ECONOMIC IMPACT OF INTEGRATED PEST MANAGEMENT TECHNOLOGY FOR CONTROL OF MANGO FRUIT FLIES IN EMBU COUNTY, KENYA

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DECLARATION

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

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ABSTRACT

Mango is the third most important fruit in Kenya in terms of area and total production. Nutritionally, mango fruit is important for vitamins and mineral provision in the daily diet of Kenyans. As an export crop, mango earns the country foreign exchange, acts as source of food and household income especially for resource poor farmers, contributing to poverty alleviation and achievement of Millennium Development Goal number 1. However, mango production and marketing is constrained by several factors, among which pests and disease infestation is major. Among the pests, fruit fly and mango seed weevil present a real challenge to producers and exporters due to losses incurred at the farm level and infested mango rejections at export points. To reduce losses, cost of production and increase the profit at producer level, International Centre of Insect Physiology and Ecology (ICIPE) developed and is implementing an Integrated Pest Management fruit fly control package in Embu County. The impact of this intervention has not been evaluated. This study therefore evaluates the impact of Integrated Pest Management fruit fly control package intervention on magnitude of mango rejections and net income from mango production. The study also assesses the effect of the control package on health and environment.

The study will use survey research design in which structured questionnaire will be administered to 280 randomly selected project participant and non participant mango farmers. Difference in difference estimation method will be employed to assess the impact of the control package on magnitude of mango rejection and net income from mango production and descriptive statistics used to evaluate the community's attitude on the effect of the IPM control package on health and environment.

ACRONYMS AND ABBREVIATIONS

DD	Double Difference (Difference in Difference)
EIA	Environmental Impact Assessment
EIE	Economic Impact Evaluation
FAO	Food and Agriculture Organization
FFS	Farmer Field School
GDP	Gross Domestic Product
HIA	Health Impact Assessment
ICIPE	International Centre of Insect Physiology and Ecology
IPM	Integrated Pest Management
IPMFFCP	Integrated Pest Management for Fruit Fly Control Package
KIT	Royal Tropical Institute
MAT	Male Annihilation Technique
MDGs	Millennium Development Goals
MOA	Ministry of Agriculture
SEA	Strategic Environmental Assessment
SIA	Social Impact Assessment

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Kenya is predominantly an agrarian economy. The agricultural sector is the means of livelihood for most of the rural population and the key to food security and poverty reduction. The sector comprises six subsectors namely, food crops, industrial crops, horticulture, livestock, fisheries and forestry. The horticulture subsector has grown in the last decade to become a major foreign exchange earner, employer and contributor to food security in the country. It contributes 33 percent of the agricultural GDP and 38 percent of export earnings. The subsector comprises of fruits, vegetables, cut flowers, nuts, herbs and spices (Government of Kenya, 2010). Fruits, key component of the subsector, generate foreign exchange earnings, provide employment opportunities and income for the rural and peri-urban communities especially women and youth. Nutritionally, fruits are important in daily diets of Kenyan people for vitamins and minerals provision.

Mango (*Mangifera indica L*) is the most important fruit of the tropics because of its attractive appearance and the pleasant taste. It grows best from 0 – 1200m above sea level but can grow in higher elevations (Griesbach, 2003). In Kenya, mango has been the third most important fruit in terms of area and total production with bananas (including plantains) and pineapples as number one and two respectively in terms of production (FAO, 2009). As of 2009, the area under mango was 32,706 hectares with total production of 474,608 metric tonnes worth Kshs. 6.28 billions (Ministry of Agriculture, 2010a). The main mango production areas in Kenya are Coast, Eastern, Nyanza, Rift Valley and Central provinces. Two types of mango are grown, the local and the exotic or improved varieties. The exotic are usually grafted on the local mango varieties. The local varieties include Ngowe, Dodo, Boribo and Batawi. The exotic varieties include apple, Kent, Keitt,Tommy atkins, Van dyke, Haden, Sabine, sabre and Kensington. Local varieties tend to have high fibre content than the exotic ones, making them unpopular for fresh fruit consumption (Griesbach, 2003).

Mango fruits are consumed locally or exported either fresh or as processed products. The bulk of mangoes produced are consumed within the same production area or sold in urban markets (Food and Agriculture Organization, n.d). Out of the total production, mango export accounts for about 5 percent. The main export market for Kenyan mangoes is Middle East countries, where the main competitors are India and Pakistan. Other outlets include United Kingdom, Netherlands, Belgium, Germany and France (KIT*et al.*, 2006). As an export crop, mango earns the country foreign exchange, acts as a source of food and household income for resource poor farmers.

Nutritionally, mango fruit contains almost all known vitamins and essential minerals which include thiamine, niacin, calcium and iron. The calorific value of mango is mainly derived from sugars and it is as high as that of grapes and higher than that of pears, apples and peaches. Generally, mango protein content is slightly higher than for other fruits except avocado. Mango contains (Griesbach, 2003).

Mango production and marketing is constrained by several factors, among which include the highly perishable nature of the fruit, inadequate clean and quality planting materials, pest and disease infestation, high cost of inputs, limited adoption of improved technologies, seasonal gluts and poor market infrastructure (KIT *et al.*, 2006). Mango fruits have short storage life, ripening within 6-7 days at 20-25^{0}c and becoming overripe and spoiled 15 days after harvest (Keryl *et al.*, 2001).

1.2 Economic importance of fruit flies and mango seed weevil in mango production

Tephritid fruit flies are recognized as one of the major and most serious insect pests of fruits and vegetables throughout the tropical and subtropical regions (Cugala *et al*, 2010). The indigenous fruit flies in Africa belong to the genera Ceratitis (e.g C. *cosyra* and C. *capitata*) and Dacus. *Bactrocera invadens* is an invasive species of Asian origin that was first detected in Kenya in 2003 (Ekesi *et al.*, 2010). The fruit fly has became established in many parts of the country, especially in areas where the host fruits and vegetables are grown. B. *invadens* has a wide range of hosts and mango is the most prefered host plant amongst the cultivated crops in Kenya (Momanyi *et al.*, 2010).

