ASSESSMENT OF YIELD LOSSES AND FARMERS' PERCEPTIONS ON CONTROL PRACTICES OF FALL ARMYWORM: THE CASE OF MAIZE INFESTATION IN TRANS-NZOIA COUNTY, KENYA

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DECLARATION

This thesis is my original work and has not been submitted for award of a degree in any other University.

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To my mother:

For your enduring love and unrelenting support

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ASALs	Arid and Semi-Arid Lands
CIDP	County Integrated Development Plan
DFDI	Department for International Development
EAC	East African Community
FAO	Food and Agriculture Organization
FAW	Fall Armyworm
FGD	Focus Group Discussion
IAS	Invasive Alien Species
IPM	Integrated Pest Management
KNBS	Kenya National Bureau of Statistics
MLND	Maize Lethal Necrosis Disease
NARS	National Agricultural Research Centers
PCA	Principal Component Analysis
PFA	Principal Factor Analysis
SPSS	Statistical Package for the Social Sciences
GoK	Government of Kenya

ABSTRACT

Maize is a principal staple crop in Kenya, largely grown under rain-fed agriculture. Its production is faced with numerous constraints both biotic and abiotic. Invasive species have been a major challenge; the most recent in Kenya being Fall Armyworm (*Spodoptera frugiperda*). Fall Armyworm is a pest native to tropical and subtropical regions of America which if not effectively managed can result in total crop failure. Maize yield loss estimates due to Fall Armyworm have been reported on a regional basis, thus masking the specific magnitude of economic loss incurred by farmers' which affects rural communities' livelihoods. Moreover, there is a paucity of information on farmers' perceptions of FAW control practices employed by farmers to curb the damage caused by the pest. This study sought to examine the magnitude of losses at the farm level caused by FAW and determine the driving factors influencing variations of losses among maize farmers. This study further sought to assess farmers' perceptions of FAW control practices and their determinants. A sample of 257 farmers from Kiminini Sub-County, Trans-Nzoia County was selected using systematic random sampling, and data collected using semi-structured questionnaires. Farmer perceived direct estimates and an iterative bidding procedure were used to assess maize yield losses, while drivers of losses among maize farmers were examined by use of a linear multiple robust regression. Principal component analysis was used to reduce the numerous and correlated variables into definite perceptions. Multiple linear regressions were fitted to determine factors influencing the perception scores obtained.

Results from the study showed that Fall Armyworm losses average at 0.703 tons per acre. Fall Armyworm maize related losses were influenced by different variables such as group membership, household size, access to extension services, years of formal schooling attained, distance to market among others. Principal component analysis showed that the main farmer perceptions were; increased productivity, environmental safety, socially acceptable, promotion efforts, and availability. These perception scores were found to be influenced by different sets of variables such as income, sex, age, primary occupation, and household size among others. Based on the findings, there is a need to increase extension services, package the approach and material training content to target farmers, organization of farmers into active groups that are agriculture-related, and consider farmer perceptions. Additionally, farmers' perceptions were explained by a combination of factors such as schooling years, sex, age, extension access, group membership among others. These will play a vital role to inform and aid policy makers and technology developers, in concerted efforts towards formulation and dispensation of a well-coordinated, flexible, and effective integrated FAW management approach.

Keywords: Maize, yield losses, Fall Armyworm infestation, perceptions

CHAPTER ONE

INTRODUCTION

1.1 Background information

Maize among other crops in Kenya is the principal staple food crop accounting for at least a third of consumed calories, where the per capita consumption is estimated to be 106 kilograms per year (Muricho et.al, 2013). In Kenya shortage of maize is equated with national food insecurity. According to FAO (2014), maize is considered an inferior good since it has the highest share in staple food expenditures. It accounts for approximately 20 percent of total food expenditures to twenty percent of poor urban households, and a low of one percent of total food expenditures among the wealthiest twenty percent. Besides farm families relying on maize as a staple food, they also depend on maize as a source of ready cash.

Approximately 50 percent of cultivated agricultural land in Kenya is under maize production and about 3.5 million smallholder farmers participate in maize production. This accounts for close to 75 percent of the maize produced, the remaining portion is produced by large-scale farmers (Kirimi and Swinton, 2004: D'Alessandro *et al*., 2015). According to Bozzola *et al.,* (2016), maize accounts for 28 percent of the gross farm output for smallholder farmers implying that maize contributes a greater portion of crop income for the rural populations.

The bulk of maize producers in Kenya are smallholder farmers and thus, the integration of this venture with other linkages of the economy has the potential and opportunity to positively impact rural incomes, poverty reduction, and food security status in Kenya (Omiti *et al.,* 2009; Karanja *et al*., 2019). Along the maize value chain, maize is utilized in a variety of forms as human food, this includes; maize meal, green maize, and maize grain (Muyanga *et al.*, 2005; Nying'uro, 2020). Additionally, maize has been used over time as a key ingredient in the processing of animal feed such as dairy and poultry feeds. This has significantly increased the demand for maize thus increasing its prices (Shiferaw *et al.,* 2011; FAO, 2020).

The 21st century has witnessed extensive adoption of improved seeds and long-term successes in evolving the maize sector in Sub-Sahara Africa. International Maize and Wheat Improvement Center (CIMMYT) is among the organizations that led in the introduction of high-yielding maize varieties, which are pest-resistant, drought-tolerant, and have a shorter growth period (Cairns *et al.,* 2012). Momentous progress has been achieved to date but still there exist drawbacks such as social instability and climate change which have greatly impacted the maize sector. Among other factors that have affected the productivity of maize are; pests and diseases, heavy rains, and lack of quality planting materials (Ndwiga *et al*., 2013).

