# Impact of Spillover Effects of Integrated Pest Management on Profitability of Non-Mango Fruit Fly Infested Crops in Meru County, Kenya

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## DECLARATION

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

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## DEDICATION

This thesis is dedicated to my husband Patrick Karanja. Your sincere love and support has brought me this far. To my daughter, Nancy and son Steve, you were my inspiration.

## ACKNOWLEDGEMENTS

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## ABSTRACT

The International Centre of Insect Physiology and Ecology (ICIPE) has recently developed and disseminated an integrated pest management (IPM) strategy for suppression of mango fruit flies among mango growing communities in Africa. Although the economic benefits of the fruit fly IPM strategy on the primary target crop (mango) are clearly demonstrated, the potential gains of the strategy on non- mango fruits hosts of the invasive fruit fly species in the same farm within which the IPM was introduced have not been quantified in the previous studies. These past studies failed to capture the widespread diffusion of the technology to other host cultivated plants which may essentially under estimate the actual impact of the fruit fly IPM on farm income. This study sought to examine the spillover effects of IPM strategy for suppression of mango fruit fly on profitability of other fruit crops. The focus was on four alternative cultivated hosts; namely, avocado, pawpaw, citrus and bananas of this major quarantine pest that are predominantly grown in Meru County, Kenya where the fly population has been observed to occur in large numbers. Using a semi-structured questionnaire, data were collected through a survey from 371 households and key informant interviews. Propensity score matching (PSM) using kernel based matching and radius matching were used to examine the indirect (spillover) impact of participating in IPM strategy on profitability of aforementioned enterprises. The results showed positive and significant cross-commodity spillover effect of the fruit fly IPM strategy on pawpaw and citrus. The strategy increased the average gross margins of citrus and pawpaw by approximately 27 percent and 38 percent per year per hectare respectively. Spillover effects were not observed for avocado and bananas at the farm level. The effort to disseminate IPM strategy would therefore yield more impact to farmers who cultivate a combination of mango, citrus and pawpaw in increasing their farm incomes.

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| | |
|---|---|
| ATT | Average treatment effect of the treated |
| CGE | Computable general equilibrium |
| DID | Difference in difference |
| DMU | Decision making unit |
| FFS | Farmer field school |
| GEE | General equilibrium effects |
| ICIPE | International Centre of Insect Physiology and Ecology |
| ICRISAT | International Crops Research Institute for the Semi-Arid Tropics |
| IITA | International institute of tropical agriculture |
| IPM | Integrated Pest Management |
| KBM | Kernel based matching |
| MAT | Male annihilation technique |
| MMM | Mahalanobis matching method |
| MoALFI | Ministry of Agriculture, Livestock, Fisheries & Irrigation |
| NNM | Nearest Neighbor matching |
| NPV | Net present value |
| OVF | Organic Vegetable Farming |
| PSM | Propensity score matching |
| RM | Radius matching |
| R&D | Research and Development |
| SD | Standardized Bias |
| SSA | Sub Saharan Africa |

# CHAPTER ONE INTRODUCTION

## 1.1 Background of the Horticultural Sub- Sector

Global horticultural production has experienced a remarkable increase over the years largely due to its profitability (Weinberger & Lumpkin, 2007). The growth is sustained by rich urban consumers in both developing and in developed countries with much of the growth concentrated in Latin America and China (Lumpkin *et al.,* 2005). About 3 percent annual growth rate of horticultural output in the world have been reported over the last decade (Salami *et al.,* 2010). In 2011, approximately 640 metric tonnes of fruit were assembled throughout the world (Year Book, 2013). Countries such as Vietnam, Indonesia, Ghana, Uganda, Rwanda, Ethiopia and Kenya which are food- insecure, horticultural production has increased over the past 10-15 years (Joosten *et al.,* 2015). Horticultural producers in food-insecure countries are also favored by plentifulness of labor where arable land is scarce with available markets hence fuelling the increase (Byerlee & Deininger, 2013). India's economy continues to improve largely due to abundance in production of fruits and vegetables while employing many rural small-scale farmers (Negi & Anand, 2015). Donors throughout the world are funding projects in favor of fruits and vegetable production (Joosten *et al.,* 2015).

The horticultural sub-sector is a major contributor in the economies of many African countries. The sub-sector is among the leading foreign exchange earners, and contributes to food security and employment, especially among smallholder farmers (Salami *et al.,* 2010). In Africa, for example, in 2007, foreign exchange earnings from fruit and vegetable exports were estimated to over US$ 16 billion creating jobs to over 40 million people (Billah *et al.,* 2015). In Kenya, the horticulture sub-sector's contribution to agricultural share of output and forex is 36 and 38 percent respectively (Kibira *et al.*, 2015). Fundamentally, this implies that horticulture sub-sector is important in generating wider employment opportunities and raising agricultural incomes to small-scale horticultural producers.

Kenya's horticultural exports have been increasing since 1975, to more than US $ 250 million in 2005, becoming the country's third largest foreign exchange earner after tourism and tea (Haggblade *et al.,* 2010). Between 2001 and 2011, the sub-sector's exports annual growth rate was 16 percent on average (Kibira *et al.*, 2015). While in 2012, total horticultural produce exports was 380,000MT which was valued at Ksh 87 billion. This was a 4 percent decrease in quantity exported as compared to 2011 (*ibid*). The reduction in quantity and value was due to the decline in quantities of nuts and processed fruits exports. In Kenya, horticultural sub-sector is composed of fruits, vegetables, cut flowers, nuts and medicinal and aromatic plants (Laibuni *et al.,* 2012). Fruits and vegetables dominating domestic and export markets are mango, citrus, pineapple, pawpaw, avocado, banana, tomatoes, pepper and the cucurbits (Billah *et al.*, 2015; Midingoyi *et al.*, 2018). Vegetables, fruits and flowers account for 44.6, 29.6 and 20.3 percent respectively of the total value of horticultural produce, with nuts, medicinal and aromatic plants accounting for the rest (Kibira *et al.*, 2015). The average annual production of fruits like mangoes had risen by about 43 percent from 2005 to 2008 (Muchiri, 2012).

Despite its importance to the Kenyan economy, the horticultural sub-sector experiences many challenges ranging from increased cost of production, high taxation and the decline of both quality and quantity of marketable produce. The latter challenge is mainly attributed to attack by insect pests such as fruit flies which causes severe ecological and economic impact (Ekesi *et al.*, 2016). Detected in Kenya in 2003, an invasive fruit fly *Bactrocera dorsalis (B. dorsalis)* species is one of the most destructive insect pests in horticultural production (Rwomushana *et al.,* 2008). The pest has since spread rapidly in Sub-Saharan Africa (SSA) (Drew *et al.,* 2005). *Bactrocera dorsalis* is found everywhere and is able to feed on various kinds of food hence attacking 40 host fruit and vegetable crops in Africa (Van Mele *et al.,* 2009). *B. dorsalis* infests cultivated and local tropical fruits like mango, pawpaw, avocado, citrus (lemon, tangerine, and sweet orange), guava, tropical almond, sugar apple and banana (Biasazin *et al.,* 2014). Although the primary host of *B. dorsalis* is mango, the preferred hosts are different for every region and differ according to climate, and host availability (Cugala *et al.,* 2014).

The average *B. dorsalis* counted in a kilogram mango, oranges and avocado in Tanzania was 149.8, 2.9 and 0.8 respectively (Mwatawala *et al.,* 2006). This shows that *B. dorsalis* is of different economic importance to different fruit crops. Control of *B. dorsalis* by use of IPM in mango can also be applicable in controlling the same pest in other host crops. The estimated global loss in mango due to pest incidence is US$ 1 billion of which more than US $ 42 million occurs in Africa (Ekesi *et al.,* 2016).

Kenya is reported to have lost US$ 1.9 million in 2008 due to *B. dorsalis* quarantine restriction put by South Africa due to pest incidence (Cassidy, 2010). In addition, farm level losses of mango produce caused by *B. dorsalis* infestation in Embu County, Kenya, ranges between 24 percent and 60 percent leading to a loss of about Ksh 3.2 million in one season (Muchiri, 2012). This has impacted negatively on the livelihoods of farmers who depend on horticulture for income, employment and food. As a result of the *B. dorsalis* menace, farmers globally have resorted to use of Integrated Pest management (IPM) practices to reduce yield losses (Hristovska, 2009). Fruit fly IPM strategy has been introduced with the aim of reducing fruit fly population densities and consequently reduce crop yield losses (Ekesi *et al.*, 2016).

One of the key advantages of IPM is that it reduces the negative productivity effects caused by pests without harming the environment with minimal risk to human health (Hristovska, 2009). Use of conventional methods like spraying with pesticides or insecticides led to increased cases of resistant and secondary pests which had brought about negative productivity (Dugger-Webster & LePrevost, 2018). Fargnoli *et al.* (2019) noted the increased concern on safer and sustainable utilization of insecticides in agricultural production globally, hence renewed attention to IPM.

The International Centre of Insect Physiology and *Ecology* (ICIPE) has developed and disseminated an integrated pest management strategy to help cope with *B. dorsalis* challenge in mango production. This is inline with the Kenyan Government objective of improving crop productivity and profitability through pest management. The use of IPM in pest control is to reduce losses in mangoes associated with fruit fly invasion. This would lower the production cost and consequently increase farm productivity and profitability.

Past studies in Kenya have shown that the application of IPM reduces mango damage resulting from fruit flies infestation by a bigger percentage than use of synthetic pesticides. For instance, Ekesi *et al.* (2014) reported a decline in mango damage caused *B. dorsalis* of less than 14 percent for adopters of IPM components in Embu, Kenya compared to an average of 42 percent damage for non-adopters relying on conventional pesticide application (*ibid*). Korir *et al.* (2015) further demonstrated that farmers who used 2–3 IPM components developed by ICIPE reduced marketable mango rejects by about 54.5 percent compared to a control site. The researchers further showed that the strategy resulted to a rise in farm income of smallholder mango growers by 22.4 percent in comparison with the control group. Muriithi *et al.* (2016) also found that the utilization of the integrated technology led to an average rise in mango net income of 48 percent regardless of the IPM combination used.

## 1.2 Statement of Problem

Although the economic benefits of the IPM strategy on the primary target crop, mango, are clearly demonstrated as highlighted above, the quantification and documentation of the benefits of non-targeted cultivated hosts of the invasive fruit fly species on the same farm have been minimal. Past studies on benefits of IPM failed to capture the widespread diffusion of the technology to other host cultivated plants; avocado, citrus, pawpaw and bananas. This implies that there has been an underestimation of the actual impact of IPM technology on profitability of farm crops. This study sought to address this gap by analyzing the economic impact of IPM on avocado, citrus, pawpaw and bananas in the same farm where mango farming has been practiced in Kenya.

## 1.3 Objectives of the Study

The general objective of this study was to assess the impact of spillover effects of IPM strategy on profitability of non-mango fruit fly infested crops in Meru County, Kenya. The specific objectives were to:

1. Determine factors influencing adoption of IPM technology for suppression of mango fruit fly on non-mango cultivated host fruit crops in Meru County.
2. Assess the spillover effect of the IPM technology on profitability of non-mango cultivated host fruit crops in Meru County.

## 1.4 Hypotheses

1. Socio-economic factors, household endowment, access to information, institutional and market services, social capital and farm characteristics do not influence adoption of IPM technology on non-mango cultivated host fruit crops in Meru County.
2. Spillover effects of IPM technology do not influence profitability of non-mango cultivated host fruit crops in Meru County.

## 1.5 Justification of the Study

Underestimation of technology benefits has implications on returns to investment and in making invalid policy recommendations. Ultimately, an understanding of this spillover by policy makers can serve to more efficiently allocate resources dedicated to agricultural research and development and by designing evidence- based policies and strategies which can reduce poverty while saving on resources. The information generated assists ICIPE, its development partners and other stakeholders in designing and scaling up similar IPM technology package to other farmers in similar socio-economic and agronomic circumstances as those in Meru County. In addition, the information assists rural communities in the study area to establish if the integrated control of the fruit fly is beneficial to other fruit crops in their farms, which would result to a decline in the total cost of controlling fruit fly and improvement of profits. The information generated contributes to the growing body of knowledge on technology spillovers and more specifically cross- commodity spillovers. This study provides information relating to cross-commodity spillover effects of the IPM technology on the profitability of other fruit crops to avoid underestimation of IPM's full benefits.

# CHAPTER TWO LITERATURE REVIEW

## 2.1 Conceptual Foundation of Spillover Effect

The studies on spillover effects in agriculture have a long history that can be tracked back to mid-twenty's century (Schultz, 1956; Johnson & Evenson, 1999). Most of these studies tend to concentrate on drift of pest from the natural plants to cultivated hosts (Tonina *et al.,* 2018). Very few studies have considered spillovers within the cultivated host fruit crops. An example was in North-Eastern South Africa where marula invasion was affiliated to nearness with mango trees at the farm (Moxley *et al.,* 2017). This study focused on spillover effect of mango fruit fly to other cultivated host crops (citrus, pawpaw, avocado and banana) which most of the reviewed studies have failed to consider that is spillovers within the cultivated crops. Other studies have not recognized the importance of diverse adjacent plants which are more significant hosts than uncultivated hosts for preserving *B. dorsalis* when mango is off season. Moxley *et al.* (2017) proposed planning of landscapes to factor in nearness and designs of plots with plants that were also hosts at various times of the year.

Agricultural technologies have been used to reduce the infestation by these pests to many different hosts. An example is the IPM technology that reduces the damage caused by *B. dorsalis* and is considered safer and sustainable than the use of pesticides. Midingoyi *et al.* (2018) noted the importance of IPM-adopting farmers who had increased mango output and disposable income while using less amounts of pesticide which caused reduced harm to the surroundings and to health of the population. Agricultural technologies can be one of the key to poverty reduction through job creation both direct and indirect leading to increased income and food security (De Janvry & Sadoulet, 2002).