Mango seed weevil and Tephritid fruit flies (*Bactrocera invadens and Ceratitis cosyra)* are the main pests causing direct damage to fruits and postharvest losses leading to more than 50 percent yield losses (Griesbach, 2003). The female fruit flies puncture the fruit to lay eggs under the skin leaving scars and holes on the fruit surface. The eggs hatch into larvae maggots that feed in the decaying flesh of the crop. The infested fruits quickly rot and become inedible or drop prematurely to the ground causing direct losses (Bissdorf and Weber, 2005). Since *B. invadens* detection in Kenya in 2003, damage to mango has increased to over 80% (Ekesi *et al.*, 2010). Fruit flies are considered a quarantine risk by many fruit importing countries (Keryl *et al.*, 2001). For this reason, export of these mango fruits into the United States, Europe, Japan and Middle East require phytosanitary measures to ensure that no live fruit fly insects are present in the imported fruits (Mitcham and Yahia, 2009). Quarantine restrictions leads to loss of marketing opportunities for smallholder producers and exporters, thus reducing profit and increasing cost of production for local and export markets. This has a wider effect on the economy of the exporting country.

1.3 Problem Statement

Below potential productivity levels for most crops continue being one of the major challenges facing agricultural sector in Kenya. Crop pests and diseases cause reduced productivity, sometimes by over 50 percent, and loss of market for products. The Government of Kenya continues to put more emphasis on the development and successful uptake of technologies geared towards control and eradication of pests and diseases in crops to improve productivity. Fruit fly infestation is a major drawback in mango production and marketing. It is a threat to mango trade and the horticulture subsector due to losses incurred at the farm level and quarantine restrictions imposed by the mango importing countries. Exporters incur losses due to rejections and subsequent destruction of the fruit fly infested mangoes. Producers reap less profit due to low marketable supply attributed to fruit fly damage at the farm level. This hamper the continued flow of both the foreign exchange and domestic earnings generated by horticulture subsector placing the industry at risk of failing to contribute as expected towards the GDP and achievement of Millennium Development Goal (MDG) number 1.

To reduce losses caused by fruit fly and increase the amount of fruit available for consumption and marketing, the International Centre of Insect Physiology and Ecology (ICIPE) Kenya, under mango IPM project, developed and is implementing an Integrated Pest Management Fruit Fly control package (IPMFFCP) in Embu County. The IPM fruit fly control package aimed at reducing economic losses at the farm level, reduce pesticide usage and enhance supply of quality mangoes to export market raising profit levels for the producers thus improving their livelihood. Less use of pesticides reduces health and environmental risks such as on-farm ingestion by workers, discharge of toxic chemicals into the air and water and consumption of mangoes that contain pesticide residues by consumers.

Much effort has been made and financial resources committed in mango IPMFFCP to achieve the fore mentioned objectives. However, the impact of the intervention has not been evaluated so far. This study, therefore, aims at assessing the economic impact of IPMFFCP on the outcome variables as indicators.

1.4 Objectives

The main objective of this study is to assess economic impact of Integrated Pest Management (IPM) technology in the control of mango fruit fly in Embu County. The specific objectives are:

1. To evaluate the impact of IPM fruit fly control package (IPMFFCP) on magnitude of mango rejections due to fruit fly damage
2. To assess the impact of IPMFFCP on net income from mango production
3. To assess the community's attitude on the effect of IPMFFCP on health and environment

1.5 Hypotheses

1. Application of IPMFFCP does not lead to reduced magnitude of mango rejections due to fruit fly damage
2. IPMFFCP has no incremental effect on net income from mango farming

1.6 Research Question

1. What is the community's attitude on the effect of IPMFFCP on health and environment?

1.7 Significance of the study

By determining the impacts of mango IPM fruit fly control package on mango rejection, pesticide use and profitability, the study generate important information for different stakeholders. The information will enhance decision making on technology adoption at the farmers' level to improve their market competiveness. To the researchers, the information will be used to set research priorities, design and evaluate research. The findings will provide feedback information to policy makers and mango IPM project funders on technology effectiveness for future adjustment and up scaling to other mango producing areas. The findings of this study will be of benefit to other players along the mango value chain, such as input suppliers, traders, processors and consumers. The generated information will also contribute to the growing body of knowledge on impact assessment.

1.8 Theoretical Framework

This study is based on profit maximization in producer theory. Farm level economic impact analysis of IPM technology investigates whether the technology and its dissemination results in higher farm profit. This is in line with the IPM technology primary objective of restraining pest damage to a level that maximizes farmers' economic returns, while utilizing smallest level of chemical inputs.

Feder & Quizon (1999) consider a farm household producing multiple outputs (Y_1, Y_2..........,Y_n) using multiple variable inputs (X_1, X_2..........X_m) including chemical pesticide (X_p). The household maximizes profit (Π) from considering prices of farm outputs and variable inputs, but subject to constraints from fixed factors of production such as land (L), pest management skills (K) and others specified as (Z). IPM dissemination efforts mainly targets variable K. The farm household maximized profits can be written as a profit function:

$$\text{Max } \Pi = P_y Y - P_x X \quad \text{s.t } Y = f(L, K, Z) \qquad (1)$$

Where: P_y refers to vector of output prices (Y) and P_x vector of input prices (X). Output supply and input demand equations, corresponding to maximized profit are expressed as:

$$Y = f(Px; Py; L, K, Z) \qquad (2)$$

$$X = g\ (Px; Py; L, K, Z) \qquad (3)$$

The IPM impacts on profits come from increasing the farmers' knowledge on pest management (K). The rise in K leads to change in input mix and practices used, in particular, less use of pesticides. Supposedly, decline in farmer's demand for pesticide and other associated inputs (such as labour) and increase in output due to improved crop protection leads to higher farming returns. From equations (2) and (3),

$$\delta X_p / \delta K \leq 0 \text{ and } \delta Y / \delta K \geq 0 \qquad \text{(i)}$$

Ceteris paribus, farmers exposed to some form of IPM dissemination have greater or equal awareness and knowledge (K_a) than their counterparts not reached by any IPM intervention (K_{na}), indicating that:

$K_a \geq K_{na}$, and therefore that: ....(ii)

$$Y_a \geq Y_{na};\ X_a \leq X_{na} \text{ and } \Pi_a \geq \Pi_{na} \qquad \text{(iii)}$$

The main desired impacts of IPM dissemination, as described by statement (iii) are raising farm yields, lowering pesticide use and thereby raising farm profit.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Integrated Pest Management Technology

According to Sandler (2010), Integrated pest management is the intellect selection and use of pest control actions that ensure favourable economic, ecological and sociological consequences. Specific cultural, chemical and horticultural needs of a particular crop are combined to develop a broad based approach appropriate to control economically threatening pests. Alston (2011) also defines IPM as a comprehensive approach to pest control that uses combined means to reduce pest status to tolerable level while maintaining a quality environment. The various definitions indicate that IPM approach integrates both preventive and corrective measures to manage pest populations to minimize economic damage, risk hazards to human and harmful environmental side effects. The aim is not to eradicate or remove the pests.