Pests and diseases have been reported to cause huge losses through loss of markets for maize, total crop failure, and reduced productivity (Republic of Kenya, 2019). Distinctively in Kenya, maize production has decreased primarily due to lower volume of rainfall, high cost of farm inputs, and the residual effects of Maize Lethal Necrosis Disease (MLND) (KNBS, 2017). According to De Groote *et al.,* (2016), MLND has the potential to cause total crop loss. Prior to the existence of Fall Armyworm which is a recent invasive alien species (IAS) was MLND, maize stalk borer (*Chilo partellus*), and Parthenium. The estimated current annual production losses to smallholder farmers in Kenya caused by the above IAS on a lower estimate is 123.6, 42.8, and 3.8 USD million respectively (Pratt *et al.,* 2017). According to Essl et al., (2011), IAS have increasingly emerged as a global problem due to the accelerating international trade activities specifically since the end of the 20th century.

Fall Armyworm is a polyphagous invasive pest native to the tropical and sub-tropical regions of America. The pest presence in Africa was first confirmed in 2016 having infested maize fields in Nigeria, Togo, and Sao Tome (FAO, 2018). Fall Armyworm has been described as a sporadic pest due to its migratory behavior and when the wind patterns are right, it can fly approximately 100km per night (Johnson, 1987; Early *et al.,* 2018). This migratory habit and its quick spread has been associated with increased global temperatures in the recent past, which has facilitated the pest to invade over 30 countries in Sub-Sahara Africa (Hardke *et al.,* 2015; Prasanna *et al.*, 2018; CIMMYT, 2017). Fall Armyworm existence in West Africa has caused significant economic damage to host plants mainly maize and sorghum. Sparks (2014) estimated total losses caused by FAW that ranged between US$ 39 to US$ 297 million annually and described the pest as the second most damaging agricultural pest. In Brazil, Fall Armyworm is one of the most important maize pests which accounts for US$ 400 million losses (Sena *et al.*, 2003).

According to (Cruz and Turpin, 1982; Assefa & Ayalew, 2019), FAW larvae feeds on ears, tassels, and young whorls leaves of maize. This has resulted in reduced quality and quantity of yields realized hence negatively impacting smallholder farmers' livelihood as illustrated by the Department for International Development framework (DFID, 2008). Indirectly, a household's assets are affected, that is, social and physical capital. Additionally, natural capital has also been affected through yield loss and also the resilience of agricultural lands in response to shock. In Sub-Saharan Africa, an estimate of 13.5 million tons is the maize yield loss which translates to a predicted loss of 3,058 US$, million (Abrahams *et al.*, 2017). Left uncontrolled, FAW significantly reduces maize yields causing approximately 47% crop damage and when severe, can result in total crop failure (Kumela et al., 2018).

Maize is an important staple and seasonal food crop in Kenya, with existing recommended regional planting schedules (GoK, 2017). However, farmers plant at different times within the season. As a result, maize plants in different sites grow at different growth stages. This propagates the breeding of the Fall Armyworm larvae (Midega, 2018), hence the continuous infestation of FAW contributing to reduced yields. Noting the risk posed by FAW infestation in the maize sub-sector, the pest downplays the critical role played by maize in enhancing food security and supporting livelihoods since it is grown both for subsistence and commercial purposes among smallholder farmers (Salami *et al.,* 2010).

To mitigate the damage caused by Fall Armyworm, farmers have resorted to coping strategies which entail the use of various control practices; traditional, physical, biological, resistant varieties, chemical applications, and use of farming systems and technologies that are focused on managing the pest (Kassie, 2017). Such practices include; scouting, application of synthetic pesticides, hand-off picking, soiling of whorls, drenching with tobacco extracts, and use of the push-pull farming system (Kumela *et al*., 2018; Midega *et al*., 2018; Prasanna *et al.,* 2018). Despite the wide range of control practices, farmers heavily depend on pesticide application which the pest has been reported to have developed resistance against (Yu, 1992).

1.2 Statement of Research Problem

Fall Armyworm has emerged to be a significant invasive insect pest causing reduced quality and quantity of maize yield, posing a serious threat to the sustainability of maize production in Kenya and across the globe (Goergen *et al.,* 2016; FAO, 2018). For instance, the pest is considered to be the most voracious in Florida, USA causing up to 20 percent yield loss in maize. The estimated yield loss in Honduras and Argentina is estimated to be approximately 40 percent and 72 percent respectively (Early *et al*., 2018). A study by Kumela *et al*., (2018) estimated that Fall

Armyworm infestation in maize fields averaged at 47.3 percent imposing an estimated maize yield reduction of approximately 1,381 kg/ha in Kenya, suggesting profound damage to livelihoods since farmers revenues are negatively impacted. A dimensional impact key for policy formulation and action prioritization in rural communities with limited resources is that of yield losses associated with invasive pest infestation. To date, studies on the impact of invasive species in agriculture are focused on individual pests and diseases, highlighting specifically on yield loss (Nghiem *et al.,* 2013). Attempts by researchers to quantify economic losses due to FAW have majorly been regional thus masking the specific impacts of FAW on rural communities (De Groote, 2002; Pimentel *et al.,* 2011; Abrahams *et al.,* 2017). Therefore, the resulting outcome is a knowledge gap which this study seeks to address in the case of FAW, a new invasive species in Kenya.