Agricultural technologies often have a specific target population, which is drawn from a subset of the larger relevant unit. It is in such target population that the “direct effects” of that technology on the enterprise can be accurately measured (Adesina & Baidu-Forson, 1995; De Janvry & Sadoulet, 2002; Angelucci & Di Maro, 2010). However, in many cases the local non-target population or non-target/host may also be indirectly affected by the technology either positively or negatively through biophysical, social and economic interaction with the treatment (Moffitt, 2001; Delmer, 2005; Angelucci & Maro, 2015). If a technology is applicable beyond the location or commodity for which it was generated, such an effect is commonly referred to as a “spillover” (externality) (Bantilan & Davis, 1991; Deb & Bantilan, 2001). Accounting for spillover effects is done for two major reasons. First, is to accurately distinguish and evaluate the intended impact of treating unsuitable subjects. Second, is to correctly discern and evaluate the unintended/ indirect impact of a treatment on ineligible subjects. Measuring direct and indirect impact enables successful designing of policies together with studying characteristics of the “local economy” and behavioral patterns of the people (Angelucci & Maro, 2015).

**2.2 Spillover Effect in Agriculture**

According to Bantilan & Davis (1991) and Deb & Bantilan (2001), there are three types of spillovers associated with use of an agricultural technology. They include cross-location (cross-environment), price and cross-commodity spillovers.

Cross-location spillovers are also known as cross-environment or regional spillovers. Such spillovers occur where a technology developed for a particular crop at a specific location is adopted in other locations.The degree of applicability varies for different regions due to agronomic, climatic, ecological and socio-economic differences in the production environments. For example, Johnson *et al.* (2006) reported how newly introduced cassava varieties spread to the neighbouring regions of Ivory Coast and Ghana with significant gain to resource-poor farmers. In United States, the rate of return on investments in potato research was estimated at 79 percent, of which 31 perecnt accrued to states conducting the research while 69 percent was from spillover effect in other regions (Araji *et al*., 1995).

Price spillover refers to a situation where technological change for a particular commodity at a specific location increases commodity supply thereby changing the cost of that commodity in other locations through trade (Deb & Bantilan, 2001). Price spillovers can also change the cost of a related commodity in the same location. Deb & Bantilan (2001) noted that such spillover occurs in the effect of process and product improvement research. Notably, such research increases product supply and therefore affects commodity price as well as the prices of its close substitutes (*ibid*).

Cross-commodity spillovers occur where a technology introduced for a specific crop has an effect on other crops. An example is the cultural management technique specifically introduced in sorghum production in Asia and SSA that improved the production efficiency of millet and other cereals (Dalton & Zereyesus, 2013). Other examples include the use of biological control of *Helicoverpa spp.* in chickpeas and pigeon peas, which was also applicable to cotton, sorghum, cereals, oilseeds, grain legumes, tomatoes and tobacco in Eastern Australia (Forrester *et al*., 1993). Agurto *et al*. (2015) analyzed short term impacts of a fruit fly eradication program in Peru and found positive effects on avocado and banana from the treated households. They further found increased yields, quality fruits and higher prices from the producers of the treated areas compared to the untreated areas. In Embu District, Muchiri (2012) found that fruit flies infestation remained in other crops such as bananas, oranges, pawpaw, avocadoes and cucurbits when mango was off season because they acted as hosts to *B. dorsalis.*

### 2.3 Negative externalities on IPM technology

Inspite of positive externalities from adoption of IPM technology in agricultural production, the conduct of refractory farmer has unfavourable impact on integrated approaches (Muchiri, 2012). Fleischer (1999) defined an externality as a positive or negative effect caused by either an individual, a firm or a nation, without compensation being paid to the affected party. The authors also defined negative externalities as those which are not included in private cost calculations and therefore not influencing the farmer's decision, since the external effects are not reflected in the market price, assessment is sometimes difficult (*ibid*). Khan & Gill (2010) noted that farmers in the Cotton growing areas in Punjab, Pakistan were more interested in costs related to insecticide use in achieving preferable outcomes rather than unpreferable spin-off in the process of production, that is negative externalities. Praneetvatakul *et al.* (2016) found that farmers cared about pesticide externalities as they were highly willing to pay to protect their health when presented with alternative pest management options in vegetable farming in Thailand. IPM training was considered important in enhancing farmers' knowledge in addressing in pesticide externalities (*ibid*). Wolff & Recke (2000) pointed out that the returns from adopting IPM increases with rise in the number of other farmers in the neighborhood, that is, the neighborhood effect.

The use of IPM has not led to a reduction in pesticide use nor elimination of negative externalities (Pretty & Bharucha, 2015). This is due to the increasing number of invasive pests and diseases mostly caused by changes in climate and weather patterns. Some farmers do not carry out pest management resulting to negative horizontal technological externalities. These are usually not accounted for in decisions regarding pest management by users of IPM. Kibira *et al.* (2015) reported the reason for such negative externalities as being the versatile essence of *B. dorsalis* together with natural parasitoid utilized in controlling the pests. For instance, if a single grower doesn't utilize the integrated technology, fruit flies increases and disperses into the neighboring fields. Therefore the integrated technology efficient grower will change the traps more often than he normally does due to faster rate of fill up. In addition, biologically released enemy will reduce in number due to increased insecticides that deviates from other farms using them and also if the natural enemy flies to those fields hence getting killed. The possible specific gains appreciated by the refractory farmer reduces with added extraneous marginal costs emerging from higher forgone output with increased cost of controlling the damage *(ibid)*. Hence economic gain from integrated technology depends on the count of additional growers who have adopted similar control technology as long as the technology is efficient.

### 2.4 ICIPE Integrated Pest Management Components

The ICIPE IPM package consists of 5 components namely; (1) localized spray of food bait, (2) male annihilation technique (MAT), (3) Metarhizium anisopliae-based bio pesticide use, (4) release of parasitoid, and (5) practicing orchard sanitation with Augmentorium. The Augmentorium, is a tent-like structure made of durable netting 13mm by 12mm mesh or 1 by 1.3 mm openings to allow the emerging parasitoid wasps to fly back, with the young emerging flies closed off and the infested fruits are collected in the tent area, hence playing the two functions of parasitoid conservation and orchard sanitation (Klungness *et al.*, 2005; Ekesi & Billah, 2007). The spray food bait is proteinous originating from ICIPE which is mixed with an insecticide then sprayed at spots which are localized at a ratio of 50 ml of the mixture to 1 $m^2$ of mango canopy

(Ekesi *et al.*, 2014; Muriithi *et al.*, 2016). The MAT involves the use of fruit fly traps consisting of male lure (methyl eugenol) together with a toxicant which are placed at regular intervals over a wide area in the mango orchard. This reduces the male numbers of fruit flies by trapping and killing male flies consequently reducing mating (Ekesi & Billah, 2007; Muriithi *et al.*, 2016). The bio-pesticides are fungus-based mixtures that are sprayed to the soil within the drip line of the canopy at the ratio of 15 ml to 20 litres of water to kill the soil-dwelling pupariating larvae and puparia reducing the fruit fly populations (Kibira *et al.*, 2015).

## 2.5 Methods for Measuring Impact of Agricultural Technologies

Several researchers acknowledge that measuring spillover effects is highly intricate, yet it is required if technology is to be used as an effective instrument for poverty alleviation (Griliches, 1991; Johnson & Evenson, 1999; Alston, 2002). This has led to measurement of direct and indirect impact in different ways. A methodology proposed in literature is computable general equilibrium modeling (CGE). De Janvry & Sadoulet (2002) evaluated the direct and indirect role of agricultural technology between countries using the CGE models. The effects resulted to higher agricultural incomes for the farmers, while food prices declined for others (price spillover). These researchers also noted that when poor rural households expands their sources of income they may benefit from continued growth more than from the direct effect of technology on their own farms. Midingoyi *et al.* (2018) also pointed out the use of multinomial endogenous switching treatment regression with ordered probit in measuring the mango yield and income effect of IPM adoption together with reduced quantities of pesticides resulting to less environmental damage and health. Moxley *et al.* (2017) used generalized linear mixed effects models to measure the spillovers occurring from crop yiels to natural vegetation. In most studies that address spillover effects, most of the work is in ascertaining the likely adoption patterns of new strategies introduced in a specific region after evaluating the extent and nature of the resulting technological improvement and the odds of successful research (Alston, 2002). Most recent studies have been contributing knowledge on how to use agro ecological information to forecast adoption patterns, although challenges of characterizing and quantifying alternative technologies are present. However, where spillover effects are relevant much of these work becomes very productive. Muriithi *et al.* (2016) evaluated the impact of IPM technology on mango using difference-in-difference method (DID), and utilized fixed effects regression to check its robustness. The results demonstrated positive and significant gain in net income from five components compared to the control subjects. Expenditure in buying pesticides for controlling fruit flies had reduced. Kibira *et al.* (2015) used Stage Least Square (2SLS) analysis and DID to evaluate the impact of IPM and found that the strategy increased incomes of the households.

Indirect impact of agricultural technologies adds to agricultural total factor productivity (TFP) (Johnson & Evenson, 1999). TFP method has also been used to measure indirect impact of technologies since 1950s. Schultz (1956) calculated total factor productivity growth as an index for American agriculture, and estimated how the technological change saved resources and compared it to the total public investments in agricultural research (Griliches, 1991). Production functions have also been largely used by different authors in measuring indirect impacts of agricultural technologies (Orlando, 2004). Wang (2015) demonstrated that agricultural technologies have positive spillover effects. The author used panel and cross- sectional data and adopted a production function that is similar with the value-added Cobb-Douglas production function. Orlando (2004) used a production-function to analyze the role of proximity to technology and geographical boundaries for inter-firm externalities and demonstrated the importance of distance.

Farm-level restricted profits are the starting point when assessing the immediate impacts of a new technology (Feder & Quizon, 1999). This is because they represent the expected profitability that drives farmers to adopt a new production strategy and provides a route through which adoption increases producer welfare. Cost benefit analysis has also been used widely to measure the farm- level impacts of agricultural technologies. Yapi *et al*. (1999) demonstrated the use of cost benefit analysis in assessing the direct and indirect impact of adoption of sorghum variety S35 in India. The researchers found that farm- level impacts were higher in Chad where the yield gain was 51% larger and cost decline was 33% more than in India. Verghese *et al.* (2004) used cost benefit analysis to evaluate profitability of IPM of oriental fruit fly (*B. dorsalis*) in India.

Propensity score matching has become an attractive approach in estimating indirect impact of agricultural technologies. It is suitable for all cases where one has a group of treated subjects and a group of control subjects utilizing cross- sectional data (Caliendo & Kopeinig, 2008). Kassie *et al.* (2011) assessed the ex post impact of uptake of hybrid groundnut seeds on crop revenue and poverty in rural Uganda using cross-sectional data. Using PSM, they found that adopting hybrid groundnut varieties (technology) significantly raised crop revenue and resulted to poverty reduction. Sanglestsawai *et al.* (2015) analyzed economic impacts of IPM using PSM and found reduction in insecticide use in growing onion by farmers in the Philippines. Evaluations that quantify indirect impacts should be designed so as to expound both the cause of these effects and the group of people they affect, this is necessary to avoid invalid policy recommendations and disregarding important mechanisms through which the programme works (Angelucci & Maro, 2015). Alston (2002) demonstrated that agricultural research spillover effects are imperative and captivating but not well documented, and hence requires more exploration.

**2.6 Profitability of Adoption of Integrated Pest Management**

Previous studies have been carried out with a purpose of quantifying IPM technology and its effect on income. The results have shown that farmers benefit from adoption of IPM in terms of reduction in pesticide expenses and pest damage, and also improving profitability from farm enterprises. In Kenya, for example, it has been demonstrated that the use of IPM improves net revenue of smallholder growers by 48 percent and yield losses by approximately 19 percent compared to the control (Muriithi *et al.,* 2016). Midingoyi *et al.* (2018) reported increased mango yields and income from adoption of more IPM components with reduced pesticide use by 0.05 litre per tree for the adoption of one IPM practice, 0.08 litre per tree for the adoption of two and 0.19 litre per tree for the adoption of three or more IPM practices.

A reduction in pesticide use by 34 percent was reported for cabbage farmers in Kenya and Tanzania as a result of adoption of a biological control agent (Jankowski *et al.,* 2007). Growers who adopted IPM practices in eggplant farming in India experienced increases in yield and profits with an increased production area of 21.6% while insecticide expenditure reduced by 52.6 percent (Baral *et al.,* 2006). Kumar (2017) also noted increased yield of 44.75 percent in the treated group in the use of IPM technology for brinjal shoot and fruit borer in India. Policy support in improving extension services is essential in passing knowledge and adoption of new and better technologies by the poor (Kassie *et al.,* 2011). Sanglestsawai *et al.* (2015) did not find strong evidence on the use of IPM on profits, although nearness to neighbor matching showed an increase in profit. The positive and significant impact on crop income is consistent with the anticipated role of new agricultural innovations in alleviating rural poverty through improved farm household income (Kassie *et al.,* 2011). The gain from agricultural technology spillover effects are more beneficial than the initial investments hence studies on this should be carried out (Alston, 2002).

IPM projects in Asia and Africa resulted to a mean yield increase of over 40.9% and a reduction in pesticide use of over 30.7% (Pretty & Bharucha, 2015). In addition other benefits fro IPM includes diversification of income, livestock integration and also improvement of soil health due to reduced pesticide use or even transition to zero pesticide use as demonstrated by Pretty & Bharucha, 2015. Midingoyi *et al.* (2018) demonstrated the importance of adopting IPM practices to the farmer and environment and found a substantial increase in crop yield and reduced pesticide use in Kenya. The researchers however recognized that increased profitability would be as a result of adoption of a bundle of practices.

# CHAPTER THREE METHODOLOGY

## 3.1 Conceptual Framework

The relationships driving the participation and use of IPM technology for suppression of mango fruit fly and the subsequent spillover effects to other host crops in the same field is depicted in Figure 1.