There is a wide variety of techniques that are applied under IPM approach. Applicability of the various techniques depend on the crop, cropping system, pest and agroecological zone. To suppress fruit flies and reduce damage to mango, ICIPE developed a fruit fly control package constituting some of these techniques.

Baiting technique is based on the use of proteinous food baits combined with an insecticide, applied to localized spots, 1 square metre spot in the canopy of each tree in the orchard. The proteinous substance attract the adult fruit fly to bait spray droplets. The fruit flies ingest the bait along with a toxic dose of insecticide, killing them before infesting the fruits (Prokopy *et al.*, 2003; Ekesi *et al.*, 2010). Fruit fly bait sprays used ,include Mazoferm and GF-120 spinosad. According to Vayssieres *et al.* (2009), weekly application of GF-120 spinosad for ten weeks period provided 82.7 percent reduction in mango damage in Benin.

Baiting techniques provide reduced dosage of active ingredient, safe to non target insects and cheap in terms of price, time and application (Vargas *et al.*, 2001; Ekesi *et al.*, 2010).

Male Annihalation Technique (MAT) involves the use of a high density of bait stations consisting of a male lure (such as methyl eugenol) combined with an insecticide, to reduce the male population of fruit flies to a low level that mating does not occur or is extremely reduced. A carrier containing male attractant plus toxicant is distributed at regular intervals over a wide area (Allwoods *et al.*, 2002; Ekesi *et al.*, 2010). The effectiveness of the MAT varies with the strength of the lures. In Northern Benin, according to Hanna *et al.* (2008), MAT application reduced fruit fly infestation by 39.8% and 46.8% for Eldon and Kent mango varieties respectively. MAT is most effective in combination with other fruit fly suppression techniques.

Biological control involves use of natural enemies such as predators, parasitoid or pathogens, use of biopesticides and sterile male insects to suppress the fruit flies. The major natural enemies include the egg parastoid *Fopius arisanus*, presently being released in Africa, entomopathogenic fungus(*Metarhizium anisopliae*) and predatory weaver ants (*Oecophylla longinoda*) (Ekesi *et al.*, 2010).

Cultural methods that prevent fruit flies build include orchard sanitation, mechanical protection by wrapping the fruit and early harvesting for some fruits like bananas and papayas, as fruit flies cannot develop when thay are green, unlike mangoes. Orchard sanitation involves removal of infested fruits and destroying them in an augmentorium, or putting them in black plastic bags,tying and exposing them to the sun or burying 46 cm underground (Klungness *et al.*, 2005; Ekesi *et al.*, 2010).

2.2 Empirical studies on impact of Integrated PestManagement

In assesing the economic impact of three reduction, three gains (3R3G) IPM technology in rice in South Vietnam, Huelgas *et al.* (2008), found out that 3R3G adopters reduced use of pesticides and spent US$ 8-12/ha/season less on pesticides than the non adopters. The results also indicated differences in annual net income/ha as US$ 1,092 and US$ 883 for adopters and non adopters respectively. However contrary to the program expectation of reducing use of inputs without sacrificing the yields, non adopters yields were higher than for adopters both in dry and wet seasons.

A study conducted in Java, Indonesia, Mariyono (2008) found out that IPM significantly reduced the use of insecticide in soya bean farming during the period of dissemination of IPM technology. The results were attributed to low pests infestations observed in soya during IPM implementation period.

A socio-economic study conducted in West Bengal, India aimed at evaluating the extent of adoption of IPM practices for the control of eggplant fruit and shoot borer and the initial economic and social impacts of such adoption by use of economic surplus method. The results showed that adopters of IPM practices reduced their labour requirement by 5.9%, while labour requirement of non- adopters rose by 1.2%. IPM adopters increased their eggplant production area by 21.6%, while non-adopters reduced the area by 8.7%. Farmers adopting IPM sprayed pesticides 52.6% less often than before while non-adopters sprayed 14.1% more often (Baral *et al.*, 2006)

Kumar *et al.* (2008) carried a study in Karnataka to find out the impact of IPM technology, resource use productivity, pest resistance externality and constraints faced by farmers during the adoption of IPM technology. They used tabular method to analyze data on impact of IPM. The results indicated that the cost of cultivation per acre in IPM farms was higher by Rs. 207.1 but the total returns and net returns were higher in IPM farms compared to non IPM farms. Human labor accounted for 24.2 and 22.2 percent of the total expenditure for IPM and non IPM farms respectively. This indicated high labour intensity in IPM farms. However there was significant difference in expenditure on plant protection chemicals, with non IPM farmers spending 25.3 percent of total chemical costs and IPM farmers minimizing the cost on chemicals by 12.8 percent of the total costs.

In evaluating the impact of IPM and Insecticide Resistance Management (IRM) on cotton fields in Punjab, Singh and Singh (2007) found out that these technologies reduced the per quintal production cost by Rs. 253 and Rs. 175 respectively. The results also showed that IPM and IRM generate more income; adopters earned Rs.6840/ha and Rs 5901/ha more income compared to that of non adopters. IPM and IRM technologies also reduced pesticide consumption by 67 percent and 54 percent respectively.

2.3 Empirical Studies using DD method

Feder *et al.* (2003) evaluated the impact of Farmer Field School (FFS) effort on yields and pesticide use in Indonesia using DD approach. The evaluation considered direct impact on participating farmers and secondary impacts through farmer- to- farmer diffusion from FFS graduates to other farmers. A control group, unaffected by the program, was constructed for effective comparison. The results indicated no differences in performance (yields improvement and pesticide reduction) between the graduates and exposed farmers after the program, thus not supporting program effectiveness.

Simwaka *et al.* (2011) assessed the impact of morbidity and mortality for HIV affected and non affected farm households on maize production in Malawi using DD estimation approach. The analysis revealed that the difference in differences in mean maize harvests between the affected and non- affected farm households over the two time periods considered, 2004/05 and 2006/07, is not statistically significant. This non-significance in differences imply that over the years both HIV/AIDS related and non HIV/AIDS related mortality and morbidity has the same impact of stagnating maize production.

A study done in Argentina by Galiani *et al.* (2003) employed double difference to assess the impact of privatization of water services on child mortality, using variations in ownership of water across municipalities and time. Their results showed that child mortality reduced by 8 percent in areas that privatized their water services and that the effect was greatest in poorest areas. Privatization is also uncorrelated with deaths unrelated to water conditions.