Efforts to manage the pest have resulted in farmers adopting different control practices; pesticides, biological, use of host plant resistance, and cultural control practices (Midega *et al.*, 2018; Kassie *et al.*, 2018). However, despite the already recommended and documented FAW control practices (FAO, 2018; FAO 2019), there exists anecdotal empirical evidence on farmers' perceptions of FAW control practices. Documenting farmers perceptions on FAW control practices is essential as it informs the need for testing and validation of the measures, to aid in the improvement of maize production systems that contribute to the incomes of maize farming households and food security. In addition, determinants influencing these perceptions are not known. Therefore, this study attempts to fill the knowledge gaps by taking the case of maize production in Trans Nzoia County.

1.3 Purpose and Objectives

The purpose of the study is to assess the magnitude of yield losses incurred due to Fall Armyworm infestation on maize as well as farmers' perceptions on the control practices and their determinants in Trans-Nzoia County.

1.3.1 Specific Objectives

1. Estimate the magnitude of yield losses caused by Fall Armyworm infestation among maize-producing households.
2. Determine the drivers on the magnitude of yield losses in maize due to Fall Armyworm infestation.
3. Analyze farmers' key perceptions of Fall Armyworm control practices.
4. Assess the determinants of farmers' key perceptions on Fall Armyworm control practices.

1.4 Hypotheses

1. Fall Armyworm infestation does not result in high yield losses in maize producing households.
2. Farmer, farm specific, and institutional factors do not affect the magnitude of yield losses in maize.
3. Farmers have negative perceptions of the control practices used in Fall Armyworm management.
4. Farmer, farm specific, and institutional factors do not affect farmers' perceptions of Fall Armyworm control practices.

1.5 Justification

This study seeks to provide empirical evidence on the extent of economic losses due to Fall Armyworm infestation on maize fields at the farm level. Such data on yield losses is fundamental for the management of FAW and the evaluation of the effectiveness of current control practices. Consequently, findings from the study will be essential for planning food policy and for economic reasons because maize yield losses will have an impact on maize prices based on the laws of supply and demand (Walker, 1983; Oliveira *et al.*, 2014). Findings on yield losses due to FAW will be essential in informing and enhancing both public and private agricultural stakeholders, on the need to mainstream funds and capacity in an attempt to address the impact of FAW on maize farmers. Additionally, among other major constraints limiting the establishment of an effective FAW management practice for maize producing farmers, is the lack of sufficient information on farmers' perceptions of the control practices in managing the pest. This knowledge gap is of much significance, therefore, findings from this study on perceptions will contribute to the growing literature on sustainable agricultural technologies aiding technology developers in the design and formulation of an effective FAW IPM package, a pest that has been a menace threatening the sustainability of maize a crop classified as a principal staple food in Kenya. This will be of essence in contributing to the waged war against malnutrition, hunger, and extreme poverty as per the Malabo declaration and Sustainable Development Goals (SDGs) number one and two as well as Kenya's Vision 2030.

CHAPTER TWO

LITERATURE REVIEW

2.1 An overview of maize sub-sector in Kenya

Maize is the dominant cereal and important food crop grown by the majority of smallholder farmers in Sub-Sahara Africa across different agro-ecological zones. Over 200 million people depend on the crop for food security (Macauley, 2015). In Kenya, maize is grown across the six existing agro-ecological zones, and the average productivity 1.8 tons per hectare while the potential yield is 6 tons per hectare (Tittonell et.al 2008).

According to (Nyoro, Kirimi, and Jayne, 2005; Odhiambo, 2012; De Groote *et.al*., 2019), farming households in potential maize producing zones such as the Western part of Kenya can produce between 3.4-5.8 tons per hectare while those in less favorable zones such as dry mid-altitude, dry transitional zones and low land tropics on the coast obtain 1.1 tons per hectare. The mid-altitude is described with a moderate yield of 1.5 tons per hectare. The average maize yields in Kenya increased between the years 1960-1970 but afterwards, the yield has remained slightly above 2 tons per hectare despite increasing acreage under maize cultivation (Figure 1). Implying that maize production in Kenya is mainly driven by area expansion which does not commensurate with the yield obtained (Smale, Byerlee, and Jayne, 2011).