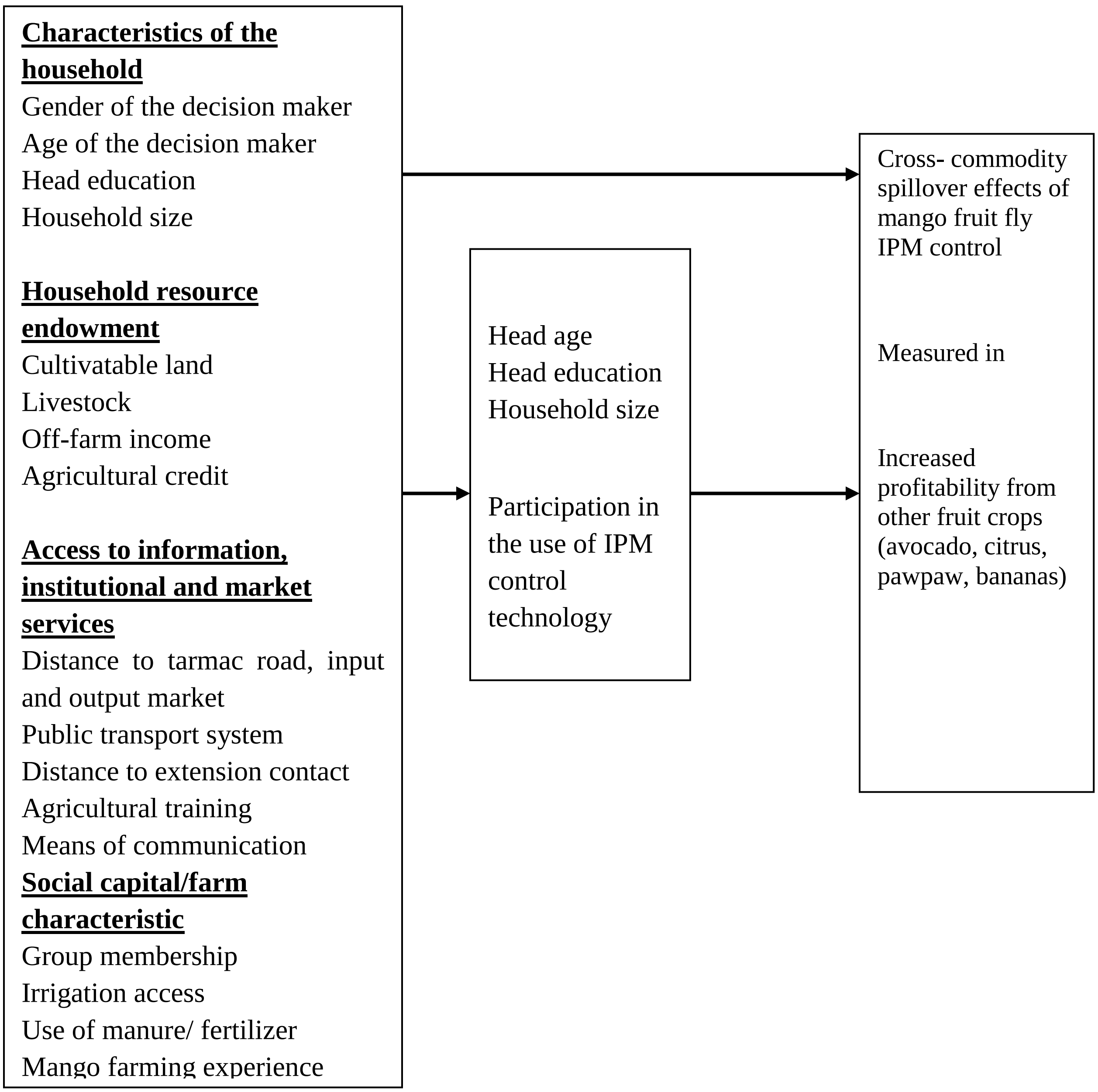



**Figure 1**: Conceptual framework of spillover effects in participation and use of IPM technology for suppression of mango fruit fly in Meru County

The direction of arrows shows the source of influence and point to the factor being influenced. The use of IPM technology means that mango farmers would realize increased incomes as a result of reduced fruit crop damage. Institutional factors; extension contact and training on IPM influence farmer's knowledge and therefore the use of the technology. Market services; distance to pesticide store and distance to nearest market too influence the mango farmers' decision to use the IPM strategy and consequently spillovers. On the other hand, household resource endowment factors; cultivatable land, livestock, off-farm income and agricultural credit access influence the use of IPM technology mango fruit fly. Increased use of IPM strategy would reduce the infestation of other host fruit crops by *B. dorsalis* leading to increased profitability on other fruit crops in Meru County thus improved livelihoods. Social capital for example being a member of a mango producing group increases the chances of adopting IPM technology and consequently spillover effects of the IPM to other host cultivated crops. The study therefore focused on assessing the indirect effects (other host crops) stemming from the use of IPM strategy on mango.

### 3.2 Study Area

This study was conducted in three Sub- Counties in Meru County, that is, Central Imenti, North Imenti and Tigania West which are some of the operational areas of ICIPE fruit fly project. Meru County lies on the northeastern side of Mt Kenya. Meru County is located in the Eastern Region,Kenya. It borders Isiolo County to the north, Laikipia County to the west and Tharaka Nithi, Nyeri, Kirinyaga and Embu counties to the south. It has an area of 6,933.01km$^2$ with a total population of 1,356,301 persons and 319,616 households.

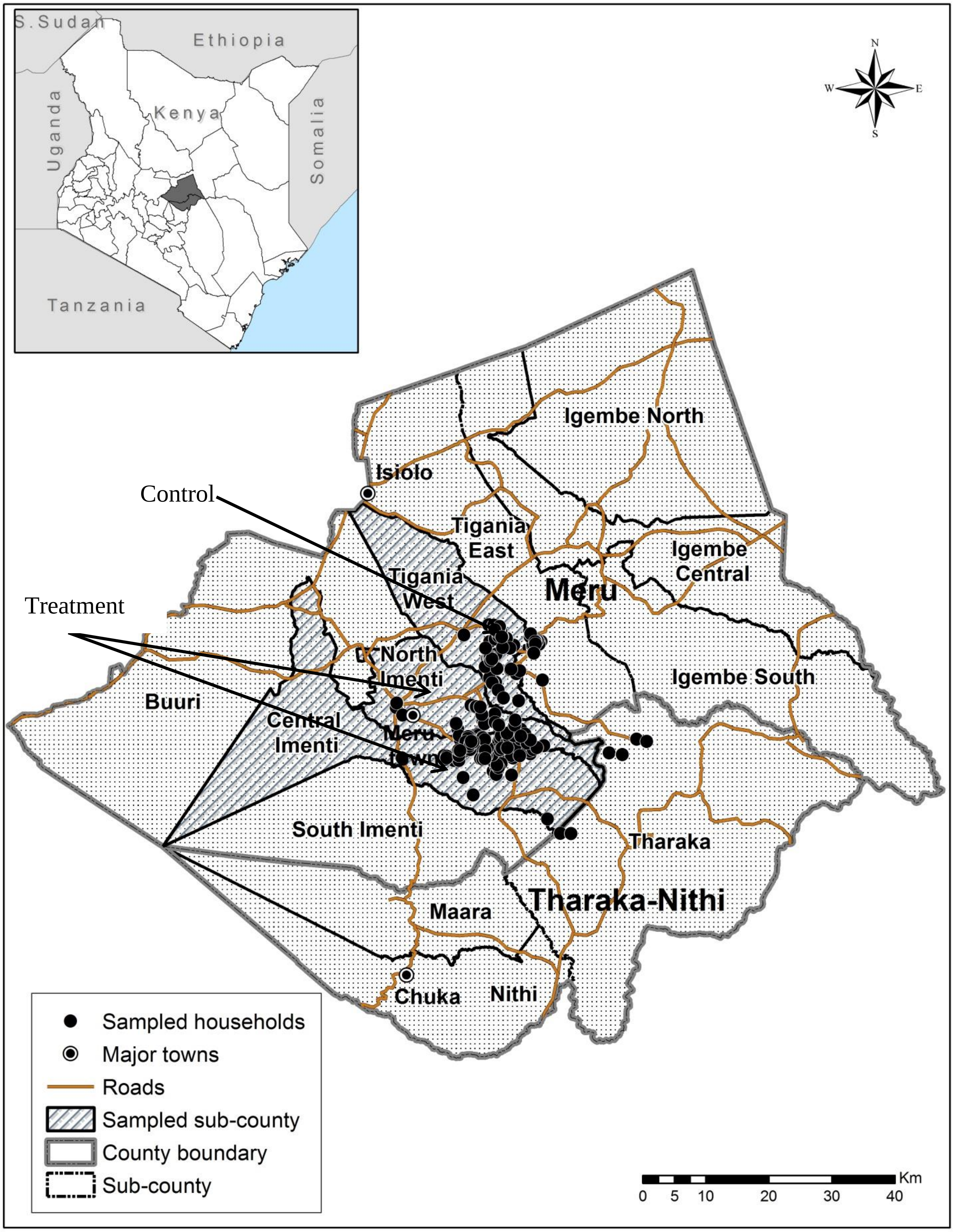



**Figure 2:** Map of Meru County showing the sampled households

**Source**: Kimathi, 2019

The rainfall distribution ranges from 300mm to 2500mm per annum with temperatures ranging from 8ºC to 32ºC during the cold and hot seasons respectively (Gakuubi & Wanzala, 2012). Meru County covers a wide range of agro ecological zones (AEZs) ranging from tropical alpine to semi-arid low midland six (LM6). These zones are upper midland II which is a major coffee zone, upper midland III which is a marginal coffee zone and mango, LM3 (Cotton zone), LM4 (marginal cotton zone) and LM6 the livestock zone. Coffee, tea, French beans, mangoes and dairy are the primary agricultural enterprises that farmers engage in Meru County. The main high value crops in Meru County are water melons, French beans and fruit trees like mangoes and *Khat (Miraa)* (Imaita, 2013).

Meru County infrastructure comprises of road network, airstrips, electricity, telecommunication, micro financial institutions, banks, education facilities, hospitals, markets and housing. The County has 48 trading centers which serve as market centers for their agricultural commodities. The tourism industry is fairly developed in the County, with Meru National park being the major tourist center. The County has developed an integrated plan which focuses on promotion of fruits and tree crop development (avocado, mangoes, macadamia, papaya, passion fruits, oranges and tree tomato). The study on cross commodity spillover effect contributes in realizing the County's integrated plan of promoting growing of fruit crops by the farmers in the region.

### 3.3 Data Collection and Sources

#### 3.3.1 Sampling Techniques

The study utilized primary data collected among smallholder mango farmers which was compiled previously by ICIPE in their impact assessment study on Integrated Pest Management. The survey comprised of mango growers from three sub –Counties; Central Imenti, North Imenti previously issued with IPM fruit fly control kits and Tigania West, control. Previous study on impact assessment provided a sampling frame of 1200 where IPM participants and non-participants were randomly selected for household interviewees.

### 3.3.2 Sample Size

The sample size was computed using Cochran's Formulae Baartlett *et al*. (2001). The nature of the study required that a confidence interval of 95% and a p= 0.05 be used. The formulae used to calculate the sample size was as shown in equation 3.1

$$\frac{n=s^2(t)(r)}{e^2} \quad \text{.....}\ldots\ldots (3.1)$$

$$\frac{n = 1.96^2(0.5)(0.5)}{0.05^2}$$

= 384

where: *n* = sample size, *S* = the standard normal deviation at the selected confidence level; the value is 1.96 for commonly used 95% confidence interval, (t)(r) = proportion in the target population estimated to have characteristics being measured (estimate of variance) = 0.25 and *e* = the desired level of precision 0.05. Thus, the calculated sample size, *n*, was 384 households. Since the sample size was more than 5% of the population, this study used Cochran's correction formulae:

$$n_1 = \frac{n}{1+\frac{n}{population}} \quad \ldots\ldots (3.2)$$

$$n_1 = \frac{384}{1+\frac{384}{1200}} = 290$$

Where population was 1200 from ICIPE previously done baseline survey, $n$= required return sample size according to Cochran's formulae = 384, $n_1$= required return sample size since the sample size exceeds 5% of the population. Assuming a response rate of 80%, a minimum of 363 households should be used as shown below.

$$n_2 = \frac{290}{0.8} = 363$$

## 3.4 Data Capture and Diagnostic Tests

### 3.4.1 Data Capture

Data were captured using open data kit (ODK), an application found in android where the questionnaire was uploaded in XLS form. The questionnaire then after being filled was sent to a server from where it was uploaded again in excel form from where data cleaning was done. Open data kit was preferred because data could be transferred to the servers at the end of each day and its also more accurate and reliable when accessing the data for use in the future.

### 3.4.2 Diagnostic Tests

#### 3.4.2.1 Specification Test

Before analyzing the data, a number of tests were done. Link test was done to show whether the model in this study is properly specified. Kernel density command in STATA was used after creating the residuals (errors). Normality of residuals is required for valid hypothesis testing of the model.

#### 3.4.2.2 Testing for Multicollinearity

The other test done was to check the existence of multicollinearity between the explanatory variables. Multicollinearity increases the probability of making type II error of accepting the 'zero null- hypothesis' when it is false resulting to imprecise and unreliable parameter estimates (Grewal *et al.*, 2004). To detect multicollinearity of the variables Variance Inflation Factor (VIF) method was used. Equation 3.3 VIF is defined as:

$VIF\ (X_i) = 1/\ (1-\ R_i^2)$………………………………………………………………… (3.3), where coefficient of multiple correlation squared of $X_i$ with other independent covariates is represented by $R_i^2$, bigger VIF value shows the severity of the multicollinearity problem. The rule of thumb used by many researchers is: A VIF greater than 10 indicates that the variable is highly collinear (Gujarati, 2005).

#### 3.4.2.3 Testing for Heteroscedascticity

The other test was to check existence of heteroscedasticity, which occurs when the variance of the error term differs across observations. If the estimates of parameters are inefficient and consistent then there is presence of heteroscedasticity. Invalid conclusions are made if there is bias in approximated standard error. Breusch-Pagan test (hettest) in STATA was used to detect heteroscedasticity. Breuch-Pagan tests the null hypothesis that the error variances are all equal versus the alternative that the error variances are a multiplicative function of one or more variables. A large chi-value, exceeding the critical chi-value shown by very small p-value, indicates presence of heteroscedasticity (Gujarati, 2005).

## 3.5 Data Analysis Techniques

STATA 14 and Ms Excel are the statistical packages used for data cleaning and analysis. Descriptive statistics were employed to analyze characteristics of the IPM users and nature of application of IPM technology. The mean, mode, standard deviation and medians of various variables were obtained. Gross margins were also calculated. T-test was used to compare selected household and farm characteristics between the two categories of farmers (IPM users and non- users). PSM using Kernel based matching ans radius matching were employed to evaluate the spillover effects of IPM technology on profitability of other fruit crops.

### 3.6 Methods to operationalize spillover effect

#### 3.6.1 Theoretical framework

Angelucci and Di Maro (2010) argues that experimental design is the most valid means to evaluate the direct and indirect (spillovers) impact of an intervention. However, in many cases, an experimental design may not be a feasible option, typically because of budgetary or ethical reasons like biasness in selecting the participants. To correctly estimate spillover effects with non-experimental or quasi-experimental evaluation design therefore, one has to use control subjects that are not influenced by the program either directly or indirectly (Angelucci & Di Maro, 2015). The quasi-experimental design uses control subjects that have resemblance with treatment subjects, at least in observed attributes. Main econometric methods used to analyze data derived from quasi-experimental designs include difference-in–difference (DID), instrumental variables (IV), reflexive comparisons and matching methods (Baker, 2000).