Omilola (2009) estimated the impact of agricultural technology on poverty reduction in rural Nigeria by use of double difference approach. The analysis showed that technology adopters received statistically significant and larger increases in agricultural income than non adopters. Non adopters had bigger changes in other sources of income than adopters.The overall findings revealed that the differences in poverty status between the adopters and non adopters of the new technology are fairly small, indicating that technology adoption did not substantially translate to poverty reduction for its adopters.

Yamano & Jayne (2004) employed DD approach to measure the impact of working-age mortality on small scale farm households in Kenya using a two year panel survey. The outcomes considered included assets, household characteristics, total land and crop outputs. The findings indicates that: The effects of aldult death on crop production was sensitive to gender, position and age categorization of the deseased; Death of working –age male head greatly affected household off-farm income negatively; Households coped with death of working –age aldult by selling particular types of assets. The findings provided little evidence of households quick recovery from effects of adult mortality.

The literature work that has been reviewed concentrated on impact of Integrated Pest Management on yields, pesticide use and net farm income on other crop commodities and employed other analytical approaches. This indicates information gap on impact of IPM in mango production in Kenya. An economic impact study on IPM in mango using the DD method goes a long way in bridging this information gap.

2.4 Definitions and types of Impact Evaluation

Impact is the change produced at farmer level as a result of research, training and adoption of new technologies. This change depends on the project objecives. For instance, IPM impacts refers to changes in pest control practices and in costs and benefits generated for the farmers. Generated impacts can be immediate, medium or long term consequencies (Ortiz and Pradel, 2010).

Impact assessment, as defined by La Rovera and Dixon (2007), is a process of systematic and objective identification of the short and long term effects on households, institutions and environment caused by an on-going or completed development program or project. These effects may be positive or negative, direct or indirect, intended or unintended, primary and secondary. Impact assessment is a continuous process involving different types of impact studies at different stages. It can be viewed as occuring in the design and post adoption stages at different levels of the research system. Based on this, impact studies are broadly categorized into *ex ante* and *ex post* impact assessment (Manyong *et al.*, 2001). According to La Rovera and Dixon (2007), *ex ante* impact studies are conducted before an intervention is initiated or an outcome is generated to ensure appropriate targeting of research, resource allocation and priority setting. *Ex post* assessment studies (which this study is meant for) are undertaken after diffusion of a research product has been initiated, to assess actual impact on the ground. FAO (2000) views impact assessment as an established practice in public goods investment activities in several fields and therefore classified according to displinary lines which include environmental impact assessment(EIA), social impact Assessment (SIA), health impact assessment (HIA), risk assessment, strategic environmental assessment(SEA) and Economic impact evaluation(EIE). Maredia *et al.* (2000) indicate that results and information obtained during impact assessment process builds confidence of researchers and stakeholders, forms a base for enhanced research support and feeds back to the research prioritization. Depending on the objectives of the exercise, impact assessment can be carried out at different levels – individual projects, specific research programs or research and technology system as a whole.

2.4.1 Economic Impact Assessment

Economic impact assessment mainly focus on effects of improvement of profitability for farmers and price reduction for consumers associated with development activities (Ortiz and Pradel, 2010). Economic impact studies range from partial to comprehensive assessment. Partial impact assessment studies quantify the application of research results without estimating aggregate benefits. Adoption studies is the most popular type of partial impact assessment in which use of innovations is traced from research stations or on-farm trials through network of adopters (Maredia *et al.,* 2000). Comprehensive economic impact assessment looks at wider economic effects of the new technology adoption. These studies estimate the economic benefits produced by research in relation to associated costs, computing rate of return to research investment (FAO, 2000).

2.5 Impact Assessment Techniques

Simply measuring the outcome of a project may not reflect the actual effects of the project or intervention on the beneficiaries. There may be other factors that are correlated with the outcomes but are not caused by the project. In addition, there may also be intervening factors on which the project has an effect that are either observed or unobserved contributing to the outcomes. Since impact is the difference between the observed outcome and the counterfactual, that is, what would have happened without the project or what otherwise would have been true, impact evaluation techniques must estimate the counterfactual. Determining the counterfactual separates or net out the effects of interventions from other factors (Baker, 2000; FAO, 2000).

According to Shahidur *et al.* (2010) and Baker (2000), effects from other intervening factors, can be controlled by introducing control groups. Control groups consist of comparator group of individuals which is not subject to the intervention but identical to the treatment group, individual who receive the intervention. The control group is selected randomly from the same population as the program participants.

Determination of control and treatment groups could be achieved by use of several quantitative methods, categorised broadly into; experimental (randomized) and Quasi-experimental (nonrandomized) designs. Qualitative and participatory methods can also be used to assess the impact (Baker, 2000).

In experimental (randomized) designs, interventions are randomly allocated to the elligible beneficiaries, automatically creating comparable treatment and control groups that are statistically equivalent to one another(drawn from the same distribution), given appropriate sample sizes. The control group thus generated serves as a perfect counterfactual free from selection bias. Program impact is determined by comparing the means of outcome variable between the two groups (Baker, 2000; Shahidur *et al.*, 2010).

Quasi experimental techniques generate comparison groups that resemble treatment groups, at least in observed characteristics when it is not possible through experimental design. The selection of these groups, either before or after the intervention, is not randomized. The main advantage with these techniques is that they can draw on existing data sources, hence quicker and cheaper to implement. The major drawbacks of quasi –

experimental design are reduced results reliability, statistical complexity and selection bias. The econometric methodologies used in quasi experimental designs include, difference-in-differences(double difference), propensity score matching, reflexive comparisons and instrumental variable methods (Baker, 2000).

This study uses Difference in Difference (DD) estimation model to evaluate the economic impact of IPM fruit fly control package. Difference in difference (Double difference) method entails comparing a treatment group with a comparison group(first difference) both before and after an intervention (second difference). The method uses panel or repeated cross sectional data that include the baseline data, which measure the outcome before the intervention, and follow-up data that measure the outcome after passage of time deemed sufficient for the impact of the intervention to set in (Kristin *et al.*, 2010; Baker, 2000). The outcomes are observed for two groups for the two time periods. In this case, one group is exposed to treatment in the second period but not in the first period. The other group is not exposed to the treatment during either period. This removes biases in second period from comparisons between the treatment and control group coming from permanent differences between those groups. It also removes biases from comparisons over time in the treatment group coming from trends. Therefore, the double difference model is an appropriate tool in solving the problems arising from non-random selection of program participants and non-random placement of the program. This is achieved by having two comparable groups, participants and non participants (Simwaka *et al.*, 2011; Yamano & Jayne, 2004).

