.1 Are there any other expenses in the household**?** [__] 1=Yes 0=No

6.16.2 If **YES,** specify? ______________________________________

6.16.3 What is the **Monthly** household expenditure on **other specify?** KES______

6.17 What is the share of food consumed at home is obtained from own farm? (percent)[_______]

6.18 Rank the different sources of income to the household and provide ANNUAL estimate by source. For ranking: 1=Main source of income, 2=2nd source 3=3rd source etc

Source of income	**Rank**	Annual estimate (KES)	Income managed by both adult male & female (percent)	Income managed by adult male (percent)	Income managed by adult females (percent)
Income from mango					
Income from other horticultural crops (fruits & vegetables)					
Income from other farm crops					
Income from livestock sales and livestock products (e.g. milk)					
Income from other farm activities (e.g. brew making, charcoal burning etc), other specify……………					
Income from wages/ salaries/ non-farm, pension and (specify profession)_____					
Income from business activities					
Income from remittances/ gifts from absent family members and other external income					
Income from rental houses					
Income from other sources, specify:					
Note: if the respondent cannot estimate annual income, ask for monthly income then multiply by 12 months					

SECTION E: FOOD SECURITY

7.1 **Dietary diversity indicators (30 days recall):** Please provide the following information about all the different foods that you have eaten in the last **30 days**. Tell us whether you ate the following foods **(The respondent of this question should be the person who is responsible for food preparation or another adult who was present and ate in the household during the 30 days of recall)**

Food item	**Frequency (codes)**	**Food item**	**Frequency (code)**
Cereals		**Fruits**	

1=Maize		21=Bananas	
2=Rice		22=Oranges	
3=Millet		23=Pawpaws	
4=Sorghum		24=Mangoes	
5=Bread /Chapati		25=Pineapple	
6=Other cereals (specify)		26=Lemons	
Roots and Tubers		27=Avocado	
7=Irish potatoes		43= Other fruits	
8=Sweet potatoes		Meat	
9= Cassava		28=Beef	
10=Ground nuts		29=Goat /sheep	
11=Other tubers		30=Chicken	
Vegetables		31=Fish (any)	
12= Sukuma wiki		32=Other sea food	
13= French beans		33= Other meat(specify)	
14=Spinach		**Milk products**	
15=Tomatoes		34=Cow milk	
16=Onions		35=Goat milk	
17=Carrots		36=Butter	
18=Okra		37=Other milk products	
19=Other vegetables		**Other items**	
20=African indigenous vegetables		38=Beans	
		39=Eggs	
		40=Edible oils/saturated fats	
		41=Sugar	
		42=Honey	
		43=other food types	

Food intake frequency codes

1= 0 days in the last one month **3**=4 to 15 days in the last one month (once or twice in a week;
2=1 to 3 days in the last month; **4**=16 to 30 days in the last days (at least every day)

7.2 Calorie intake (7 days recall)

Code	Group	Food Item	Consumption in the household over the last 1 week		Consumption in the household over last 24 hours
			Quantity	**Unit**	**0=no; 1=yes**
1	Cereals	Maize			
		Millet			
		Sorghum			
		Rice			
		Wheat (and wheat flour)			
		Other:			
2	Tubers and starchy food, high in vitamin A, yellow or orange in colour	Orange fleshed sweet potatoes			
		Other:			
3	Tubers II, low in vitamin A, usually white in colour	Sweet potatoes			
		Irish potatoes			
		Cassava			
		Arrow roots			
		Yams			
4	Vegetables high in vitamin A, dark green or orange	Carrots			
		Kale			
		Other green leafy vegetables including AIVs			
		Pumpkin leaves/ pumpkin fruits			
5	Vegetable II, low in Vitamin A	Onion			
		Cabbage			
		Okra			
		Tomato			
6	Fruits I (high in vitamin A)	Orange/Citrus			
		Mango			
		Papaya			
7	Fruits II(low in vit A)	Avocado			

		Bananas			
		Passion fruit			
		Pineapples			
8	Meat				
9	Eggs				
10	Fish				
11	Beans	Common Beans			
		Cowpeas			
		Soya			
		Groundnuts			
		Peas(field, pigeon)			
		Green grams			
		Faba beans,			
		Sesame/ simsim			
		Dolicholis(lablab/njahi)			
12	Dairy products (milk, yoghurt….)	Milk			
		Cheese			
13	Fat and Oils	Oil			
		Butter			
		Homemade butter/ ghee			
14	Sugar and Honey				
15	Other (condiments, coffee, tea)	0=no; 1=yes			

Units (code d)