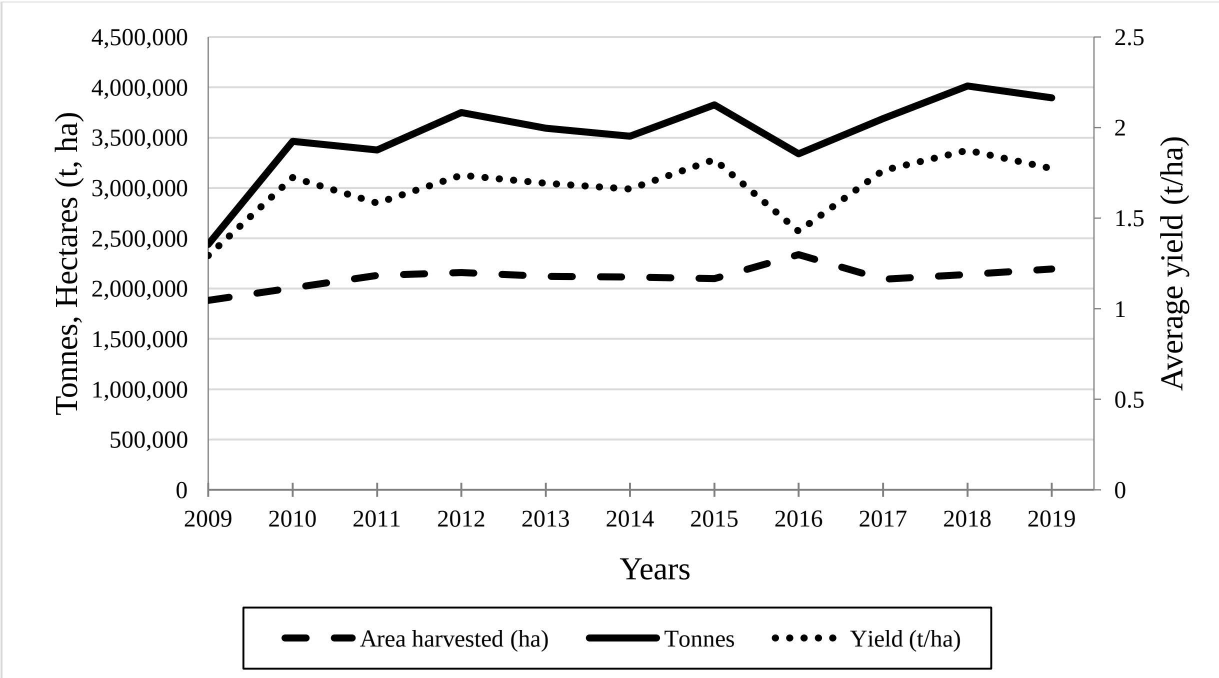

Figure 1: Kenya's maize production from 2009 to 2019

Source: FAOSTAT 2021

Kenya's national maize production has over time not matched with the commodity's consumption pace due to the increased demand which has mainly been driven by population growth over time (Onono *et al.*, 2013). As an attempt to bridge up the continuously increasing gap between maize supply and demand, Kenya has continued to import maize. The KNBS (2018) showed that maize production dwindled significantly resulting in a substantial increase in imports valued at Kshs. 40.3 billion in 2017 from Kshs. 3.6 billion in 2016. This has transited Kenya's trade status from a net export to a net importer of maize dating back to the early 1990s (Odhiambo, 2012). The importation has occurred both formally and informally across the border of neighboring countries in the East African Community (EAC) accounting for approximately 60 percent of trade in staple grains (Ackello-ogutu, 1997; Little, 2015). Additionally, when imports from Tanzania and Uganda are insufficient, large offshore imports from Malawi, South Africa, the United States of America, Mexico, Argentina, and Brazil are allowed into the country by lowering import duty (FAO *et al.,* 2014). Imported maize from neighboring countries is cheaper compared to that produced domestically, due to lower production cost margins from exporting countries. This aggravates the food price dilemma where policymakers have to strike a balance of improving the competitiveness of domestic maize production. This helps deal with the ability to reduce the cost of maize production to ensure profitability to producers', while at the same time improving local consumers' access to the commodity.

Despite maize being grown across different agro-ecological zones in Kenya contributing to rural household incomes, most rural households have diversified their sources contributing to household income. Nyoro *et al.,* (2004) demonstrated that livestock rearing and non-farm activities are important sources of income that collectively together exceed crop production. Across the seven agro-ecological zones, small-scale rural households extract between 23 to 70 percent of their income from off-farm sources. Nonetheless, maize when bundled with other horticultural produce it accounts for approximately 14 percent of the household income. This is obtained when surplus maize is sold to help farming households purchase other goods from the market, thus attaining self-sufficiency (Nyoro *et al.,* 2005). Additionally, Mathenge *et al.,* (2014) showed that maize accounts for approximately 28 percent of gross farm output for small-scale farmers, whereas the share of crop income among farming households has averaged between 44 to 48 percent over time (Bozzola *et al.,* 2016).

2.2 Constraints to maize production

Maize production is affected by both biotic and abiotic factors. Among the abiotic factors, drought is the major factor affecting maize production in the tropics a region where most maize producing countries are located. Agricultural production systems mainly in developing countries are rain-fed and hence lack of sufficient moisture suffices as a challenge leading to the withering of plants (D'Alessandro *et al*., 2015). Poor soil fertility has led to the use of artificial fertilizers which over time has resulted in soil acidity thus affecting maize production (Morris *et al.,* 2007). Additionally, the low uptake of technologies designed to improve productivity such as the adoption of high-yielding maize varieties which are drought and pest resistant has facilitated low production levels of maize (Shiferaw *et al.,* 2011). For instance, CIMMYT is one of the organizations that has spearheaded the introduction of high-yielding maize varieties which a shorter growth period, which is drought tolerant and pest resistant (Cairns *et al.,* 2015).

Fungal diseases of economic importance include Kernel, Southern corn leaf blight (*Bipolaris maydis*), Northern corn leaf blight (*Exserohilum turcicum*), Common rust (*Puccinia sorghi*), Southern rust (*Puccinia polysora*), Stalk and ear rots (*Diplodia* spp., Fusarium spp and *Aspergillus* spp), Gray leaf spot (*Cercospora* species) (Shiferaw et al., 2011). Kernel and ear rot caused by *Fusarium* spp. and *Aspergillus* spp leads to food contamination as a result of mycotoxin production thus reducing the quality and safety of the seed (Macdonald and Chapman, 1997).

Maize lethal necrosis disease (MLND) is among the viral disease that adversely affects maize production, which occurs as a result of synergistic interaction of two viruses; Maize chlorotic mottle virus and Sugarcane mosaic virus (Adams et al., 2014). For instance, KNBS (2017) report demonstrated that maize production decreased from 42.5 million bags in 2015 to 37.1 million bags in 2016 mainly due to lower volumes of rainfall, high farm input costs, and the residual effects of MLND. Among other viral diseases affecting maize production is Guinea grass mosaic disease caused by *Guinea grass mosaic virus*, Maize eyespot virus disease caused by *Maize eyespot virus*, Maize chlorotic stunt virus, Maize dwarf mosaic disease caused by *Maize dwarf* *mosaicvirus* and maize stripe disease caused by *Maize stripe virus* and Maize mosaic virus disease caused by *Maize mosaic virus* (Redinbaugh and Zambrano, 2014).