The difference in difference or double-difference (DID) can be applied on data from both experimental and quasi-experimental designs. The fundamental reason for utilizing double difference is to show the trend the outcome would have had in the treatment subjects had the programme not been implemented using the differences in outcome values from the treatment and control group before and after the programme (Angelucci & Di Maro, 2015; Baker, 2000). The second difference is calculation of the effect of the program. After controlling for this inclination, the remaining difference between the two groups can then be associated with the technology. DID is convenient when the outcome values are different from the baseline, but it has its drawback which is the possible endogeneity of interventions themselves.

Another method which can be applied to evaluate the direct and indirect impact of a technology is an instrumental variables (IV) method.  Normally, any non-random assignment to a program creates a bias (Baker, 2000). Usually, one could control for some of these differences, including many observed attributes in the model, but mostly, participation or inclusion into the program would depend on measures that were not necessarily observable, for example convenience, logistic, political or budgetary deliberations. The IV approach uses another variable known as an instrument which is correlated with the assignment to treatment variable but is not affected by the bias (Khandker *et al*., 2010). The potential pitfalls of IV are bad instruments (those correlated with omitted variables or error term) and instruments that are weakly correlated with endogenous explanatory variables (Angrist & Krueger, 2001).

Reflexive comparison is a quasi-experiment research in which  initial  participants precedes the follow up survey of the intervention. Comparison of program participants with themselves is done with or without and taken as both control and treated subjects (Baker, 2000). But the design becomes favorable when evaluating the complete intervention where the whole population participates entirely. The main drawback with reflexive comparison is that the situation of the participants may change due to reasons independent of the intervention. In such cases, the method may not differentiate between the intervention and other outside causes, thus authenticity of findings is compromised (Morton, 2009;  Kibira *et al.*, 2015).

The other method most widely used is the matching technique, that is, propensity score matching (PSM). A set of observable attributes which are believed to affect program participation in the form of a "propensity score" are used to match the comparison subjects to the treatment subjects (Khandker *et al*., 2010). Given observable attributes, the propensity score is the predicted probability of participation in an intervention. The match is considered favorable when the propensity scores for the treatment and the control subjects are closer (Baker, 2000). On the other hand, the probability of observing two units with exactly similar value as the propensity score, p(X), is in principle zero since it's a continuous variable therefore, an estimate of the propensity score is not sufficient to calculate the average treatment effect (Becker & Ichino, 2002). Various ways have been suggested in the literature to deal with this problem, and four of the mostly used are Nearest-Neighbor Matching, Stratification Matching, Radius Matching and Kernel Matching (Baker, 2000; Becker & Ichino, 2002).

The stratification method is achieved by dividing the set of variation of the propensity score in intervals so that within each interval, treated and control groups have on average equal propensity score (Becker & Ichino, 2002). Similar blocks established by the algorithm that estimates the propensity score can be utilized. Then, computation of the change in average outcome of both treated and control subjects within each interval are done. The average treatment of the treated (ATT) is then attained as an average of the ATT of every block with weights given by the distribution of treated units across blocks (Becker & Ichino, 2002). One of the flaw of the stratification method is that it eliminates observations in blocks where either treated or control units are missing.

Nearest-Neighbor Matching (NNM) matches the treatment and comparison units with the closest propensity score (Baser, 2006). Although it is not necessary, the method is usually utilized with replacement, that is, a control subject can be matched to more than one treated subject. Once each treated subject is matched with a control subject, the difference between the outcome of the treated subjects and the outcome of the matched control subjects is calculated. An average of these differences is referred to as ATT. With NNM, all treated subjects have a match. However, some of these matches are fairly poor since for some treated units the nearest neighbor may have a very different propensity score, but still contribute to the calculation of the treatment effect regardless of this difference (Caliendo & Kopeinig, 2008).

This challenge is solved by the use of Kernel Matching (KM) and Radius Matching (RM) approaches. With RM, each treated subject is matched only with the control subjects whose propensity score lies into a predefined neighborhood of the propensity score of the treated subject (Becker & Ichino, 2002). If the radius of the neighborhood is set to be very small, some of the treated subjects may not match because the neighborhood might not contain control subjects, on the other hand, the smaller the size of the neighborhood, the better the quality of the matches. With KBM, all treated units are matched with a weighted average of all controls with weights that are inversely proportional to the distance between the propensity scores of both groups (Baker, 2000; Becker & Ichino, 2002). Due to the shortcomings of the other methods discussed, PSM with kernel based and radius matching techniques was employed in this study.

### 3.6.2 Estimation of the Average Treatment Effect of the Treated (ATT)

If IPM strategy was randomly assigned to farmers as in experimental data, one could evaluate the causal effect of technology use whether direct or in direct on farmer's income by comparing the difference in profitability of the crops between IPM users and non- users or through ordinary least squares. Farmers' participation or non- participation is determined by a set of socio-economic attributes because the process of selection is not random and hence a semi-parametric matching method to evaluate the spillover effects of the IPM technology was used. Since the adoption of most agricultural technologies is not random, this method is appropriate as it does not need any specification of the selection equation to reduce selection bias issues or design the counterfactual.

Furthermore, with cross-sectional data in a non-experimental approach, to solve selection bias challenge matching method is recommended. This is because, unlike the Heckman correction and Instrumental variable (IV) approach, which are also appropriate for non-experimental study in absence of panel data, the matching method addresses the selection bias problem without assuming the distributional and functional form or exogeneity of variables (Jalan & Ravallion, 2003; Heckman *et al.*, 1997).

Following Ariane & Guthiga (2012) this study models the indirect impact (spillovers) of participation and use of fruit fly IPM strategy by smallholder mango growers on profitability of other fruit crops. $Y_i$ is the outcome variable (gross margins as a proxy for profitability of the four crops) of the *i*th household- as a linear function of vector of independent covariates (**$X_i$**)**,** the vectors of parameters to be estimated are $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$, $P_i$= is IPM participation dummy variable which equals 1 if the technology is used by the farmer and 0 if not, while $\mu_i$is the error term (Equation (3.4).

$Y_i = \alpha X_i + \beta P_i + \mu_i$. ........................................................................... (3.4)

To calculate the profitability of crops, gross margin (GM) was obtained by calculating the total revenue (multiplying the yield by the "farm-gate" cost of the product), and deducting the variable costs of the production. Gross margins for pawpaw, avocado, citrus and bananas were calculated for each particular crop with a specific unit (one hectare) and a particular time frame (one year of a perennial crop) since the fruit trees are perennial. Total yield included the quantity consumed and sold while the variable costs were captured from the costs for material inputs - own or purchased farmyard manure, fertilizers, pesticides, herbicides, electricity/fuel for irrigation, value of family and hired labor, cost of land preparation using tractors, ox- plough or ox-cart for that season and any IPM cost incurred (equation 3.5).

$GM_i = TR_i - VC_i$ ........................................................................... (3.5) where

$GM_i$ = the gross margin of the *i*th household

$TR_i$= Total revenue of the *i*th household

$VC_i$=Variable costs *i*th household

Whether a farmer uses fruit fly IPM strategy or not is dependent on the household and farm attributes, resources, information access and social capital. Hence the decision by a farmer to participate in the IPM programme and use the technology is not randomly assigned but relies on farmers' self-selection. The index function to evaluate participation can be written as follows (Equation 3.6);

$P_i^* = aX_i + e_i$ ........................................................................ (3.6)

The difference between utility from participating in the fruit fly IPM programme and use of the technology $U_{iA}$ and the utility from not participating $U_{iN}$ is denoted by a latent variable $P_i^*$. If $P_i^* = U_{iA} - U_{iN} > 0$ then the farmer will participate in the technology. The difference in utility from participating ($U_{iA} - U_{iN}$) estimate is given by the term $aX_i$ considering the household and farm-level attributes as exogeneous conditions, with an error term $e_i$. In estimating Eqns. (3.4) and (3.6), it is noted that the relationship between the fruit fly IPM strategy and outcome (gross margin) could be interdependent. That is, technology helps increase output and therefore the wealthier households are expected to be better adopters of new technologies. This also means that there will be selection bias problem because of IPM participants being systematically different.

The first step in matching technique uses a discrete choice model. To estimate the probability of participation and use IPM technology for suppression of mango fruit fly a logit model was used. Following Kassa *et al*. (2013) the probability, $p_i$ that the household participates in the IPM programme and use the technology is given as shown in Equation 3.7:

$$p_i = \frac{e^{w_i}}{1+e^{w_i}} \quad \ldots\ldots (3.7)$$

where, $w_i$ is a latent covariate that takes the value of 1 if the farmer participated in IPM programme and use the technology and 0 otherwise. Following Wainaina (2012), a logit transformation of P is given by w and is expressed as in Equation 3.8;

$$w_i = \ln\left(\frac{P}{1-P}\right) \ldots\ldots (3.8)$$

where Equation 3.9;

$$\mathbf{w}_i = a_0 + \sum_{i=1}^{n} a_i X_i + U_i \quad \ldots\ldots (3.9)$$

i = 1, 2, 3, - - -, n, $\mathbf{w}_i$ is a vector of outcome covariates for household *i* (gross margins of pawpaw, oranges, avocado and bananas), $a_0$ is intercept, $a_i$ is the coefficient of the explanatory variables to be estimated, while $U_i$ is a disturbance term. $X_i$ represents the household characteristics for household *i* that affect the gross margins. The choice of the explanatory variables that were used in the empirical analysis of cross-commodity spillover effects from IPM technology impact were dictated by the participation and profitability condition as shown in literature. Farm profitability at each time, depend on farm and household attributes (farm size, age, gender, education level) and the information variables; contacts with extension services, membership to groups and trainings on production (Genius *et al*., 2013). The corresponding probability of non-participation is given by Equation 3.10:

$$1 - p_i \frac{1}{1+e^{w_i}} \quad (3.10)$$

Kassa et al. (2013) noted that in generating the propensity score using logit model, the predictor covariates which determines the method of selection or adoption of a technology and the resultant effect should be included. As shown in equation 3.11, $P(X)$ refers to the odds ratio or the conditional probability that a household participates in the IPM strategy given the following variables.

$$\begin{aligned} P(X) = {} & \beta_0 + \beta_1 age + \beta_2 gender + \beta_3 householdsize + \beta_4 education \\ & + \beta_5 cultivatable\ land + \beta_6 livestock + \beta_7 off\ farm\ income + \beta_8 credit \\ & + \beta_9 distance\ to\ tarmac + \beta_{10}\ public\ transport\ system \\ & + \beta_{11} input\ market\ distance + \beta_{12}\ product\ market\ distance \\ & + \beta_{13}\ distance\ to\ source\ of\ information + \beta_{14}\ agricultural\ training \\ & + \beta_{15}\ means\ of\ communication + \beta_{16}\ means\ of\ transport \\ & + \beta_{17}\ group\ membership + \beta_{18}\ irrigation + \beta_{19}\ manure\ or\ fertilizer \\ & + \beta_{20} years\ producing\ mango + \mu_i \quad (3.11) \end{aligned}$$

Literature suggests matching algorithms which are essentially supposed to yield same results. However, Caliendo & Kopeinig (2008) noted that this may not be possible due to apparent bias present in each algorithm. This study implemented two matching algorithms; KBM and RM because a accepted level on the minimum propensity score distance is imposed (Caliendo & Kopeinig, 2008). Nearest neighbor matching (NNM) was omitted as it discards a large number of observations and also provides poor matches especially if the closest neighbor is very far thus leading to declined power (Caliendo & Kopeinig, 2008). Stratification method discards the observations in blocks where either control or treated subjects are absent. Mahalanobis Metric Matching (MMM) matches samples on a scalar function of $\boldsymbol{X}$, referred to as Mahalanobis Distance (MD), the distance between a control and treatment subjects in the high dimensional space of $\boldsymbol{X}$. Rosenbaum & Rubin (1985) showed that MMM was far less successful in reducing the standardized mean difference on e(x), the scalar function of the covariates.

The difference between expected outcome values with and without treatment for those who actually participated in treatment is referred to as ATT (Equation 3.12) (Caliendo & Kopeinig, 2008).

$$ATT_i = \mathrm{E}(M_{1i}|\mathrm{S} = 1) - \mathrm{E}(M_{0i}|\mathrm{S} = 1) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.12)}$$

$ATT_i$ in this study, is the difference between the actual gross margins for the four fruit crops i.e. pawpaw, avocado, citrus and bananas of the *i*th farmer and the gross margins if the *i*th farmer did not use IPM, after controlling for exogenous variables. $M_{1i}$ is the gross margins for pawpaw, avocado, citrus and bananas of the *i*th farmer who participated in the program and used IPM (S=1) while $M_{0i}$ is the gross margin of the *i*th farmer if he had not participated in the program. Caliendo & Kopeinig, (2008) highlights that one has to select a good replacement for the unobserved average for those being treated- $\mathrm{E}(M_{0i}|\mathrm{S} = 1)$ in order to estimate ATT. It is usually not a wise idea to use the mean outcome of untreated subjects $\mathrm{E}(M_{0i}|\mathrm{S} = 0)$ in non-experimental studies since it is probable that attributes that determine the selection decision also determines the outcome variable of interest. Therefore, even in the absence of treatment leading to a 'selection bias' the outcomes from both the treatment and comparison groups would be different (*ibid*). ATT is shown by Equation 3.13;

$\mathrm{E}(M_{1i}|\mathrm{S}=1) - \mathrm{E}(M_{0i}|\mathrm{S}=0) = ATT_i + \mathrm{E}(M_{0i}|\mathrm{S}=1) - \mathrm{E}(M_{0i}|\mathrm{S}=0)$...................................... (3.13)

Selection bias (Equation 3.14, $\varepsilon = \mathrm{E}(M_{0i}|\mathrm{S}=1) - \mathrm{E}(M_{0i}|\mathrm{S}=0)$ .......................................... (3.14)

The difference between the counterfactual and the non- adopters should be zero for non-adopters of IPM to be considered as an adequate comparison group to give a true parameter of ATT, but one has to invoke some identifying assumptions to deal with the selection problem stated in equation 3.13 and 3.14 because this condition is rarely met with non- experimental data (Equation 3.15).