1=Kgs 2=50Kgs bag 3=90kgs bag 4= numbers/pieces	5=Wheelbarrow 6=gorogoro 7=debe 8=ox-cart 9=bale	10=pickup 11=bunches 12=crate 13=120 kg bag 14=6 kgs carton	15=4 kgs carton 16=20litres bucket 17=17kgs bucket 18=Lorry 19=Tones	20=grams 21=litre 22=milliliter 23=Other(specify

7.3 Household food shortage coping strategies : Please tell us if you applied the following food shortage copping strategies within the household in the last **seven days** (*codes; 1=Never; 2=Rarely (may be once); 3=From time to time (2-4 times); 4=Often (>5 times))*

Strategy	Code
a. Consumed less of the preferred food?	
b. Reduced the quantity of food serve to men in the household?	
c. Reduced the quantity of food serve to women in the household?	
d. Reduced own food consumption?	
e. Reduced the quantity of food served to children in the household?	
f. Some or all members skipped some meals during the seven days?	
g. Some or all members skipped meals for a whole day?	

7.4 Household hunger scale: Please tell us about the following food-related concerns about your household for the past **30 days**

Question	***Code***
1. Did you lack any food to eat of any kind in your house because of lack of resources to get food? *(0=No (skip 2); 1=Yes)*	
2. How often did this happen? (***code a)***	
3. Did you or any household member go to sleep at night hungry because there was not enough food? *(0=No(skip 4); 1=Yes)*	
4. How often did this happen? (**code (a)**	
5. Did you or any household member go a whole day and night without eating anything at all because there was not enough food? *(0=No(skip 6); 1=Yes)*	
6. How often did this happen? (**code (a)**	
Codes (a); 1*=Never;* ***2****=Rarely (may be once);* ***3****=From time to time (2-4 times);* ***4****=Often (>5 times)*	

7.5 Maize Stocks

7.5.1 How many 90 kg bags of **maize** did you have **in stock** from **your own production** just **before** you began **harvesting** your 2013/2014 main season maize crop (Jan-March 2014)_____ (bags)

7.5.2 How many 90 kg bags of **maize** do you have **in stock** right **now from the last harvest**? __________ (bags) **(record "=0" if the household did not plant maize.)**

7.5.3 **IF** ***question 7.5.2=0*** (no maize stocks), in which **month** and **year** did you run out of maize stocks from your own production? __________ (month) ______(Year)(2013,2014,2015, other years(specify)____

1=January 2=February	3=March 4=April	5=May 6=June	7=July 8=Aug	9=September 10=October	11=November 12=December
13 =2013	14=2014	15=2015			

7.6 **Sorghum stocks**

7.6.1 How many 90 kg bags of **sorghum** did you have **in stock** from **your own production** just **before** you began **harvesting** your 2013/2014 main season sorghum crop (Jan-March 2014)_____ (bags)

7.6.2 How many 90 kg bags of **maize** do you have **in stock** right **now from the last harvest**? __________ (bags) **(record "=0" if the household did not plant sorghum.)**

7.6.3 **IF *question 7.6.2=0*** (no **sorghum** stocks), in which **month** and **year** did you run out of maize stocks from your own production? __________ (month) ______(Year)

1=January 2=February	3=March 4=April	5=May 6=June	7=July 8=Aug	9=September 10=October	11=November 12=December
Year	1 =2013	2=2014	3=2015		4=other(specify)

7.6.4 Did you receive relief food (for the last 12 months? **1=Yes 0=No [___]**

7.6.5 If **YES**, how many months______

END
(Please remember to thank the farmer genuinely)

0.11 Household location GPS coordinates
longitude________________________________
Latitude_________________________________
Altitude_________________________________

The enumerator to answer section 8 below privately immediately after the interview

8.1 In your opinion, how did you establish rapport with this respondent /_________/

1=with ease	**2**=with some persuasion	**3**=with difficulty	**4**=it was impossible

8.2 Overall, how did the respondent give answers to the questions /_________/

1=willingly	**2**=reluctantly	**3**=with persuasion	**4**=it was hard to get answers

8.3 How often do you think the respondent was telling the truth /_________/

1=rarely	**2**=sometimes	**3**=most of the times	**4**=all the time

I (the enumerator) certify that I have checked the questionnaire two times to be sure that all the questions have been answered, and that the answers are legible.

Signed: __________________Date/____________/End time:

Appendix 2: Adult-equivalent conversion factors for estimated calorie requirements according to age and gender.