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study Area

The study will be conducted in Embu East District, one of the districts in Embu County. Embu East district comprises of two divisions namely Runyenjes and Kyeni, with a total of eleven locations (See map appendix 4). The district borders Mbeere North to the south, Embu West and Meru South to the east and then narrows to the north bordering Mount Kenya forest. The district has a total area of 253.4 km^2, of which 177.3 km^2 is arable land. The average farm size in the district is 1.2 hectares and farm families are estimated at 30,000, out of which 3030 are mango growers (MOA, 2010b). According to 2009 population and housing census the study area has a total population of 115,128 persons.

The district is characterized by three main agro ecological zones namely Lower Highlands (LHI), Upper Midland (UM_1, UM_2, UM_3, and UM4) and Lower Midland (LM_3, LM_4). Rainfall is bimodal with long rains season in March/June and short rains in October/December, ranging between 800mm – 1500mm per year. The soils are well drained, extremely deep, dark reddish brown to dark brown and friable clay with humic top soils; mainly humic nitisols and andosols (Jaetzold *et al.*, 2006).

Agricultural production in this district is mainly rain fed. The main cash crop enterprises are tea, coffee, mangoes, avocadoes, bananas, and passion fruits. Maize, beans, cassava and sweet potatoes are mainly grown as food crops. Other important crops include macadamia nuts, vegetables and Irish potatoes.

3.2 Sampling procedure

The population will be composed of mango farmers in Embu East district. Based on the study carried out in 2010 on farmers' willingness to pay for the IPM control package and intervention implementation, the sites purposively selected to constitute treatment or intervention group are Nthagaiya, Kiringa, Karurumo, Kathunguri, Kariru and Kasafari sub-locations. From the compiled list of mango farmers applying the IPM control package in the selected six sub-locations, 140 respondents will be randomly selected.

Mukuria and Kigumo, nearby comparison sub-locations, in which mango farmers have not used IPM control package, but in which are otherwise similar to the treatment sites, are purposively selected. One hundred and forty farmers will be randomly selected from these sub-locations for the interview, to constitute the control group.

According to Ortiz and Pradel (2010), samples of 60 to 100 farmers, who participated in IPM technology and a similar number of farmers who did not, has been found to be sufficient in estimating the impact.

To determine the sample size, the following formula by Cochran, (1963) is used.

$$n = (Z^2pq)/ e^2 \qquad (4)$$

Where n = Sample size; Z = the standard normal deviate at the selected confidence level; the value is 1.96 for commonly used 95% confidence interval; P = Proportion in the target population estimated to have characteristics being measured; q = 1 – p and e = the desired level of precision (5%)

In this case; p is determined as the proportion of farm families in Embu East district growing mangoes. Out of 30,000 farm families in this district, 3030 are mango growers.

$$n = 1.96^2 * 0.10 * 0.90/ (0.05)^2 = 138, \text{ rounded to } 140.$$

3.3 Data Collection

Both primary and secondary data sources will be used for this study. Primary data will be elicited from respondents using formal survey. A structured questionnaire (appendix 3) will be administered to 280 sampled mango producers; IPM control package participants (intervention group) and non-participants (control group), from the selected sub-locations. Prior to questionnaire administration, enumerators will be trained and the tool pre-tested in order to clarify issues in the questionnaire and make correction if any. Secondary data on volume of conversion rates used in the areas and the cost of the intervention will be sourced from Ministry of Agriculture Embu East District office and ICIPE office respectively. The data collected will be analyzed together with that collected during baseline study conducted in 2011. The baseline and the follow up survey measure the same variables, only at different times.

3.4 Data Analysis

Both descriptive statistics and econometric model will be used in impact analysis. Descriptive statistics techniques to be used include mean, standard deviation and percentages. This helps one to have a clear picture of respondents' characteristics. Difference in differences method will be employed to quantify important empirical results. STATA software will be used for data analysis.

3.4.1 The Empirical Model

The difference in differences (double- difference) method, in this study compares the outcome indicators with and without before and after adoption by using pre intervention baseline survey and post intervention data. The method is superior to single difference method used in impact evaluation, which only compares outcomes between a sample of adopters and one of non adopters, as it helps in resolving the selection bias (Omilola, 2009).

IPM control package impacts, using this method, are estimated by calculating the mean difference in magnitude of mango rejection and net income between the treatment and comparison groups after the intervention minus the mean difference in outcomes between the treatment and comparison groups before intervention. Table 1 below, displays the format, showing the groups being compared on the columns and the time periods on the rows. The difference (DD), shown in the lowest right cell of the table, is refered to as difference in differences estimate.

Table 1: Difference in difference (DD) estimate of average program effect

Survey round	**Intervention Group (Group *I*)**	**Control Group (Group *C*)**	**Difference across groups**
Follow up (2012)	I_1	C_1	$I_1 - C_1$
Baseline (2011)	I_0	C_0	$I_0 - C_0$
Difference across time	$I_1 - I_0$	$C_1 - C_0$	DD=[$I_1 - C_1$] – [$I_0 - C_0$]

Source: Ahmed *et al.*, 2009

DD approach is also estimated using regression approach provided there is baseline and post- intervention data for treatment and control groups (Omilola, 2009). The following regression equation is therefore estimated:

$Y_{i,t} = \alpha + \beta T_i + \gamma P_t + \delta T_i * P_t + \lambda_i X_i + \varepsilon_{i,t}$ ....(5)

Where: Y_i is the outcome of interest change in period t for farmer i = 1....n, in this case magnitude of mango rejections and net income from mango production.

T_i is a dummy variable: =1 if farmer i is in the treatment group; = 0 if in control group.

P_t is a dummy variable: = 1 if in posttreatment period: =0 if in pretreatment (baseline) period.

$T_i * P_t$ is an interaction term i.e. the product of the two dummy variables: =1 only in 2012 if farmer i applies the control package. It represents the actual treatment variable.

X_i is set of household/farm characteristics affecting the outcome of interest.

α is a constant term

β is specific effect of the treatment group, which accounts for average permanent differences between the treatment and control groups.

γ is the time trend common to both treatment and control groups

δ is the difference in differences estimate (effect of the treatment)

λ is the coefficient of X_{is}

ε is the error term

3.4.2 Variable definitions and measurements

The descriptions of the variables used in the model are as presented in table 3.1 below.