Pests and diseases have been noted to have a drastic decline in maize productivity over time (Shiferaw et al., 2011). As a result, pest management has important implications for African agriculture where a majority of the farming community consists of smallholder farmers who experience low agricultural productivity (Bature *et al.,* 2013). Striga, a parasitic plant weed has been classified as one of the major constraint maize production constraints (Khan *et al.,* 2002).

Pests in maize are either above-ground pests or root pests. Above ground, pests include grasshoppers, stem bores, aphids, spider mites, termites, thrips, adult rootworms, and armyworms (Ortega, 1987). A study by Kfir *et al.,* (2002) noted that stem borers can result in a yield loss of up to 30%, whereas, Pratt *et al.,* (2017) estimated an annual production loss to smallholder maize farmers in Kenya as a result of stem borer infestation to be US$ 46.9 million and further predicted a future loss of US$ 37.5 million on average. Before the introduction of FAW in Africa, stem borer was the most important pest causing devastating yield losses in maize production (De Groote, 2002). Mature maize grain either in storage or at the field face the risk of being infested with grain borers and grain weevils (Tefera, 2012). Post-harvest pests such as grain weevils (*Sitophilus zeamais*), larger grain borer (*Prostephanus truncatus*), angoumois grain moth (*Sitotroga cereallela*), and the lesser grain weevil (*Sitophilus oryzae*) all together can lead to yield loss ranging between 20-30% of the stored grain (Yuya *et al.*, 2009).

2.3 Spread and Economic importance of Fall Armyworm

Fall Armyworm is an IAS native to the tropic and sub-tropic regions of America, where it is a prime noctuid pest of maize. FAW has remained confined in this region despite the extensive interceptions by the European quarantine services (Goergen *et al.,* 2016). Its introduction to

Africa has already moved to over 30 countries, which have confirmed the presence of the pest within their territories (FAO, 2018). Countries of initial FAW breakout in Africa include; Nigeria, Ghana, Benin, and Togo in West Africa which has major air transportation hubs and are highly climatically similar to the regions from which the flights originate. South America and Africa having been infested with FAW, vulnerable destinations for the pest are countries that receive exported commodities from Africa. Such countries include India, China, Indonesia, Thailand, and Australia. These countries are immensely threatened by FAW invasion (Early *et al.,* 2018).

Fall Armyworm has emerged to be the most damaging pest since it can feed over 80 different crop species (Prasanna *et al.,* 2018). The pest preference is plants of the grass family (maize, wheat, sorghum, rice, millet, and sugarcane), it will also attack other economically important crops such as cotton, peanuts, soybean, and potato (Ali *et al.,* 1989). In Brazil, FAW is considered as one of the chief pests in maize (Cruz *et al*., 2012) where it has been reported to cause massive maize yield losses worth US$ 400 million (Sena *et al.*, 2003). In Kenya, compared to other common maize pests such as stem borer, FAW is considered as much more problematic resulting in higher yield losses (Kumela *et al*., 2019).

The breakout of FAW in Africa coincided with the duration when the region was recovering from the 2015-2016 El-Nino rains which had wreaked havoc affecting approximately 40 million people (Prasanna *et al.,* 2018). With its quick spread and existence of a wide spectrum of host plants, FAW presented a serious threat to the livelihoods of farmers and the nutritional security of farming households across Sub-Sahara Africa, especially when added to other existing factors that influence food security. The estimated impact of FAW infestation in among 12 of Africa main producers of maize (Ghana, Zambia, Malawi, Democratic Republic of Congo, Zimbabwe, Benin, Ethiopia, Tanzania, Mozambique, Nigeria, Uganda, and Cameroon) as an extrapolation of proportional estimate yield losses from data obtained from Ghana and Zambia where yield loss due to FAW was first estimated. Abrahams *et al.*, (2017) demonstrated that in the absence of appropriate control measures, Africa stands to incur a margin maize yield loss of between 8.3 and 20.6 million MT amounting to a marginal economic loss of between US$ 2.4 and US$ 6.1 billion annually. Due to the pests' wide range of host plants, the total expected production yield loss was estimated to be 39 million MT translating to a total expected value of US$ 11.5 billion annually. These accounts for 21-53 percent maize yield losses representing a three-year period of maize production (Prasanna *et al.*, 2018).

Kumela *et al*., (2018) showed that a FAW infestation imposed an estimated yield loss of 1.3 tonnes per hectare of maize. Kenya's maize productivity is 1.4 tonnes per hectare (FAOSTAT, 2016) while the potential productivity is 6 tonnes per hectare. This suggests that farmers incur profound yield losses which further impact their revenues negatively after harvesting. In addition to these yield losses incurred, farming household's capital cost is directly affected by the increased need for labor, the knowledge required to manage the pest, ability of agricultural lands to respond to shocks, and increased cost of production. Additionally, the resulting indirect impacts occur due to quantity and quality yield loss, control measures in terms of costs and time (DFID, 2008; FAO, 2020). These include reduced food and income, as well as wide-ranging economic, social and environmental impacts.

2.4 Review on yield loss estimation

The variance between attainable and actual yield is described as crop yield loss (FAO, 2015). Estimating yield loss can be achieved through different approaches. These include direct and indirect estimations, use of field surveys or experiments, and creating a link between yield loss and pest incidence respectively (Walker, 1983; Walker, 1991). Other estimation approaches involve the use of farmer-based estimates (De Groote, 2002; Kansiime, 2019), and the use of community surveys (De Groote *et al*., 2016; De Groote *et al*., 2020). Moreover, Teng (1990) demonstrated the use of expert opinion in establishing yield loss.