$\mathrm{E}(M_{0i}|\mathrm{S}=1) - \mathrm{E}(M_{0i}|\mathrm{S}=0) = 0$ ........................................................................................................ (3.15)

The conditional independence assumption (CIA), implies selection into the treatment group depend solely on observable attributes, and the overlap condition (Caliendo & Kopeinig, 2008). The area where balancing of scores have positive density for both treatment and comparison subjects is known as common support. No matches can be found to estimate the ATT parameter when there is no overlap between the control and treatment subjects. The spillover effects of the fruit fly IPM strategy come as a result of impact on host crops when a farmer uses the strategy on mangoes. Therefore, the set up for estimating the spillover effects (indirect impacts), was not different from estimation of direct impact of the IPM technology.

The balance requirement should be met by attributes included in the model. To check for differences in average propensity scores between users and non-users of the fruit fly IPM strategy conditional on *X*, this study used statistical significance and the pseudo-$R^2$ test. Balance requirement is met when there are insignificance differences in the propensity scores of the treatment and control. Common support condition is imposed to ensure that any integration of attributes observed for the treatment subjects can also be observed among the control subjects. It requires dropping all observations out of the overlapping region whose propensity scores are lower than minimal and higher than the maximal, of the treatment and control subjects respectively (*ibid*).

The distribution of covariates balancing across the adopter and non- adopter groups was also used to check the matching quality. This was done by use of standardized bias (SB) and *t*-test for differences (see Rosenbaum & Rubin, 1985). In addition, Sianesi (2004) and Wu *et al.* (2010) suggest re-estimating the propensity scores using only adopters and matching non-adopters. The value of the associated pseudo-$R^2$ should be fairly low if the explanatory variables $X$ are randomly distributed across adopter and non-adopter groups. With non-experimental data it is not possible to calculate the magnitude of selection bias after checking the robustness of results, the challenge was addressed by sensitivity analysis. The fundamental idea behind all these approaches is to check if after conditioning on the propensity score there are any differences that remains and comparison of the situation before and after matching (Caliendo & Kopeinig, 2008; Wu *et al*., 2010).

According to Muriithi *et al.* (2016) adoption of two or more components of IPM technology is influenced by socio-economic characteristics, access to information, institutional and market services, social capital and farm or plot characteristics. Socio-economic characteristics controlled for household heterogeneity by adding household size, age, education level and gender of the household head to the model. These were relevant covariates that may influence farm management decisions and consequently determine the profitability of fruit crops.

**Table 1: Description of the hypothesized explanatory variables**

| Variables | Description | Expected sign |
|---|---|---|
| *Socio-economic characteristics* | | |
| Gender of the decision maker | 0=Female 1= Male | + |
| Decision makers's age | Age of the decision maker in a household in years | −/+ |
| Education level of the decision maker | Years in school of the decision maker in a household | + |
| Total family size (number) | Number of members of a household | + |
| *Household resource endowment* | | |
| Agricultural cultivatable land | Size of cultivatable land in hectares | + |
| Household livestock holding in Tropical Livestock Units (TLU) | Number of livestock household owns in TLU | + |
| Household have access to off-farm income | 1= access to off-farm income<br>0= no off- fam income | + |
| Household have access to agricultural credit | 1= access to agricultural credit in the last one year<br>0= no access to credit | + |
| *Access to information, institutional and market services* | | |
| Distance to the nearest tarmac road | Distance to the nearest tarmac road in kilometers | + |
| If public transport system is available in this village | 1= Avalability of public transport in the village<br>0= Public transport not available in the village | + |
| Distance to nearest input market | Distance to the nearest input market in kilometers | - |
| Distance to nearest product market | Distance to the nearest product market in kilometers | + |
| Distance to the nearest extension | Distance to the nearest extension service provider | + |

| | | |
|---|---|---|
| service provider | in kilometers | |
| Training on agricultural production | 1= trained on agricultural production in the last one year<br>0= Not trained in agricultural production in the last one year | + |
| If household owns a communication equipment (TV/radio/phone) | 1= Yes<br>0= No | + |
| If a household owns a transport facility (car\van/motorbike/bicycle) | 1=Yes<br>0=No | + |
| *Social capital* | | |
| Household belong to a mango production group or organization | 1= Any of the household member belonged to a mango production group<br>0=No | + |
| *Plot/farm characteristics* | | |
| Access to irrigation water | 1= Household access to irrigation water<br>0= No access | + |
| Use manure/fertilizer on either avocado/citrus/pawpaw/ banana | 1= If the household head used manure or fertilizer on the four crops<br>0= No | + |
| Experience in mango production | Number of years in production of mango | + |

Age as a factor is contentious in many studies since some take it to negatively influence adoption while others notes that it influences adoption positively (Miyinzi, 2016). An explanation to these different views are that age is associated with ambitions, innovativeness, risk perceptions and vigour for work (*ibid*). Education improves the skills and ability of farmers to utilize knowledge and information on the use of a technology to solve their crop production constraints (Muriithi *et al*., 2016). With regard to household resource endowment, this study used the size of cultivatable land, livestock owned by the household, members of he household access to off-farm income and agricultural credit. Dummy variables for off-farm income and agricultural credit were included as indicators for working capital, that a farmer may use to invest in a new agricultural technology or innovation (Kassie *et al*., 2013). Similarly, large herds of livestock may provide alternative working capital for technology investment, but also tend reduce labor availability for other agricultural activities. Farmers with bigger landholdings are assumed to have ability to adopt improved technologies that may enhance farm productivity and thus level of farm income.

As noted by Minot and Ngigi, (2004) and Muriithi and Matz (2014), households closer to market towns, which are characterized by presence of tarmac roads, are likely to engage more in non-farm activities such as small businesses compared to households that are further away from market centers and whose livelihood opportunities are limited to farm enterprises thus positively influence adoption . Alternative sources of employment are however known to compete for time with agricultural activities that may reduce investment in agricultural technology and labor availability. Farms situated further away from urban areas are more likely to invest in agricultural technologies. Distance to the nearest output market influenced the level of marketed output (Muriithi & Matz, 2014).

Access to extension services remains a relevant channel for agricultural technologies and thus increased level of farm income. Agricultural training, on the other hand, enhances access to information that is important for making informed decisions on taking up new innovations (Swaans *et al*., 2013). Similarly, ownership of a means of communication and a means of transport may enhance access to agricultural production and marketing information that may impact on uptake of new technologies.

Individuals' social networks impacts on agricultural technology adoption and farm-income (Shiferaw *et al*., 2011). Social networks facilitate the exchange of information and helps farmers to have timely access inputs and deal with credit constraints and shocks in cases where markets are imperfect, especially in the rural settings (Kassie *et al*., 2015). Farmers can earn more income from their farms by reducing transaction costs and improving their negotiating power. Access to irrigation water is necessary for uptake of IPM packages, for instance, bio-pesticide which requires moist soil for efficient operation, thus having a positive effect on farm income. Use of manure and fertilizer in the cultivated fruit crops orchard is also an important factor that has been considered in many adoption studies (Kibira *et al.*, 2015).

# CHAPTER FOUR RESULTS AND DISCUSSION

## 4.1 Characteristics of Sampled Households

Definitions and descriptive statistics of the common household-level covariates that were expected to influence farm income and technology adoption were as shown in Table 2. The model specification draws from review of economic theory and empirical literature on the adoption of agricultural technologies and spillover effects literature, discussed in chapter 3. Three (3) households were dropped from the selected sample due to missing data and apparent enumerator errors, leaving a sample of 371 mango growing households that were utilized in the analysis.

On average, fruit fly IPM users had significantly more years of schooling in comparison with the non-users. Majority (80%) of the interviewed households were male-headed, with average household head's age being 55.5 years. Old age of the household head is often related to risk aversion or less flexibility in adopting new technologies (Hristovska, 2009; Witt *et al*., 2011). Older household heads tend to be more experienced in production practices and greater accumulation of physical and social capital, that may facilitate technology adoption (Kassie *et al*. 2015).

On average fruit fly IPM users had significantly larger farms that is 2.56 hectares and more livestock measured in Tropical livestock units (TLU) of 2.40 compared to the control households who had on average 1.58 hectares of cultivatable land and 1.86 TLU. Farmers with larger plots are considered to have the ability to adopt agricultural technologies more than those with smaller plots (Muriithi *et al.,* 2016).

**Table 2:** Selected farm and household characteristics comparing fruit fly IPM users and non-users

| Variables | Description of variables | **IPM users (n=209)** | | **IPM non-users(n=162)** | | **t-test** | |
|---|---|---|---|---|---|---|---|
| | | Mean (A) | Standard deviation | Mean (B) | Standard deviation | Difference (A-B) | t-value |
| *Household characteristics* | | | | | | | |
| Gender of the decision maker | 1= if gender of the decision maker is male; 0=female | 0.822 | 0.38 | 0.779 | 0.42 | -0.04 | 1.03 |
| Head age | Age of the decision maker (years) | 55.00 | 12.44 | 56.00 | 13.20 | 1.00 | 0.58 |
| Head education | Education level of the household head (years of schooling) | 9.06 | 3.82 | 7.79 | 4.61 | 1.27 | 2.90*** |
| Household size | total family size (number) | 4.93 | 2.12 | 5.06 | 2.10 | -0.13 | 0.58 |
| *Household resource endowment* | | | | | | | |
| Cultivatable land | Agricultural cultivatable land (hectares) | 2.56 | 5.81 | 1.58 | 4.54 | 0.98 | 4.354*** |
| Livestock | Household livestock holding in Tropical Livestock Units (TLU) | 2.40 | 1.60 | 1.86 | 1.02 | 0.54 | 3.77*** |
| Off-farm income | If household have access to off-farm income (1=Yes,0=No) | 0.53 | 0.50 | 0.47 | 0.50 | 0.06 | 1.36 |
| Agricultural credit | If household have access to agricultural credit (1=Yes,0=No) | 0.26 | 0.44 | 0.24 | 0.43 | 0.02 | 0.55 |
| *Access to information, institutional and market services* | | | | | | | |
| Distance to tarmac road | Distance to the nearest tarmac (km) | 17.2 | 11.08 | 2.3 | 3.27 | 14.9 | 16.56*** |
| Public transport system | If public transport system is available in the village (1=Yes,0=No) | 0.97 | 0.18 | 0.888 | 0.33 | 0.082 | 3.316*** |
| Distance to input market | Distance to nearest input market (km) | 16.6 | 8.38 | 9.9 | 6.33 | 6.7 | 2.63*** |
| Distance to product market | Distance to nearest product market (km) | 25.4 | 9.86 | 15.3 | 3.96 | 10.1 | 1.24 |
| Distance to extension service provider | Distance to the nearest extension service provider (km) | 3.06 | 8.14 | 3.23 | 6.57 | -0.17 | 0.21 |
| Agricultural training | Training on agricultural production (1=Yes,0=No) | 0.76 | 0.43 | 0.46 | 0.50 | 0.30 | -6.33*** |
| Means of communication | If household owns a communication equipment (TV/radio/phone (1=Yes,0=No) | 0.10 | 0.07 | 0.98 | 0.15 | -0.88 | 1.64 |
| Means of transport | If a household owns a transport means (car\van/motorbike/ bicycle (1=Yes,0=No) | 0.79 | 0.41 | 0.72 | 0.45 | 0.07 | 1.56 |
| *Social capital* | | | | | | | |
| Mango farmers' group membership | Household belong to a mango production group or organization (1=Yes,0=No) | 0.70 | 0.48 | 0.63 | 0.46 | 0.07 | 1.31 |
| *Plot/farm characteristics* | | | | | | | |
| Irrigation access | Access to irrigation water (1=Yes,0=No) | 0.54 | 0.50 | 0.39 | 0.49 | 0.15 | -2.98*** |
| Use manure/fertilizer | Use manure or fertilizer on either mango/avocado/citrus / pawpaw (1=Yes,0=No) | 0.95 | 1.68 | 0.91 | 2.34 | 0.04 | 1.26 |
| Mango farming experience | Number of years the farmer has been producing mango | 27 | 8.85 | 28 | 8.71 | -1.00 | 0.06 |

*Note:*, ** and **** indicate significance at 10%, 5% and 1% levels respectively
*Source:* Own survey data

Distance to the tarmac road was significantly different for the IPM users and non- users. IPM farmers were as far as 17.2 kilometeres (KM) while the non- users were 2.3 KM from the tarmac road. As was expected, Muriithi and Matz (2014) found out that households closer to tarmac roads where markets are situated are likely to engage more in non-farm activities. Alternative sources of employment characterized by off- farm income in this study are known to take up time which would have otherwise been used by agricultural activities hence reducing investment in agricultural technology. Distance to the input market was also significantly different for the two groups as IPM users were 16.6 KM away from the input market while IPM non- users were 9.9 KM away. These meant that farmers in the treatment region would only use IPM technologies because of its availability compared to the longer distance they would have travelled to buy the conventional pesticides.

Access to extension services remained a relevant channel for agricultural technologies adoption and thus increased leve of farm income. A significantly bigger proportion of the fruit fly IPM users had attended agricultural training compared to the control group. Midingoyi *et al.* (2018) noted the importance of training,extension services and membership to groups as important factors in adoption of IPM technology. Group membership however compared between the treatment and the control subjects. Access to irrigation water was significantly different between the treatment and control subjects. The fruit fly IPM users had more households accessing irrigation water, which is necessary for uptake of some of the IPM packages like the biopesticide spray.

### 4.2 Farm crop enterprises

All of the interviewed farmers in the region grew mango as their main economic activity followed by other fruit trees like bananas 84%, avocado 73%, maize 70%, pawpaw 69%, oranges 51% and macadamia 29% (Figure 3). Other crops grown were cashew nuts, pigeon peas, pumpkins, butternuts, water melon, passion fruits, groundnuts, and cash crops such as coffee and miraa (*Khat*). These crops were either intercropped (44%) with fruit trees or were grown as pure stands (56%). Farmers who had access to irrigation water were 50% but only a few farmers were irrigating their farms with a mean percent of the irrigated land of 17% for both the treatment and the control subjects. The farmers therefore relied on rain fed agriculture.