Table 2: Variable definitions and measurements

Variable	Definition	Measurement
Dependent variables		
MAREJT	Proportion of harvested fruits rejected by the market (export, domestic) due to fruit fly damage.	Percentage
NINCOME	Value of mango output sold less cost of production for the two specified periods.	Amount (KES)
Explanatory variables		

IPMTRT	IPM control package application	Dummy 1= applying, 0= not applying
TIMPRD	Period survey conducted	Dummy 1=2012(follow up), 0=2011(Baseline)
IPMEFFT	IPM package control effect	Dummy 1= only in 2012 if farmer applies IPM; 0 otherwise
MFEXP	Experience in growing mango	Years
LMP	Land under mango production	Acres
EDUCLV	Highest level of education achieved by household head	(1=none,2=primary, 3=secondary, 4=college/polytechnic, 5=university, 6=other)
MMTR	Number of mature mango trees	Number
DPRATIO	Proportion of household members fully dependent on the farm	Percentage
EXTS	Number of times household sought extension service	Number
OFFINCOME	Amount of off farm income earned by household per year	Amount(KES)
DISMKT	Distance to nearest market	Kilometers
CREDIT	Credit acquisition for mango improvement purposes	Dummy(1=accessed, 0= not accessed)

Source: Author compilation

To assess the impact of IPM control package on magnitude of mango rejections and net income from mango production (objectives 1&2), the model (equation 5) is modified to take form of the two dependent variables as specified below by equations (6) and (7).

$$MAREJT = \alpha + \beta(IPMTRT) + \gamma(TIMPRD) + \delta(IPMEFFT) + \lambda_1(MFEXP) + \lambda_2(MMTR) + \lambda_3(EDUCLV) + \lambda_4(EXTS) + \varepsilon \quad \text{.......(6)}$$

$$NINCOME = \alpha + \beta(IPMTRT) + \gamma(TIMPRD) + \delta(IPMEFFT) + \lambda_1(LMP) + \lambda_2(MFEXP) + \lambda_3(DISMKT) + \lambda_4(OFFINCOME) + \lambda_5(CREDIT) + \lambda_6(DPRATIO) + \varepsilon \quad \text{.......(7)}$$

where α is intercept; β,γ, δ and λ_1...... λ_6 are parameters to be estimated.

Table 3: Summary – Plan of data collection and Analysis

Objective	Type of Data	Data source	Data collection method	Data analysis
To evaluate the impact of IPMFFCP on magnitude of mango rejections due to fruit fly damage.	Quantitative- Amount mango harvested, sold, % rejected due to damage, demographic data	Primary-farmers	Structured questionnaire	Ordinary Least Square
To assess the impact of IPMFFCP on net income from mango production	Quantitative- Mango output, price, fertilizer, manure, pesticides, labour and their costs	Primary-farmers	Structured questionnaire	Ordinary Least Square
To evaluate the community's attitude on the effect of IPMFFCP on health and environment	Number of HH members/laborers poisoned after spraying pesticide in mango orchard , cost of treatment, change in negative effect of pesticide on health and environment	Primary-farmers	Structured questionnaire	Descriptive statistics

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APPENDICES

Appendix 1: Research Budget

Activity	Description	Unit	Unit cost(Kshs)	Total cost (Kshs)
Proposal development	Stationery	6	400	2400
Questionnaire printing	Stationery	500	30	12000
Consultative meetings with key informants and opinion leaders	Transport Lunch allowance	3 trips 8	1000 500	3000 4000
Training enumerators and pretesting of questionnaire	Transport Allowance	6 8*2	1000 700	6000 11200
Data collection	Transport (Fuel) Enumerators' allowance Researcher Accommodation/meals Stationery	90 litres 8* 20 days 25 10	130 700 3000 100	11700 112000 75000 1000
Data analysis	Software procurement/Training cost Travel costs during consultation/presentation meetings	1 3	10000 1000	10000 3000
Thesis printing and binding	Stationery	7	1000	7000
Grand Total				**278,300**

Appendix 2: Time schedule

Activity	2011		2012											
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Proposal Presentation and submission														
Pre-testing Questionnaire														
Data collection														
Data analysis														
Thesis writing														
Thesis Submission														
Thesis Defense														
Graduation														

Appendix 3: Survey Questionnaire

ECONOMIC IMPACT ASSESSMENT OF MANGO IPM FRUIT FLY CONTROL TECHNOLOGY PACKAGE IN EMBU EAST DISTRICT, EMBU COUNTY

SECTION 1: BASIC DATA

Name of enumerator……………………………………………………………

Date of interview…………………………………………

Division………………………………………… Location…………………………………………

Sub location…………………………………… Village…………………………………………

SECTION 2: HOUSEHOLD CHARACTERISTICS

2.1 Household type: 0= Non participant in IPM package 1= Participant in mango IPM package

2.2. Name of household head____________________________________

2.2.1 Farmer's contact telephone number ________________________

2.3. Gender of household head 1. Male /_______/

2. Female/_______/

2.4. Name of the respondent, if not the household head________________________

2.5. Respondent's relationship to head of the household

1. Wife/_______/ 2. Oldest son /_______/ 3. Other (Specify) /________________/

2.6. Age of household head: /__________/ years.

2.7. Highest level of formal education of household head (Tick one)

1. None…… 3. Secondary 5.University

2. Primary….. 4. College/Polytechnic… 6. Other (specify)…………………

2.8. How many years of schooling for the household head? /_________/

2.9. Household composition:

Age	Male	Female	Total
0 year to 14 years			
15 years to 64 years			
More than 64 years			

2.9.1 How many household members work in the farm full time? /_______/

2.9.2 How many household members work in the farm part- time? /______/

2.9.3 How many household members work outside the farm? /_________/

2.10 Distance of farm to the local shopping centre/ village market ________ Km

2.11. Total land size in acres: (1 acre = approx. 4,000m^2) (1ha = 2.47 acres = 10,000m^2)

	Acres Cultivated	Acres left fallow	Total size in acres
Owned			
Rented in			

2.12 Total land area under mango production last season /_______/acres.

2.13 Is the land under mango rented or owned? 0 = Rented 1 = owned

2.14 If land is rented for mango production, what is the rental rate per growing season? /____/ Ksh/acre

2.15. What are the major crops that you grow?

Cash / commercial crops	**Food crops**
1	1
2	2
3	3
4	4
5	5

2.16. Share of land under: Mango production _____% other crops____% Fallow____%

2.17 Type and value of physical assets

Asset	**No.**	**Value (Kshs)** ***	**Asset**	**No**	**Value(Kshs)** ***
1=Ox-plough			7=Water pump		
2=Ox-cart			8=Hose pipe		
3=Bicycle/motorcycle			9=TV		
4=Wheelbarrow			10=Radio		
5=Vehicle			11=Mobile phone		
6=Knapsack sprayer			12=Generator		