A community survey was used in estimating the impact caused by the Maize Lethal Necrosis Disease (MLND) in Kenya, establishing a 22 percent yield loss equivalent to 0.5 million tons per year (De Groote *et al*., 2016). Moreover, De Groote *et al*., (2020) used community surveys to estimate maize yield losses due to FAW incidence. The study established that maize yield losses due to FAW infestation had slightly decreased from 54 percent to 48 percent for the season 2017 and 2018 in Kenya respectively.

Through direct estimates of maize losses due to FAW, Baudron *et al*., (2019) estimated maize yield loss to be 11.57 percent among two districts in Zimbabwe. This involved rigorous plot-level scouting using digital imaging in assessing grain weight losses in sampled maize plots. Basing on farmer estimates Kumela *et al*., (2018) estimated that FAW led to maize yield reductions of 934 kg/ha and 1381 kg/ha in Ethiopia and Kenya respectively, while Kansiime *et al*., (2019) estimated the effect of FAW incidence to have resulted to a 28 percent yield loss in Zambia for the 2016/2017 cropping season. De Groote, (2002) through direct estimation established a yield loss of 12.9 percent, which is equivalent to 0.4 million tonnes of maize due to stem borer infestation.

Direct estimates produce more precise observations on yield, but they are time-consuming and expensive undertakings compared to relying on farmer-based estimates which are easy and cheap to collect data on (Fermont *et al*., 2009; Lobell *et al*.,2018). Basing on farmers' experience and overtime field observations, given that the pest is easily visible and identified, farmers, can aptly establish good estimates on crop yields in the absence or presence of the pest (De Groote 2002; De Groote *et al*., 2016).

2.5 Review of empirical literature

2.5.1 Factors affecting yield loss

There exist biotic and abiotic aspects that affect staple crop productivity contributing to the reduced pace in addressing poverty, achieving food security, and realizing sustained economic growth (Pretty *et al.,* 2011). This has resulted in the existence of a gap between site-specific potential yield and the actual yield realized (Van Ittersum *et al.*, 2016). Some of the aspects that influence yield loss include socioeconomic, farm, farmer specific, and institutional factors.

Education is a social capital component, which is a significant positive determinant of agricultural production (Sarris, Savastano & Christiaensen, 2006; Babatunde *et al.*, 2007). Weib and Gollenhon (2007) noted that education imparts individuals with skills that help in solving problems and is, therefore, a human capital investment, which commensurates to a farmer's investment in physical capital. Kipkemei (2001) found that farmers with secondary school agricultural knowledge perform significantly better in farming aspects compared to farmers with no secondary school agricultural knowledge. This implies that secondary school agricultural knowledge not only broadens farmers' capacity but also makes them more self-reliant, effective, resourceful, and capable of solving farming problems. Evenson and Mwabu (1998) found out that the effects of schooling on-farm yields are positive and statistically significant. The larger part of literature measures education level in the household, by use of the education level of an individual in the household (usually the household head) or the average level of education in the household (Onphanhdala, 2009). Education has overly contributed to reduced reliance on family labor and increased the use of hired labor by farm households (Bagamba *et al.,* 2008). This implies that education increases the probability of participation in off-farm work, hence reducing work effort in farm production and consequently creating negative effects on farm yield.

Extension as a form of education is important, in determining what methods farmers use to produce crops (Nganje *et al.,* 2001). Particularly for the relatively more profitable mono-cropping, extension contact by extension personnel is significant and positive. Extension services access can be obtained through different methods. Apart from on-farm visits, information and knowledge on farming can be obtained through television, radio, and pamphlets which are in English and Swahili (Kilonzi, 2011). This implies that farmers who can read and write may have access to more farming information. Educated farmers may adopt newer technologies and better farming techniques which in turn shields them from increased farm yield losses.

Waithaka *et al.,* (2007) noted that higher incomes for a household translate to the ability to satisfy its basic requirements plus a surplus for productive activities such as purchasing of pesticides. Such incomes may also allow households engagement in casual labor. Investing income (farm and off-farm income) obtained in farming practices improves farm yield.

Farmers practice different forms of farming systems, which affect their farming activities. Muchiri (2012), a study on assessing economic losses in mango due to fruit fly infestation noted that farmers who intercropped other crops in the mango orchard experienced higher losses. This implied that intercropping in a fruit orchard increased the level of fruit fly infestation incidence reducing the mango fruit yield realized. The regression result posited a positive sign on the cropping system variable. The study also noted that an increase in the size of land under mango production by 1 acre was associated with increased loss due to fruit fly damage. This was explained to have resulted because of managerial weakness arising due increase in the production area. However, in some incidence, farming systems have been used as techniques to control the pest. Midega (2018) noted that the use of push-pull technology as a way to manage FAW compared to monocrop maize plots improved grain yields ranging from 3.6 to 5.7 tons per hectare.

The age of a farmer can be used as a proxy for the farmer's experience in farming (Wiredu *et al.*, 2010). This implies that an experienced farmer is more likely to be an older farmer. Wiredu *et al.,* (2010) a study on rice cultivation in Ghana, noted that age had a positive effect on yield meaning experience in rice cultivation implied accumulated knowledge in rice production. However, age was found not to significantly affect a farmer's adoption decision (Bonabana-Wabbi, 2002). The study noted that because of investing several years in a particular practice, older farmers were hesitant in trying out new methods. In other words, with age, a farmer can become more or less risk-averse to new technology. In the case of pest management, older farmers can become hesitant to new pest management technologies resulting in poor yields obtained. This variable can thus have a positive or negative effect on a farmer's decision to adopt, for example, a pest control technology.