Age (years)	Adult-equivalent conversion factor
Newborns	
0-1	0.29
Children	
1-3	0.51
4-6	0.71
7-10	0.78
Men	
11-14	0.98
15-18	1.18
19-50	1.14
51+	0.90
Women	
11-50	0.86
51+	0.75
Breastfeeding women	
11-50	1.06
51+	0.94
Pregnant women	
11-50	0.98
51+	0.82

Source: Claro *et al*. (2010)

Appendix 3: Tropical Livestock Unit (TLU) conversion factors

Species	TLU conversion factors
Cattle	0.7
Donkey	0.5
Pig	0.2
Sheep	0.1
Goat	0.1
Chicken	0.01

Source: Jahnke (1982)

Appendix 4: Proximate Principles and Energy Composition in terms of 100g of Selected Food items

Food item	Kcal	Food item	Kcal
Maize meal	373	Avocado	128
Finger millet	332	Banana	94
Rice	359	Passion fruit	87
Sorghum	343	Pineapples	54
Wheat flour	340	Meat	220
Sweet potatoes	143	Eggs	154
Irish potatoes	81	Fish	230
Cassava	134	Common beans	352
Arrow roots	129	Cowpeas	334
Yams	110	Soya	398
Carrots	38	Groundnuts	570
Kale	52	Pigeon peas	332
Amaranthus vegetables	45	Green grams	339
Pumpkin leaves	39	Milk	73
Onion	65	Cheese	348
Cabbage	28	Oil	900
Tomato	26	Butter	729
Orange	43	Homemade butter	885
Mango	60	Sugar	373
Papaya	37	Chocolate	351

Appendix 5: Multicollinearity test for independent variables

Variable	VIF	1/VIF
AGE	56.80	0.017
AGESQUARED	58.36	0.017
EDUCATION	1.42	0.705
GENDER	1.10	0.908
HHSIZE	1.08	0.927
MODERATEWEALTH	1.19	0.839
WEALTHY	1.40	0.716
CREDIT	1.02	0.976
LIVESTOCK UNITS	1.22	0.819
FARMSIZE	1.33	0.753
EXTENSION	2.16	0.463
EXPERIENCE	2.09	0.478
FARM INCOME	1.28	0.784
DISTANCE	1.20	0.831
GROUP MEMBERSHIP	1.10	0.911
MEAN VIF	**7.87**	

Appendix 6: Pairwise correlations matrix

```
. pwcorr logfa agrinpmktdist training farmincome hhsize wealthcat age yearsch farmingyrs agesq  gender groupmemb totallivestock
```

	logfa	agrinp~t	training	farmin~e	hhsize	wealth~t	age
logfa	1.0000						
agrinpmktd~t	0.0225	1.0000					
training	0.0124	-0.3065	1.0000				
farmincome	0.2642	-0.0233	-0.0150	1.0000			
hhsize	0.0107	0.0152	0.0571	-0.0017	1.0000		
wealthcat	0.2304	-0.0233	0.0388	0.3566	0.0395	1.0000	
age	0.1756	0.0051	-0.0742	0.0716	-0.2071	0.0617	1.0000
yearsch	0.1209	0.0290	-0.1321	0.1715	0.0475	0.3227	-0.2835
farmingyrs	0.1220	0.0577	-0.0631	0.0556	-0.1510	-0.0004	0.6982
agesq	0.1612	0.0060	-0.0718	0.0628	-0.2072	0.0616	0.9909
gender	0.0680	0.0304	0.0115	0.0147	0.1040	0.0446	-0.0400
groupmemb	0.0815	-0.0575	0.1950	0.0437	-0.0574	0.0659	0.0676
totallives~k	-0.0215	-0.0251	-0.0382	0.0076	-0.0247	0.0291	0.0074

	yearsch	farmin~s	agesq	gender	groupm~b	totall~k
yearsch	1.0000					
farmingyrs	-0.2804	1.0000				
agesq	-0.3006	0.7055	1.0000			
gender	0.2256	-0.1200	-0.0416	1.0000		
groupmemb	0.0596	0.0502	0.0657	-0.0063	1.0000	
totallives~k	0.0409	0.0043	0.0045	0.0122	-0.0161	1.0000

Appendix 7: Cumby-Huizinga test for autocorrelation

```
Cumby-Huizinga test for autocorrelation
  H0: variable is MA process up to order q
  HA: serial correlation present at specified lags >q
```

H0: q=0 (serially uncorrelated) HA: s.c. present at range specified				H0: q=specified lag-1 HA: s.c. present at lag specified			
lags	chi2	df	p-val	lag	chi2	df	p-val
1 - 1	59.370	1	0.0000	1	59.370	1	0.0000

```
  Test allows predetermined regressors/instruments
  Test requires conditional homoskedasticity
```

Appendix 8: Breusch-Pagan / Cook-Weisberg test for heteroskedasticity

Ho: Constant variance

Variables: fitted values of per calorie intake

$chi^2(1)$ = 0.43

Prob > chi^2 = 0.5108