*** In its current state, for how much would you buy it from someone else?

2.18 Livestock Assets (Records for Mar '11 to Mar'12)

Livestock type	**Number at start of Mar 2011**	**No. sold between Mar '11 - Mar '12**	**Selling Price per head in kshs**	**No. bought between Mar '11 - Mar '12**	**Stock at Mar 2012**	**Value of stock as at Mar '12**
1.Cows						
2.Calves						
3.Heifers (mori)						
4.Bulls						
5.Chicken						
6.Sheep						
7.Goat						
8. Donkey						
9.Ducks						
10.Geese						
11=Turkeys						
12= pigs						
13= Rabbits						

2.19 What were the sources of income for the household in 2011/12 season?

2.19.1 Off-farm income	**Amount earned in 2011/12 (Kshs)**	**2.19.2 Farm income**	**Amount earned in 2011/12 (Kshs)**
1= Salary from formal employment (not casual)		1= Annual crop** sales	
2= Agricultural casual labor		2= Cash crop*** sales	
3=Non agricultural casual labour		3= Sale of own trees/timber/firewood	
4= Received pension		4= Value of livestock sold	
5=Remittances from family members/friends		5=Value of livestock product sold	
6=Running a business			
7=Renting out land, structures, oxen/bulls etc			
Total			

** **Annual crops**- Vegetables, fruits and food crops.

*** **Cash crops-** Coffee, macadamia, tea, sunflower, others (mango not included)

SECTION 3: MANGO PRODUCTION

3.1. How many years have you been growing mangoes? /__________/

3.2. What is the total number of mango trees in your farm? /________/

3.3. What mango varieties/cultivars did you grow last season (2011/12)?

Variety	**Number of young trees**	**Number of trees in production**	**Total number**	**3.4 Main reason for growing this variety** (*See code*)
1. Apple				
2. Tommy atkins				
3. Ngowe				
4. Kent				
5. Van dyke				
6. Keitt				
7. Sensation				
8. Haden				
9. Sabine				
10. Other (specify) ------------				

Reason: 1 = preferred by buyers, 2 = Higher returns, 3= yield potential, 4= longer shelf life

5= Disease tolerance, 6= pest tolerance, 7=Early maturing, 8= any other reason given

3.5. How have you planted your mango trees?

1= pure stand 2= intercrop 3= both but in different parts of the farm

3.6 If intercrop, which crops do you intercrop with?

a)................. b)...................... c)............................ d)...................

3.7 Did you use the following farm inputs in your mango farm last season (2011/12)? If yes, fill the details:

Input	**1=yes, 0=No**	**Source** *(See code)*	**Quantity (Kgs)**	**Unit code** *(See code)*	**Cost per unit (kshs)**	**Total cost (Kshs)**
Fertilizer						
Manure						

Source: 1=Own farm, 2=Stockiest, 3= Group 4= Friends

Unit code: 1= Wheelbarrow, 2=Bags, 3=20kg debe, 4=pickup, 5= lorry, 6= ox-cart

3.8 Did you apply pesticides on mango trees last season (2011/2012)? 1=yes 0=No

3.8.1 If yes, fill the details:

Product name	Target pest or disease Name	Timing of application	Source (see code)	Package size		Price of package (A)	How many times did you spray (B)	No. of pumps used per time (C)	Ml/mg /g used per pump (D)	Total amount used B*C* D=E	Total cost (Ksh:
				qty	unit						

Source: 1= old stock (From previous season), 2= Market, 3=Stockist/ agrovet, 4=Friends/family, 5=Group, 6= Produce buyer, 7= other (specify)

Timing of application e.g at flowering, at fruit set, before harvesting, as told by farmer

3.9 From your experience, are there any negative/harmful effects of using pesticides? 1=yes 0=No

3.10 If yes, list the negative/ harmful effects:

1)..

2)..

3)..

3.11 How many members of your household / laborers fell sick as a result of spraying pesticide in mango orchard last season? _______________

3.12 Did the affected seek any treatment in health facility? 1=Yes 0=No

3.13 If yes, how much money was spent for the treatment? ______________Kshs

3.14 (*To participants only*) From your experience in using IPM fruit fly control package, is there reduction in negative/harmful effect(s) of pesticide use on human health and environment? 1=Yes 0=No

3.15 How much labour did you use in the following farming activities related to mango production last season (2011/2012)?

A. Activity (*Fill only if the farmer carried out the activity)*	**B. Did you hire labour for this 1=Yes, 0=No**	**C. Hired labour (No. of people)**	**D. No. of days hired**	**E. Rate per day (Kshs)**	**F. Family labour (No. of people)**	**G. No. of days worked**	**Total Cost (Kshs)**
1. Digging up							
2. Weeding							
3. Irrigation							
4. Fertilizer Application							
5. Manure Application							
6. Pesticide Spraying							
7. Pruning of dead twigs							
8. Orchard sanitation							
9. Top-working							
10. Harvesting							
11. Grading							
12. Transporting to market							
Total labour cost							
Cost of hire of ox-plow or ox-cart for specific activity, if done, to be indicated in the Total cost column under the specific activity e.g digging, transport etc.							

3.16 What main constraints do you experience in mango production?

Constraint	**1=yes 0=No**	**Rank** *(See code)*
1) Propagation problem		
2) Access to farm inputs		
3) Pests		
4) Diseases		
5) Post harvest handling		
6) Other (specify)……………		

Rank: 1= Most serious, 2=fairly serious, 3=least serious

3.17 Mention the names of three most important insect pests and diseases that damage your mangoes:

Insect pests: 1)………………………………………………………………………..

2)……………………………………………………………………………

3)……………………………………………………………………………

Diseases: 1)...

2)...

3)...

3.17.1 Of the pests mentioned above, rank the most destructive pest(s) during 2011/2012 season.

Rank	Pest
Most destructive	
Second most destructive	
Third most destructive	

3.18 What is the level of damage caused by pests after harvesting mangoes?

1=low (0-30%) 2=moderate (31-50%) 3=Severe (51-90%)

3.19 What is the level of damage caused by diseases after harvesting mangoes?

1=low (0-30%) 2=moderate (31-50%) 3=Severe (51-90%)

SECTION 4: MANGO YIELDS, DAMAGE LEVEL AND MARKETING

4.1 During the last mango season (2011/12), how would you describe the damage level caused by fruit fly?

1=low (0-30%) 2=moderate (31-50%) 3=Severe (51-90%)

4.2 Out of the quantity you harvested during the last mango season (2011/12), what quantities (estimates) were damaged by fruit flies and diseases and quantity fit for sale?