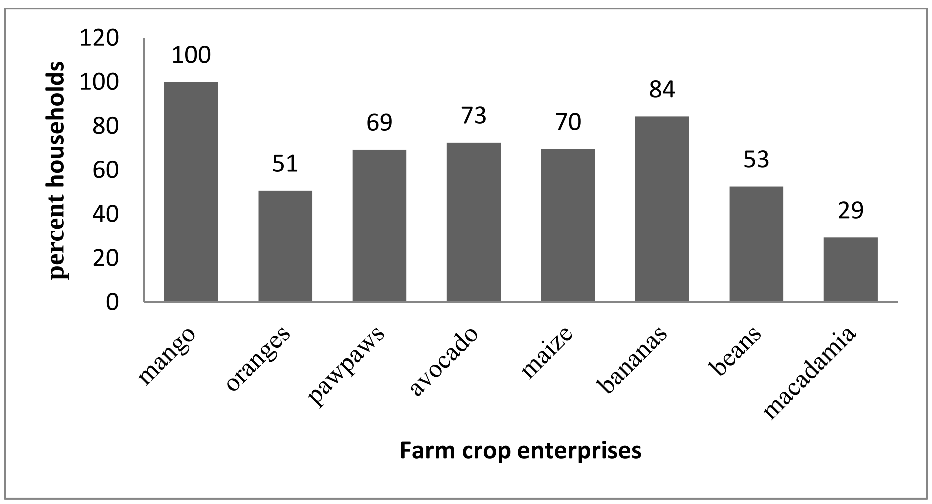



**Figure 3**: Farm crop enterprises in Meru County

### 4.3 Crops Applying Mango IPM Technologies for Fruit Fly Control

The more crops a farmer grew that benefit from the IPM technology, the more likely they would have benefits from spillover effects of the technology. This means that the cost of IPM is spread across a number of products hence economies of scale**.** Most of the crops which were either intercropped with mangoes or were in adjacent fields acted as hosts to fruit fly when mango fruits were off season. Results showed that 56% percent of the interviewed farmers were applying mango IPM strategy on mango and effect was also evident in other fruit crops like oranges, pawpaw, lemons, water melons, cashew nuts, butter nuts, passion and guava with improved quality and quantity of the produce.

This finding is in line with other researchers who have noted that *B. dorsalis* infests cultivated and local tropical fruits (Mwatawala *et al.,* 2006, 2009; Biasazin *et al*., 2014; Cugala *et al.*, 2014). The results also supports findings of other researchers who acknowledged that although the primary host of *B. dorsalis* is mangoes, the preferred hosts vary according to the region, climate, and host availability (Ekesi *et al*., 2006; Vayssieres *et al.*, 2010; Goergen *et al.,* 2011).

Results from t-test in Table 2 show that there was a significant difference in the acreage of the crops applying IPM technology (mangoes *p= 0.0000*, avocado *p= 0.0243*, oranges *p=0.0014*, pawpaw *p=0.0000*) for the control and treatment group except in bananas.

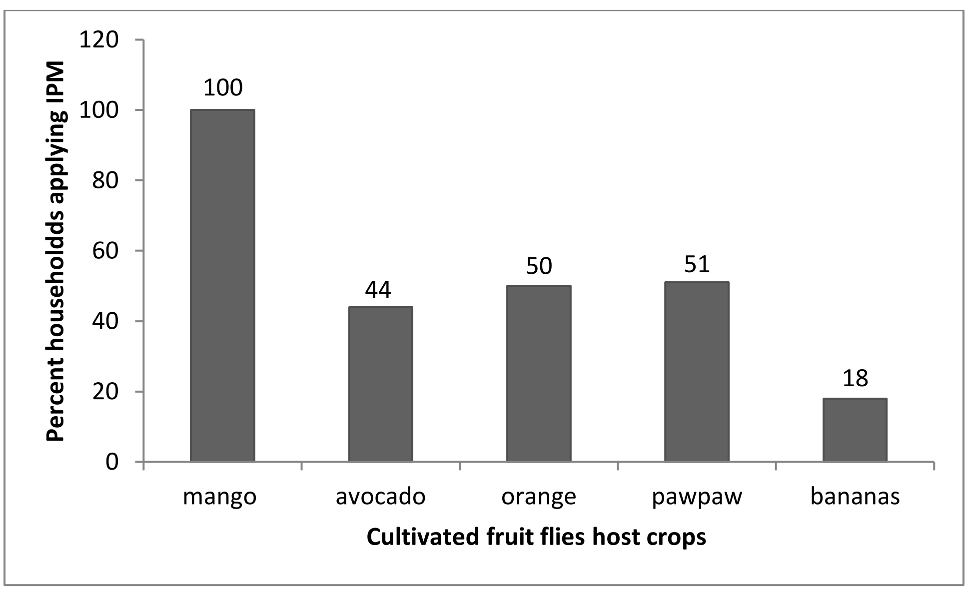



**Figure 4:** Percentage of IPM users who had planted alternative fruit flies' host crops
*Source*: Author's computation

Figure 4 shows percent of IPM participants who used IPM suppression technology on mangoes and had also planted other alternate hosts, specifically avocado, oranges, pawpaw and bananas. Out of 208 farmers from the treatment group 44% had grown avocadoes, 50% had oranges, 51% had pawpaw and 18% had bananas and all of these crops benefitted from the IPM technology used in mango orchards. The mean hectares of mangos, oranges and pawpaw was more in the treatment area while in the control region farmers had more acres under avocado, bananas and macadamia.

**Table 3:** Average land size allocated to selected cultivated fruit flies host crops in hectares

| Crop name | IPM users | IPM non-users | t-test | p-value |
|---|---|---|---|---|
| Mango | 0.967 | 0.291 | 6.3009 | 0.0000*** |
| Avocado | 0.040 | 0.089 | -2.2619 | 0.0243** |
| Oranges | 0.194 | 0.049 | 3.2593 | 0.0014*** |
| Pawpaw | 0.065 | 0.004 | 5.3227 | 0.0000*** |
| Bananas | 0.134 | 0.227 | -1.5488 | 0.1223 |

*Notes: *, *** and *** denote significant at 10%, 5% and 1% significance levels respectively
*Source*: Survey data

### 4.4 Gross Margins

The gross margins per hectare of mango, avocado, oranges, pawpaw and bananas were as shown in Table 4. There was a significant difference in the calculated average gross margins per hectare of mangoes, avocado, oranges, pawpaw and bananas between the adopters and the non- adopters.

**Table 4:** Gross margin (Ksh/per hectare of major cultivated fruit flies host crops

| **Crop** | **IPM users (n=209)** | **IPM non-users (n=162)** | **Difference** | **t-test** |
|---|---|---|---|---|
| Mango | 76,527 | 31,705 | 44,822*** | 5.1400 |
| Avocado | 30,176 | 67,866 | (37,690) *** | -6.1288 |
| Citrus | 51,513 | 27,112 | 24401*** | 3.7096 |
| Pawpaw | 159,614 | 84,444 | 75,170*** | 3.5699 |
| Bananas | 44,814 | 98,751 | (53,937) *** | -6.6430 |

*Notes:* The exchange rate during the survey was approximately 91 Kenya Shilling (Ksh/US$); *, ** *and* *** denote significant at 10%, 5% and 1% significance levels respectively
*Source*: Study survey data

The mean gross margins (GMs) for IPM uses and the non-users for the four crops in Kshs are 30,176 and 67,866 for avocadoes, 51,513 and 27,112 for citrus, 159,614 and 84,444 for pawpaw, 44,814 and 98,751 for bananas respectively. Thus, GMs for avocado and bananas were lower for the treatment group. The farmers from the control group reported to be growing avocado and bananas as their main cash crops unlike the treatment group.

### 4.5 Empirical Analysis

#### 4.5.1 Factors Influencing use of IPM Technology by Farmers on Non- Mango Fruit Crops

To assess the spillover effects of applying the IPM strategy propensity score matching was applied. The matching process is preceded by specification of the propensity scores using a logit model with the results as presented in Table 5. Empirical analysis was carried out using the STATA statistical package. The dependent variable is a binary variable defined as 1 if the household used the strategy and zero otherwise. Prior to running the model, a test is conducted to detect the problem of multicollinearity between the covariates included in the analysis (Molefe & Hosmane, 2007). According to Maddala (1993), a VIF above 10 signifies the existence of multicollinearity. Salaried household member and off-farm income were correlating (see appendix 3) hence one variable was dropped.

The mean VIF was 1.36; all the variables in the model had a VIF far less than 10 which satisfy the rule of thumb. The suitability of the model is examined by overall goodness-of-fit tests once a logistic regression model has been fit to a given set of data (Archer *et al.*, 2007). Link test was used which regresses the dependent variable (y) on the predicted y value and the square of the predicted y value. If the quadratic term or the square of the predicted values is statistically significant, this is interpreted as a sign that the original model is not correctly specified (*ibid*). In this study the square of the predicted value of y was insignificant at *p* (0.811) while the predicted value of y was significant at *p* (0.000) which was in line with theory (Molefe & Hosmane, 2007).

**Table 5:** Propensity score estimates: Logit estimates

| Explanatory variables | Coefficient | Std Error | P-value |
|---|---|---|---|
| Dependent variable: [1= IPM participant 0=Non-Participant] | | | |
| *Socio-economic characteristics* | | | |
| Gender of household head is male (1=Male 0=Female) | 0.22 | 0.32 | 0.493 |
| Age of the household head (years) | -0.02* | 0.01 | 0.063 |
| Education level of the household head (years of schooling) | 0.05 | 0.03 | 0.156 |
| Total family size (number) | -0.08 | 0.06 | 0.211 |
| *Household resource endowment* | | | |
| Agricultural cultivatable land (hectares) | 0.08** | 0.03 | 0.007 |
| Household livestock holding in Tropical Livestock Units (TLU) | 0.14 | 0.10 | 0.168 |
| Household accessing off-farm income (1=Yes,0=No) | -0.35** | 0.16 | 0.031 |
| Household have access to agricultural credit (1=Yes,0=No) | 0.14 | 0.29 | 0.631 |
| *Access to information, institutional and market services* | | | |
| Distance to the nearest tarmac road (km) | 0.006 | 0.01 | 0.555 |
| If public transport system is available in this village (1=Yes,0=No) | 0.64** | 0.32 | 0.045 |
| Distance to nearest input market (km) | 0.24 | 0.20 | 0.294 |
| Distance to nearest product market (km) | -0.028 | 0.29 | 0.337 |
| Distance to the nearest extension service provider (km) | 0.03 | 0.02 | 0.192 |
| Training on agricultural production (1=Yes,0=No) | 0.74*** | 0.27 | 0.000 |
| If household owns a communication equipment (TV/radio/phone)(1=Yes,0=No) | 0.44 | 0.79 | 0.729 |
| If a household owns a transport facility (car\van/motorbike/bicycle) (1=Yes,0=No) | 0.21 | 0.30 | 0.467 |
| *Social capital* | | | |
| Household belong to a mango production group or organization (1=Yes,0=No) | 0.89*** | 0.02 | 0.002 |
| *Plot/farm characteristics* | | | |
| Access to irrigation water (1=Yes,0=No) | 0.57** | 0.26 | 0.028 |
| Use manure/fertilizer on either mango/avocado/orange/pawpaw (1=Yes,0=No) | 0.36 | 0.27 | 0.172 |
| Number of years the farmer has been producing mango | 0.05*** | 0.02 | 0.002 |
| Constant | -1.90 | 1.67 | 0.253 |
| Number of observations | 371 | | |
| Psuedo $R^2$ | 0.194 | | |

*Notes: *, ** and **** indicate significance at 10%, 5%, and 1% levels respectively

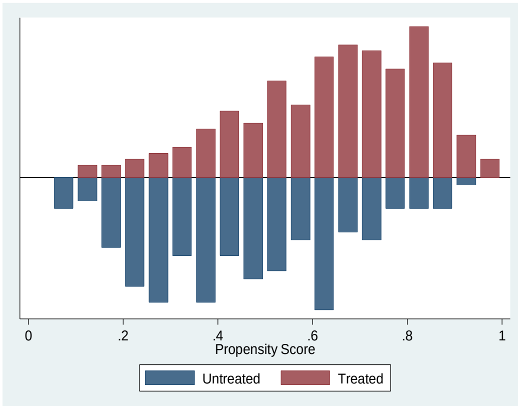
*Source*: Own survey

The Hosmer and Lemeshow's test, large *p*-value of 0.9929 shows that the model fits the data well. Table 5 shows the pseudo $R^2$ and the *p*- values from the likelihood ratio tests results before and after matching.

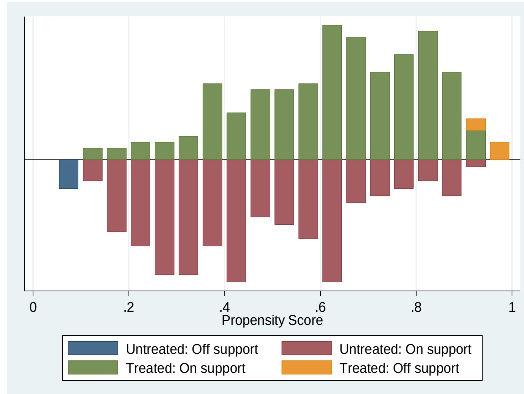
The results of estimation of the logit shows that household head's age, whether any of the members of the household had a salaried employment, area under cultivation, a household had access to public transport system, access to irrigation water, whether any household member belonged to a mango production group, also if a household member had attended training on mango production in the past one year and number of years the farmer has been producing mango influences the use of IPM. Holding other variables constant, the size of cultivatable agricultural land positively influences farmer's application of mango IPM at 5 percent level of significance. The results are in line with those of other authors for instance (Ali & Abdulai, 2010; Wu *et al*., 2010). This means that the farmers with bigger land sizes are more likely to apply IPM strategy. Attendance to trainings positively increases the probability of participating in the technology at 1 percent level of significance. Results indicate the probability of applying IPM for those farmers who had attended training is higher by 74% compared to those who never attended trainings. This suggests that farmers who attended trainings are more knowledgeable on the advantages to damage control measures in crop production like the IPM. These results are in line with those of other authors who found that respondents who attended trainings have better access to information which may increase adoption of innovations such as IPM strategies for suppression of mango fruit flies (Witt *et al*., 2008; Hristovska, 2009; Swaans *et al*., 2013). Access to irrigation water also positively influenced farmers' participation in the IPM technology at 5% level of significance. Since some of the components of the package (use of Metarhizium anisopliae-based fungal bio pesticides) required availability of water to wet the ground, it was important for farmers to have water in their farms.