Typically, in the rural areas of Kenya, almost all members of a family go to the farm including children. Bagamba *et al,* (2008) showed that household size had a positive effect on family labor use. The positive relationship between farm size and family labor use can be attributed to a higher marginal product of labor for households with large farm sizes. Larger households would be able to provide more labor for their farms than smaller households would, especially if they cannot hire labor. Size of farm cultivated and the timely carrying out of procedures like ploughing, weeding, pest control would affect farm yields. Oluwasola *et al.,* (2008) showed that household size positively related to farm income implying that larger households had more labor which contributed to farming as an enterprise hence higher farm incomes. The study noted that a unit increase in farm expenditure results in a 75 percent increase in net farm income. This means that farm expenditure had a positive relationship to net farm income and was statistically significant. This implied that more farm investment tended to increase yield realized from the farm. A household faced with other pressing needs like clothing and school fees spends less on farming may most likely get lower farm yields.

2.5.2 Review on farmers' perceptions of agricultural pest control technologies

Pests have continuously impacted agriculture around the globe by being a major cause of yield losses (Oerke, 2006). This has resulted in pests being classified as an important cause of food insecurity in developing countries (Zakari *et al.*, 2014). Consequently, farmers are driven to obtain crop and pest management decisions with reference to their production contexts in which production takes place; economic, physical, technical, biological, and social context, which in turn shape their production frontiers (Savary *et al.*, 2006a, b). Although the linkage between vulnerability to pest infestation and the production situation has been demonstrated (Savary *et al.*, 2017), there exists paucity on the relationship between production situations and farmers' perceptions of pest control practices. Hence, an assessment to capture farmers' perceptions on pest control technologies is considered important for aiding technology developers and policymakers to facilitate the production of an effective FAW management approach.

A study by Nabifo (2003) noted that farmers' perception of a technology is a significant determinant in the decision to use a technology. Therefore, if farmers' perception is that the efficacy of a technology does not meet their profit expectations, there will be low investments in the technology. In most cases, the proxy to the efficacy of a technology is equated to improved yields realized. For instance, perception studies on soil fertility improvement technologies have concentrated both on perception based on soil fertility, whether farmers view it as a problem or not, and based on specific attributes and benefits of the technology (Marenya *et al.*, 2008; Meijer *et al;* 2015). As a result, farmers who view soil fertility as a problem have a higher acceptance and adoption of a technology.

Farouque and Hiroyuki (2007) carried out a study in Bangladesh aimed at determining farmers' perception of integrated soil fertility and nutrient management for suitable crop production realized that marginal, landless, and small farmers had a low awareness level compared to medium and large farm holders and thus affected their perception. The study noted that a significant 78 percent of the farmers had a very low perception while 22 percent of the farmers had a medium to a high level of perception. This implied that farmers had a low perception of farmyard manure and the role of organic matter as well as the beneficial aspect of nutrient management and integrated soil fertility for suitable crop production. Determinant farmer characteristics that influenced farmers' perception of integrated soil fertility and nutrient management positively include; farming experience, education level, farm size, and communication exposure while fertilizer use and family size influenced farmers' perceptions negatively.

Previous studies on the perception of farmers on agricultural technologies indicate that varying socio-economic factors do influence farmers' perceptions of the various agricultural technologies. For instance, (Adeola, 2015), demonstrated that a farmer's age which is often associated with farm experience plays a significant role in the perception of pesticides as hazardous to the environment. Additionally, other factors such as education and extension contact affected the use of pesticide perception.

Kumela *et al.,* (2018) showed that in Kenya 60 percent of farmers did not perceive the use of pesticides to be effective, whereas, in Ethiopia, compared to Kenya, 46 percent of farmers perceived the use of pesticides as effective in controlling FAW. In pest control management currently, the use of pesticides has been demonstrated to have adverse effects. For instance, the emphasized use of synthetic pesticides, which have overly been applied indiscriminately has caused potential damage to the animal, human, environmental health, and economic consequences (Nyakundi *et al.,* 2010; Prasanna *et al*., 2018; Kumela *et al*., 2018).

Midega *et al.*, (2018) demonstrated the use of push-pull technology (PPT) an organic agricultural technology to be more effective in the control of Fall Armyworm, which initially was used to control Striga and stem borer (Khan *et al.,* 2010; Kassie *et al*., 2018). Findings from Midega *et al.,* (2018) showed that PPT managed to reduce FAW infestation by 97 percent, resulting in increased maize yield, thus perceived as an effective FAW control practice. Using the Tobit model, Adesina and Baidu-Forson, (1995) showed how farmers' intuitive perceptions of new technologies affected their adoption. Hence, there is a need to integrate farmers' perceptions in this study to add to socioeconomic, demographic, and institutional aspects to aid in obtaining impartial estimates. Consequently, the capture of these perceptions will enable technology developers to design an effective FAW management approach (Oladele and Fawole, 2007).

2.5.3 A review on methods for perceptions analysis

Perception analysis is performed to identify variables in a set that are consistent subsets and are relatively independent of one another (Kim and Mueller, 1978; Kisaka-Lwayo and Obi, 2012). Factor analysis has been classified as a multivariate statistical method employed to summarize a larger number of variables to smaller fundamental dimensions without distorting the initial information (Widaman, 1993; Cumming and Woof, 2007). Observed variables can therefore be put together to form an authentic estimate of the factor being examined. Principal Component Analysis (PCA) has been used in various studies to summarize variables into smaller components. For instance, Kisaka-Lwayo and Obi, (2012) used PCA to condense twenty identified perceptions on the sources of risk to only seven principal components which explained 66.13 percent of the variation. This was done because the 20 identified perceptions on sources of risk depicted high multicollinearity, hence, to obtain the best linear combination it was necessary to reduce the variables to seven to include them in a linear regression.