A. Mango Variety	**B. Total quantity of mango harvested.**		**C. Quantity damaged by fruit fly**		**D. Quantity damaged by diseases**		**Total quantity of mango sold**		
	Qty	Unit	Qty	Unit	Qty	Unit	Qty	Unit	Price per Unit (Ksh)
1.									
2.									
3.									
4.									
5.									
6.									

***Unit codes:* 1= pieces; 2=bags; 3=crate; 4=4kg carton; 5=6kg carton; 6= other (specify)**

....

4.3 What are your estimated total earnings from mango last season (2011/12)………..Kshs

4.4 Do you sell your mangoes (1) individually or as(2) a group of farmers? ....

4.5 Who are the main buyers of your mango produce?

Buyer of mango(*See codes*)	**Percentage of mango sold**
1.	
2.	
3.	
4.	
5.	

Buyers: 1=Wholesaler/broker; 2=exporter; 3=processor; 4=large scale traders from big towns; 5=Local small scale traders; 6=consumers

4.6 How would you rate the market you have for your mango produce?

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

4.7 If not fully satisfied with the market of your mango produce, mention four main challenges experienced.

1)………………………………………………………………………………………

2)………………………………………………………………………………………

3)………………………………………………………………………………………

4)………………………………………………………………………………………

SECTION 5: FARMERS' PERCEPTION ON MANGO IPM CONTROL PACKAGE

5.1 Have you heard about ICIPE fruit fly IPM control package? 1=yes   0=No ………..

5.2 If yes, from who did you first hear about it? …… and when ……….year

1=extension officer   2=ICIPE staff   3=buyer   4=other farmer   5=other (specify) ……

5.3 If you participate in mango IPM control package, how long have you applied the package? ....season

5.4 Having applied the mango IPM control package for the stated period, what would you say in relation to the following IPM attributes?

Attribute	**Rating** *(See codes)*
5.4.1 Reduction in labour costs	
5.4.2 Reduction in pesticide use	
5.4.3 Reduction in pesticide expenditure	
5.4.4 Increase in yields	
5.4.5 Better mango prices/ quality improvement	

Rating: 0=ineffective; 1=less effective; 2=effective; 3=very effective

SECTION 6: ACCESS TO AGRICULTURAL INFORMATION, EXTENSION SUPPORT AND CREDIT

6.1 During the last three years have you received any training on any aspect related to mango production?

1=Yes 0=No

6.2 From whom do you primarily obtain technical information on practices to improve mango production?

0=Nobody; 1=Agricultural extension officer; 2=other farmers; 4=NGO; 5=Radio/TV/publication; 6=other(specify)...........

6.3 How many times during the last mango season did you consult an agricultural extension officer to seek advice or assistance on mango production? ....

6.4 How many times did you attend farmer field day, demonstration or field trial during 2011/12 season? ....

6.5 Did you get any form of credit/loan during 2011/12 period for the purpose of improving mango production? 1=yes 0=No

Appendix 4: Study area map

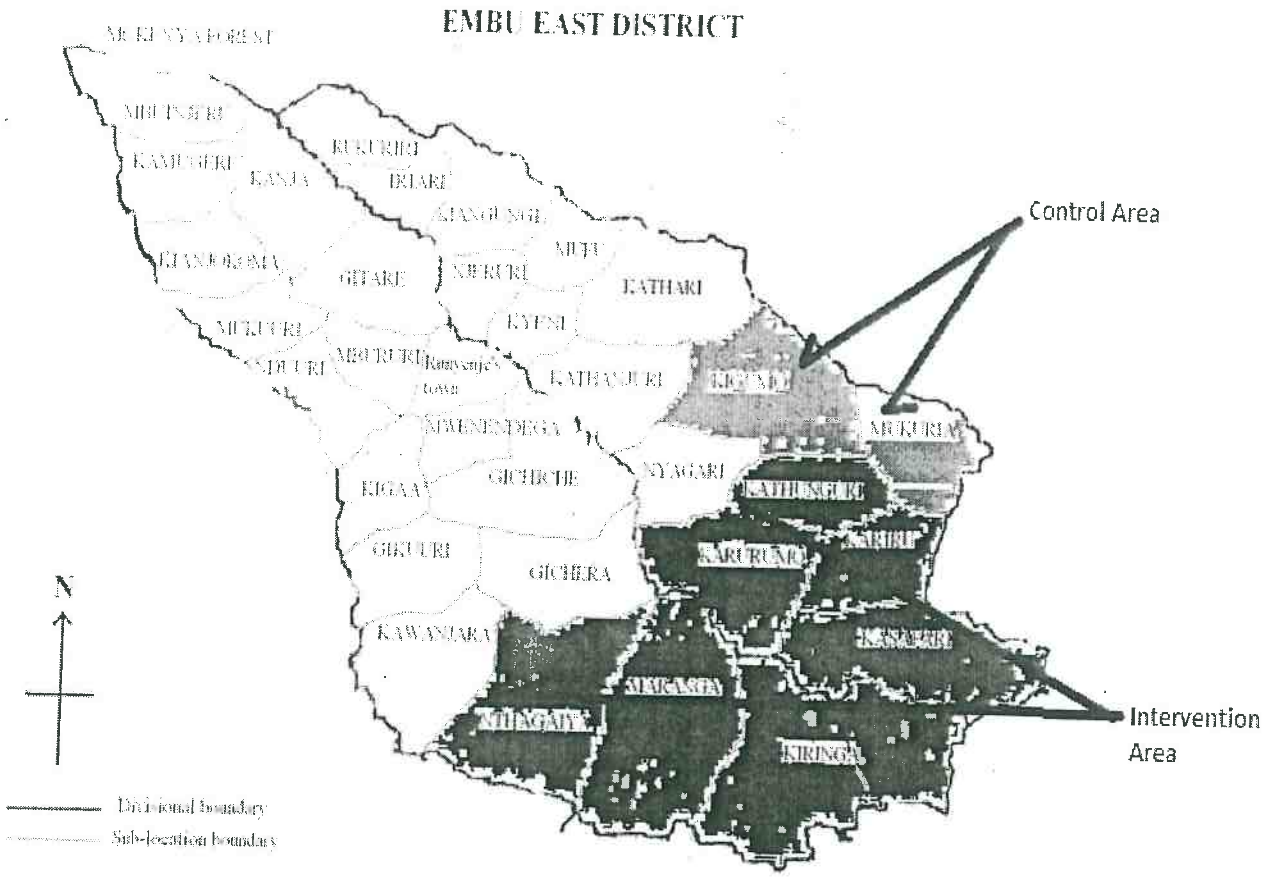

Figure 1: Map of Embu East District