### 4.5.2 Spillover Effects of IPM Technology on Profitability of other crops

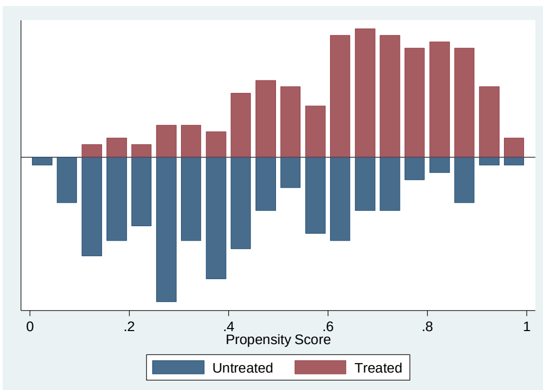
Propensity scores using trimming option were estimated for all the 371 mango growers including 209 IPM users (treated) and 162 in the control group. Among the IPM adopters, the predicted propensity score ranged from 0.0468 - 1 with a mean of 0.9110. Among the non- adopters the predicted propensity score ranged from 0. 0028 - 1 with a mean of 0.1255. This study found out that there was a considerable overlap in common support. Estimated propensity scores for IPM users and non- users are presented in histograms as shown in Figure 5.



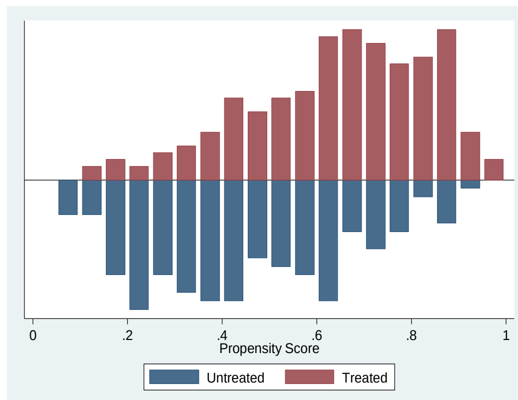

Effect on avocado gross margin




Effect on oranges gross margin




Effect on pawpaw gross margin




Effect on banana gross margin

**Figure 5**: Propensity score ditribution and common support for propensity score estimation

***Note:*** Treated on support found a suitable match among those who did not participate while off support were treated individuals (adopter) who did not find a suitable match.

A visual look of the density distributions of the estimated propensity scores for the treatment and control subjects indicated that common support condition was satisfied; there was substantial overlap in the distribution of the propensity scores of both adopters and non-adopters. The upper half of the graph shows the propensity scores distribution for the adopters and the bottom half refers to the non- adopters. The histogram shows that all the treated individuals were on support on effect of IPM on gross margin of avocado, pawpaw and bananas indicating that all the IPM users (treated) found a suitable match among the IPM non-users (control), but there was off support in the case of oranges meaning there were treated individuals (users) who did not find a suitable match.

Estimation of propensity score is aimed at balancing the distribution of relevant covariates in the treatment and control groups. To examine the balancing powers of the estimation, decline in median absolute bias between the matched and unmatched models was used as presented in Table 6. It is evident from the results that substantial decline in bias was obtained after matching (columns 7 and 8).

**Table 6:** Indicators of covariate balancing, before and after matching

| Crop enterprise [1] | Matching alogarithm [2] | Pseudo R-squared (unmatched) [3] | Pseudo R-squared (matched) [4] | *P*-value of LR (unmatched) [5] | *P*-value of LR (matched) [6] | Median absolute bias (before matching) [7] | Median absolute bias (after matching) [8] | %bias reduction [9] |
|---|---|---|---|---|---|---|---|---|
| Avocado | KBM | 0.185 | 0.017 | 0.000*** | 0.591 | 14.2 | 5.4 | 52.6 |
| | RM | 0.185 | 0.006 | 0.000*** | 0.984 | 14.2 | 3.5 | 54.5 |
| Citrus | KBM | 0.190 | 0.017 | 0.000*** | 0.629 | 15.2 | 5.0 | 31.2 |
| | RM | 0.190 | 0.012 | 0.000*** | 0.986 | 15.2 | 4.7 | 48.5 |
| Pawpaw | KBM | 0.186 | 0.018 | 0.000*** | 0.552 | 14.0 | 4.4 | 38.9 |
| | RM | 0.186 | 0.013 | 0.000*** | 0.785 | 14.0 | 3.9 | 44.1 |
| Bananas | KBM | 0.185 | 0.017 | 0.000*** | 0.589 | 13.9 | 5.2 | 53.1 |
| | RM | 0.185 | 0.013 | 0.000*** | 0.757 | 13.9 | 4.4 | 61.7 |

*Notes:* *, ** and *** denote significant at 10%, 5% and 1% significance levels respectively; KBM= Kernel Based matching with band width 0.03 and common support; RM= Radius matching with 0.03 caliper and common support

*Source:* Author's computation using survey data

The reductions in bias are all greater than 20 percent and hence considered large (Rosenbaum & Rubin, 1985; Ali & Abdulai, 2010). The joint significance of the independent variables is always rejected after matching; this is the case with KBM and RM, that is there is no difference in the distribution of variables between the participants and non- participants.

The estimates of the average treatment effects (ATT) by the KBM and RM methods are shown in Table 7. The matching results showed that application of the IPM had a positive and significant effect on gross margins of pawpaw and citrus, but avocado and bananas had negative and significant effect on gross margins. The IPM technology for suppression of mango fruit flies increased the average gross margin for pawpaw and citrus in the range of Ksh 25,216 to 32,093 and Ksh 24,643 to 33,936 per year per hectare using KBM and RM respectively and hence more income to the farmer. The negative causal effect for avocado and bananas implied that fruit fly IPM users had lower gross margins per hectare in the two crops compared to non-users.

Although the negative outcome was unexpected in respect of the gross margins of avocado and banana, the qualitative information gathered during the survey revealed that avocado and banana tended to be more popular as cash crops among farmers in the control area compared with citrus and pawpaw, which dominated among farmers in the treatment area. Furthermore, relatively larger plantations of banana production were characterised by economies of scale in production, in that they needed fairly monitoring labour input, less specialised extension Delgado (1999), and less pest and disease control measures. This could offer additional insight into the higher gross margins for banana crops in the control area in comparison with the treatment area, as the former reported larger areas under cultivation for banana compared with the latter (see Table 3). On the other hand, as observed by Mwatawala *et al.* (2006) and (Rwomushana *et al.* (2008), in order of preference, B. dosaris wound first select mango as a host and then citrus, with avocado and banana being least preferred. The higher gross margins in the control group with regard to avocado and banana could be attributed to the fact that farmers in the control region embraced avocado and bananas as cash crops and it was their main economic activity in that area as gathered during the survey. Mwatawala *et al*. (2006) observed that in Tanzania mango was the most preferred host of *B.dosaris* followed by citrus with avocado and bananas being in the less preferred category of the fruit fly.[1]

**Table 7:** Average treatment effects of fruit fly IPM strategy

| | | Average gross margin before and after matching | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Crop enterprise | Matching algorithm | IPM users before matching | IPM non-users before matching | ATT | IPM users after matching | IPM non-users after matching | ATT | t-values | Critical level |
| Avocado | KBM | 30,176 | 67,866 | 37,690 | 29,558 | 63,531 | -33,971 | -3.44*** | 2.00-2.05 |
| | RM | | | | 29,558 | 64,073 | -34,514 | -3.59*** | 1.95-2.00 |
| Citrus | KBM | 51,513 | 27,112 | 24,401 | 50,620 | 25,401 | 25,216 | 2.65** | 2.05-2.10 |
| | RM | | | | 50,620 | 25,977 | 24,643 | 2.65** | 2.20-2.25 |
| Pawpaw | KBM | 159,614 | 84,444 | 75,170 | 154,328 | 122,235 | 32,093 | 2.35** | 2.15-2.20 |
| | RM | | | | 154,328 | 120,392 | 33,936 | 2.16** | 2.20-2.25 |
| Bananas | KBM | 44,814 | 98,751 | 53,937 | 46,857 | 103,858 | -57,001 | -4.47*** | 2.15-2.20 |
| | RM | | | | 46,857 | 103,641 | -56,783 | -4.54*** | 2.00-2.05 |

*Notes:* *, ** and *** denote significant at 10%, 5% and 1% significance levels respectively; KBM with band width 0.03 and common support, RM with 0.03 caliper and common support
The exchange rate at the time of the survey was approximately 91 Kenya Shilling (Ksh/US$)
*Source:* Study survey data

### 4.5.3 Sensitivity Analysis

The PSM model assumes that the differences between users and nonusers of fruit fly IPM are due simply to the differences in their observable characteristics, as used in the data set. This supposition is referred to as the conditional independence – or unconfoundedness – assumption. However, if the two comparison groups differ in unobservable characteristics, the conclusion that adopting IPM has a positive effect on the gross margins for citrus and pawpaw production may be questionable. We used the Rosenbaum bounds (rbounds) test to eliminate this uncertainty by

[1] The exchange rate at the time of the survey was approximately 91 Kenya Shilling (Ksh/US$)

carrying out a sensitivity analysis. Since it is not possible to estimate the magnitude of selection bias if one uses a non-experimental model, Aakvik (2001) proposes the use of the rbounds test which tests the null hypothesis that there is no change on the treatment effect for different values of unobserved selection bias.

Thus, our study conducted a sensitivity analysis for the presence of hidden bias by using the rbounds test in Stata 14. In this test, the level of gamma is checked, and it is defined as the odds ratio of differential treatment assignment due to an unobserved covariate. The test shows how hidden biases might alter inferences about treatment effects, although it does not indicate whether biases are present or what magnitudes are acceptable (Wainaina *et al.,* 2012).

From the last column in Table 7, the lowest critical value in the two matching algorithms is 1.95 to 2.00 while the largest critical value is 2.20 to 2.25. For a gamma level of 2.25 it signifies that if individuals who have the same explanatory characteristics differs in their odds ratio of participation in the use of IPM strategy by a factor of 125 percent then the significance of the evaluated participation effect on farm income may be questionable. As pointed out by Faltermeier & Abdulai (2009); Becker & Caliendo (2007), a critical value of 2.25 does not show that there is no effect of participation on the outcome or existence of unobserved heterogeneity in the sample. Rather, it implies that the positive significant effect of IPM on farm income would necessitate a hidden bias of 2.15 to 2.20 to render the positive effect specious. This result shows that the confidence interval for the effect would include zero if an unobserved covariate resulted to odds ratio of treatment assignment differing between the comparison and treatment groups by 2.15.

# CHAPTER FIVE CONCLUSION AND RECOMMENDATIONS

## 5.1 Conclusions

The study assessed the factors influencing use of IPM technology by farmers on non- mango fruit crops. This study focused on four alternative cultivated hosts of *B. dorsalis* - avocado, pawpaw, citrus, and bananas. The results of estimation of the logit showed that age of the decision maker, employment of any of the household members and earning salary, size of land in hectares under cultivation, access to public transport system, access to irrigation water, whether any household member belonged to a mango production group, also if a household member had attended training on mango production in the past one year and number of years the farmer has been producing mango influenced the use of IPM technology on non- mango fruit crops. Some of the factors were significant while others were not hence rejection of the null hypothesis that stated that socio-economic characteristics, access to information, institutional and market services, social capital and farm characteristics do not influence adoption of IPM technology on non-mango fruit fly infested crops in Meru County.

This study also assessed spillover effect of the IPM technology on profitability of other fruit crops in Meru County, Kenya. The results indicated that applying the IPM strategy to control fruit flies in mango generates a positive and significant effect on gross margins for citrus and pawpaw at the household level. The adoption of IPM increased the average gross margins for citrus and pawpaw by approximately 38% and 27%, respectively, per year per hectare. The gross margins for avocado and banana were found to be negative and significant. These two contrasting findings in respect of gross margins could be explained by the possible economies of scale associated with bigger land sizes under production for avocado and banana in the control area in comparison with their counterpart allocations in the treatment area. In addition, avocado and banana are relatively less preferred hosts of the target fruit fly; thus, the two crops are not likely to benefit as much from IPM adoption as citrus and pawpaw. Spillover effects were positive and significant for citrus and pawpaw and not for banana and avocado, therefore rejection of the null hypothesis that claimed that spillover effects of IPM technology do not influence profitability of non-mango fruit fly infested crops in Meru County and accepted the alternative.

## 5.2 Recommendations

To achieve greater impact on profitability of the non-mango fruit crops with adoption of IPM technology effort should be focused specifically on disseminating the fruit fly IPM especially among farmers who cultivate a combination of mango, citrus and pawpaw. Cultivation of bananas and avocado did not yield posive impacts from adoption of IPM technology for farmers in the treatment region hence it would be prudent to promote the same in the control region where the gross margins were more to increase their income.

Age negatively influenced adoption of IPM technology on non- mango fruit crops. Old age is often related to risk aversion or less flexibility in adopting new technologies. There is need for the extension workers to create awareness on safer and sustainable fruit fly control practices to aged farmers to enable them adopt the IPM on other fruit crops in the farms.

The size of cultivatable agricultural land positively influenced farmer's adoption of IPM on non-mango fruit crops. It is important for the government to discourage farmers from sub- division of land to small parcels. This study showed that with bigger cultivatable land sizes then farmers are more likely to adopt IPM. Household access to off- farm income was also assessed. It negatively influenced the adoption of IPM technology. ICIPE and the Ministry of Agriculture, livestock, fisheries and irrigation (MoALFI) should promote the IPM technology to rural farmers who are mostly engaged in farming without off- farm income.

Access to public transport system posively influenced adoption of IPM. It is importance for the Ministry of transport to improve the infrastructure especially the roads to enable the farmers in the rural areas access markets and sell their produce at better prices. Attendance to trainings positively increased the probability of participating in the technology. This is mostly because farmers who attended trainings were more knowledgeable on the advantages to damage control measures in crop production like the IPM. Therefore the MoALFI through the extension staff should train farmers more on IPM and its benefits through field days, demonstrations and also barazas.

Access to irrigation water also positively influenced farmers' participation in the IPM technology. Since some of the components of the package (use of Metarhizium anisopliae-based fungal bio pesticides) required availability of water to wet the ground, it was important for farmers to have water in their farms. Therefore it is important for the government to ensure that farmers in regions producing non- mango fruit crops have access to water for irrigation to promote adoption of the IPM technology. Number of years the farmer had been producing mango was also found to be significant. The extension staff in the MoALFI should use those farms as demonstration sites since it also showed that those with aged trees were more likely to adopt the IPM technology

The results of this study suggest that there is a wide scope for the fruit fly IPM strategy investment in Kenya, and the rest of the affected regions in SSA. Up-scaling the IPM technology throughout Kenya, in regions where mango, citrus and pawpaw are grown would therefore be expected to substantially boost productivity of existing cultivated hosts of *B. dorsalis* and subsequently improve livelihoods of many fruit growing rural communities.

### 5.3 Suggestions for further research

- It would be imperative to do a follow up study after 3 to 5 years to get a long term indirect impact of mango IPM fruit fly control technology on avocadoes, oranges, pawpaw and bananas.
- Further research using panel data would be paramount to address the effects of unobserved heterogeneity, and other estimation challenges associated with cross-sectional data. Studies focusing on other technology spillover pathways such as cross-location spillover should be considered for further research.

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## APPENDICES

### Appendix 1: Survey questionnaire used for data collection

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

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

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

**If No, why…………………………………………………….**

**Identifying Variables**

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

**SECTION 3: HOUSEHOLD ASSETS, LAND USE AND OUTPUT**

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

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

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

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

| Crop | Area owned (acres) TEXT | Area leased in (acres) TEXT |
|---|---|---|
| Mango | | |
| Oranges | | |

| | | |
|---|---|---|
| Paw paws | | |
| Avocadoes | | |

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

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

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

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

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

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

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

3.11 At present, do you own the following assets?

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

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

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

| | | | | | |
|---|---|---|---|---|---|
| market | | | | | |
| **Code (a)** Means of Transport<br>1= Walking<br>2= Bicycle | 3= Matatu/bus<br>4= Motorbike | 5=Other (specify) ______ | | | |

## SECTION 4: ICIPE FRUIT-FLY PROJECT

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

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

| | What is the number of mature trees (producing) on this parcel? | What is the number of young trees not in production on this parcel | Cropping system 1=intercrop 2=pure stand | If intercrop, what is the other enterprise(s) | What IPM technologies have you applied on this parcel: (**Codes a**)[1] | Where did you acquire it? (**Codes b**) |
|---|---|---|---|---|---|---|
| 1=Mangoes | | | | | | |
| 2=Avocadoes | | | | | | |
| 3=Oranges | | | | | | |
| 4=pawpaws | | | | | | |

| **Codes a: ICIPE fruit-fly control package components** | | **Code b:where IPM was acquired** | |
|---|---|---|---|
| 1= Parasitoid(p), Orchard Sanitation(OS), Male annihilation Technique (MAT)<br>2= Parasitoid(p), OS, Food bait (FB)<br>3= Parasitoid(p), OS, Bio pesticide (Biop)<br>4=Parasitoid(p), OS, MAT,FB | 5= Parasitoid(p), OS, FB, Biop<br>6= Parasitoid(p), OS, MAT,Biop<br>7= Parasitoid(p), OS, MAT, FB, Biop<br>8= Other (specify)……… | 1=ICIPE<br>2= MoA<br>3= Farmer<br>4= Exporter | 5= NGO<br>6= Agro-vet<br>7=Other (specify) |

[1]***Note: If the farmer applies only one of the listed ICIPE fruit fly control component, type the specific component.***

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

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

| **Crop (type)** | Size of the plot (acres) | What IPM technologies have you applied on this parcel: (**Codes a, in question 4.2**) | Where did you acquire it? (**Codes b in Qn 4.2**) |
|---|---|---|---|
| | | | |
| | | | |

[1]***Note: If the farmer applies only one of the listed ICIPE fruit fly control component, type the specific component.***

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

## SECTION 5: INPUT AND OUTPUT FOR MANGO, PAWPAWS, ORANGES AND AVOCADOES

**5.1 For each of the crop mentioned above, provide details of the cost of production for the last one complete cycle**

| Crop | Input | No. of times applied | Amount used each time | Unit (Kgs, liters, wheelbarrow) | Total amount used | Product price per unit | Total cost (Kshs) |
|---|---|---|---|---|---|---|---|
| Mangoes Avocado Oranges Pawpaws | Organic matter/manure | | | | | | |
| | Own farmyard manure | | | | | | |
| | Purchased farmyard manure | | | | | | |
| | Fertilizers | | | | | | |
| | 1. | | | | | | |
| | 2. | | | | | | |
| | 3. | | | | | | |
| | 4. | | | | | | |
| | Pesticides | | | | | | |
| | Herbicides | | | | | | |
| | Electricity/fuel for irrigation | | | | | | |
| | Other inputs(specify) | | | | | | |
| | | | | | | | |
| | | | | | | | |

**5.2 For the above crops, please specify the labor for the following activities were carried out for the last complete season per the plot given in question 3.4.**

| Crop | Activity | Number of times? | No. of persons involves | | No. of days each time | No. of hours per day | How many of those usually hired labourers | | Total cost paid (Kshs) |
|---|---|---|---|---|---|---|---|---|---|
| | | | Male | Female | | | Male | Female | |
| **Mangoes** | a)Digging up | | | | | | | | |
| **Avocadoes** | b)Weeding | | | | | | | | |
| **Oranges** | c)Irrigating | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Pawpaw** | d)Fertilizer application | | | | | | | | |
| | e)Manure application | | | | | | | | |
| | f)Pesticide application | | | | | | | | |
| | g)Pruning of dead twigs | | | | | | | | |
| | h)Orchard sanitation | | | | | | | | |
| | i)Top working | | | | | | | | |
| | j)Harvesting | | | | | | | | |
| | k)Grading | | | | | | | | |
| | l)Transport to market | | | | | | | | |
| | m) other specify | | | | | | | | |

5.3 What is the cost of hiring casual laborer (Kshs/day)_____

**5.4** Was a tractor, an ox-plough or ox-cart hired **from the beginning of the season** for land preparation (ploughing and harrowing**?** /________/ 0=No, 1=Yes

**5.5** If yes, what was the total cost of hiring (Kshs/Acre)________

| | | | |
|---|---|---|---|
| Mango_______ | Avocado_______ | Oranges_____ | Pawpaw_______ |

**5.6** How many years have you been producing the following fruits?

| | | | |
|---|---|---|---|
| Mango_______ | Avocado_______ | Oranges_____ | Pawpaw_______ |

**5.7** Please fill the following information for the total produce harvested during the last season for that particular fruit enterprise.

| **Crop** | **Varieties** | **Total quantity produced** | | **Total consumed at home** | | **Total quantity damaged** | | **Total quantity sold** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Qty** | **Unit** | **Qty** | **Unit** | **Qnty** | **Unit** | **Qty** | **Unit** | **Price per unit[a]** |
| **Avocado** | | | | | | | | | | |
| **Oranges** | | | | | | | | | | |
| **Pawpaws** | | | | | | | | | | |
| **Mango** | | | | | | | | | | |
| | | | | | | | | | | |

**Unit codes:**

| | | | |
|---|---|---|---|
| 1=Pieces ; | 4=6Kg carton; | 7=90 kgs bag; | 10=lorry |
| 2=bags; | 5=4kg carton | 8=pick-up; | 11=others(specify)............... |
| 3=crate; | 6= 20 litres bucket; | 9= wheelbarrow | .......... |

| |
|---|
| (**NB**: where pickup, lorry, canter or cart apply; write in words in the unit box); [a]Give the common price at sale |

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

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

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

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

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

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

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

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

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

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

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

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

| **Source** | **Form** | **Purpose of credit** | |
|---|---|---|---|
| 1= Farmer group;<br>2= other self-help group;<br>3= Friends/Relatives;<br>4= Bank;<br>5=Microfinance;<br>6=Other (specify) | 1= in kind e.g. inputs,<br>2=money,<br>3=other (specify)__________<br>__________ | 1- To purchase seedlings<br>2- To purchase fertilizer<br>3- To purchase pesticides<br>4- To expand crop area<br>5- To invest in business<br>6- To buy construction materials | 7- To purchase livestock<br>8- To Improve water system<br>9-To pay school fees<br>10-To purchase basic items like food, clothing<br>-<br>11-Other (specify)____________<br>__ |

**SECTION ONE: HOUSEHOLD DEMOGRAPHICS (this information has been collected in previous survey and will be provided to the enumerators to confirm if Table 9 is correct- to be asked as the last section)**

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

1.2 Age of the household head (years)_______

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

| | | |
|---|---|---|
| 0=None<br>1=Primary | 2=High school<br>3=University | 4=College or polytechnic<br>5=Other(specify) |

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

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

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

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

| Age (years) | Male | Female |
|---|---|---|
| 0-14 | a | E |
| 15-64 | b | F |
| 64+ | c | G |

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

| | | |
|---|---|---|
| (1) Married (one spouse) | (2) Married (more than one group) | (3) Single |
| (4) Divorced | (5) Widowed | (6) Separated |

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

| | | |
|---|---|---|
| **0** = None<br>**1** = Farming<br>**2**=Cereal production<br>**3**= Livestock production | **4**=Mango production<br>**5**=Casual labourer<br>**6**=Civil servant<br>**7**=Production of other fruits | **8**= Other (specify)__________ |

## SECTION 2: OFF-FARM INCOME

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

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

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

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

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

**END: (Please remember to thank the farmer genuinely)**

**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___/___/______

## Appendix 2: Conversions from trees to acreage

| Fruit | spacing | Number of trees per acre |
|---|---|---|
| Avocado | 8mx10m | 50 |
| mango | 8mx10m | 50 |
| pawpaw | 2.5mx2.5m | 647 |
| citrus | 6mx6m | 112 |
| banana | 3mx3m | 450 |

## Appendix 3: Correlation matrix on exogenous variables

| | gender | hhage | yearsc~l | q31_ag~d | q36_ir~n | tot_TLU | hhsize | salaried | commfi~l | transp~l | fert_t~l | credit~w | q312_t~l | q31~pmkt |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| gender | 1.0000 | | | | | | | | | | | | | |
| hhage | 0.2540 | 1.0000 | | | | | | | | | | | | |
| yearschool | -0.0009 | -0.2064 | 1.0000 | | | | | | | | | | | |
| q31_agrland | 0.0625 | 0.2744 | 0.1119 | 1.0000 | | | | | | | | | | |
| q36_irriga~n | 0.0291 | -0.1219 | 0.0359 | 0.0771 | 1.0000 | | | | | | | | | |
| tot_TLU | -0.0212 | 0.0882 | 0.1796 | 0.2962 | 0.0827 | 1.0000 | | | | | | | | |
| hhsize | 0.0147 | -0.0981 | 0.0573 | -0.0182 | 0.1127 | 0.1166 | 1.0000 | | | | | | | |
| salaried | -0.0576 | -0.1580 | 0.2168 | 0.0276 | 0.0369 | -0.0249 | 0.0044 | 1.0000 | | | | | | |
| commfinal | 0.0029 | -0.1177 | 0.1373 | 0.0687 | 0.1111 | 0.0786 | 0.1098 | 0.0439 | 1.0000 | | | | | |
| transportf~l | 0.1051 | -0.0594 | 0.1176 | 0.0915 | 0.1042 | 0.1476 | 0.0820 | 0.0627 | 0.1557 | 1.0000 | | | | |
| fert_total | -0.0725 | -0.1942 | 0.0807 | -0.0277 | 0.0984 | 0.0343 | 0.0522 | 0.1350 | 0.0637 | 0.1376 | 1.0000 | | | |
| creditnew | 0.0110 | -0.1406 | 0.0626 | 0.0065 | 0.0755 | 0.1165 | 0.0799 | 0.1226 | 0.0683 | 0.0587 | 0.0506 | 1.0000 | | |
| q312_tarma~l | 0.0229 | 0.0300 | 0.0273 | 0.0079 | -0.0482 | -0.0465 | 0.0273 | 0.0464 | 0.0036 | 0.0279 | 0.0364 | -0.0307 | 1.0000 | |
| q312_ag~pmkt | 0.0366 | 0.0995 | -0.0382 | 0.0011 | 0.0916 | -0.0007 | 0.0167 | 0.0482 | 0.0540 | -0.0069 | 0.0742 | -0.0044 | 0.0317 | 1.0000 |
| q312_ag~dmkt | -0.0036 | 0.0092 | -0.0656 | 0.0250 | 0.1204 | -0.0019 | -0.0620 | 0.0164 | -0.0330 | -0.0094 | -0.0273 | -0.0042 | 0.0188 | 0.1346 |
| q66_farmgr~p | 0.0061 | 0.0720 | 0.0754 | 0.1182 | 0.0879 | 0.0377 | 0.0715 | -0.0298 | -0.0340 | 0.0093 | -0.0419 | 0.0309 | 0.0372 | -0.0884 |
| q61_training | -0.0438 | -0.0085 | 0.0977 | 0.1153 | 0.1213 | 0.1431 | -0.0106 | 0.1373 | 0.1038 | 0.1139 | 0.1433 | 0.0080 | 0.0350 | 0.0958 |
| q56a_yrsma~o | 0.0643 | 0.2986 | 0.0229 | 0.2705 | 0.0353 | 0.1105 | -0.0292 | 0.0370 | -0.0152 | -0.0959 | -0.0933 | 0.0186 | -0.0168 | 0.0431 |
| q312_publi~p | -0.0833 | 0.0166 | -0.0532 | 0.0349 | 0.0995 | 0.0410 | 0.0415 | 0.1221 | 0.0570 | -0.0830 | 0.1484 | -0.0522 | 0.0195 | 0.3641 |
| q321_agrie~t | 0.0148 | -0.0575 | 0.0894 | 0.0087 | -0.0651 | -0.0518 | 0.0641 | -0.1213 | -0.0757 | 0.0310 | -0.0850 | -0.0194 | -0.0218 | -0.2995 |

| | q31~dmkt | q66_fa~p | q61_tr~g | q56a_y~o | q312_p~p | q321_a~t |
|---|---|---|---|---|---|---|
| q312_ag~dmkt | 1.0000 | | | | | |
| q66_farmgr~p | -0.0022 | 1.0000 | | | | |
| q61_training | -0.0442 | 0.1883 | 1.0000 | | | |
| q56a_yrsma~o | 0.0519 | 0.0901 | 0.1448 | 1.0000 | | |
| q312_publi~p | 0.0008 | -0.0904 | 0.1929 | 0.0531 | 1.0000 | |
| q321_agrie~t | -0.0453 | 0.1299 | -0.0911 | -0.0764 | -0.2093 | 1.0000 |