Delnero and Weeks (2000) used PCA in the field of education, where they bundled together varying perceptions on how important secondary school agricultural teachers regarded their work responsibilities. The Kaiser Normalization method was used where three theoretical factor arrays were generated. Thecla *et al.*, (2018) used PCA to summarize ten significant negative effects of flooding on food security where three principal components of Eigenvalues greater than one were obtained that explained over sixty-eight percent of the variation. The three principal components obtained from their study that summarized the negative effects of flooding on food security were; farm labor and facilities, food supply and distribution, and household income and investment.

Wang and Fok, (2018) used PCA where they condensed forty variables that characterized Bt cotton farmers' spraying activities in China which were correlated. This presented the criterion for use of PCA where they extracted four principal factors from twelve generic variables regarded as items of spraying strategies through their correlations with the original variables. Barreiro-Hurlé *et al.*, (2008) summarized fifteen red wine consumer preferences into four variables using PCA, which explained 66 percent of the variation thus enabling the use of the four variables in a choice experiment model.

2.6 Theoretical framework

The study is based on the random utility theory. The theory postulates that individuals will make decisions with an aim to maximize utility (McFadden, 1974). In standard utility maximization, it is assumed that an increase in control measures to cushion against risks raises the level of utility, while reducing the utility from accessing other goods and services by dispensing of available resources within a constrained production frontier (Tesfaye *et al*., 2021). If the gain acquired from the control measure balances the loss of value due to a reduction in resource utilization of resources, then people would be indifferent between the utilization of these two packages of gain acquired and control measure. This assumes that people's preferences do not depend on their current assets as observed by Tversky and Kahneman (1991). This theory is built on the consideration that when individuals have something of importance to them, they would be reluctant to lose that and so would like to get more compensation for that good than what they would be willing to pay to acquire that good in the first place.

Along the risk mitigation context, if gains and losses from control measures are preferred differently, then for the same level of change in risk, the value of the loss would be considered much higher than the value of the gain brought about by the instituted control measure. In this framework, instituting a control measure reduces the yield loss risk posed by FAW incidence, which is considered as a gain as long as farmers are willing to dispense resources to achieve this improvement in FAW management. Nonetheless, an increase in risk from a status quo situation is considered a loss by some individuals (Ward & Singh, 2015). The level of risk before any change occurs is considered a reference perception of the problem, and contextual actors treat a gain and a loss of the same magnitude of risk change relative to that reference point.

In this study context, Fall Armyworm incidence is the risk which inflicts a shift within a production frontier that hampers optimal farm operation. Farmers are thus motivated to dispense control measures using resources they are endowed with. The control measures have to be seen in their specific social and economic context which are aspects that influence farmers perceptions of the risk facing them in their production frontiers with reference to the safety measure and the potential gains. The FAW control measures have to be economically feasible and reward the user with an economic advantage. Rodima-Taylor *et al*. (2012) noted that farmer interventions responding to potential threats are a function of change. Such changes are threats, which alter normal crops and livestock development. These changes thus trigger institutional interventions to strengthen adaptation through research and development. Farmers will also seek new knowledge to overcome these new changes in their domains and eventually, they are motivated to innovate and adapt to a new frontier.

CHAPTER THREE

METHODOLOGY

3.1 Study Area

The study was carried out in Kiminini Sub-County, Trans Nzoia County, of the former Rift Valley province. The area was selected because of the importance of maize in sustaining farmers' livelihoods and additionally because FAW first incidence was reported in Trans Nzoia County (GoK, 2017). The Sub-County covers a surface area of 366.9 $Km^{2.}$ According to KNBS (2019), Kiminini Sub-County has an estimated population of 242,823 persons with a population density of 662 Km^2. The population composition (Bukusu and Kalenjin) has evolved to a currently more cosmopolitan comprising of inhabitants from other ethnic communities in Kenya. The area is generally flat with gentle slopes, rising steadily towards Mount Elgon; northwest, and to the foot of Cherengani Hills in the East. River Nzoia with its tributaries Koitobos, Ewaso Nyiro, Nogamet, and Rongai rivers drain part of the study area flowing into Lake Victoria. At an altitude of 1,800 meters above sea level, the area experiences a highland equatorial climate that favors maize farming in the region. The area has a bimodal rainfall pattern that ranges between 1,000 mm to 1,700 mm per annum while temperatures range from a low of 10 ^{0}C to 30 ^{0}C. Therefore, the area enjoys a favorable climate for both crop production and livestock rearing. Located in the Upper Midland Agro-ecological Zone (UMZ), the area is enriched with fertile soils (brown-red and brown clay soils derived from volcanic ash) (Horváth, 2006; Trans-Nzoia CSP, 2014). Moreover, the AEZ provides a suitable climatic condition for maize production in the area. These include; well-drained loam soils, rainfall amounts ranging between 1,000 mm to 1,700, and temperatures above 15^{0}C (Wanyama *et al.*, 2019; Ratip *et al.*, 2019). Comparing the similarity of the agro-ecological zone description to the pest native origin, the favoring climatic condition is likely to make the pest become resident resulting in subsequent maize yield losses (Day *et al*., 2017), hence making Fall Armyworm a subsequent threat to maize production.

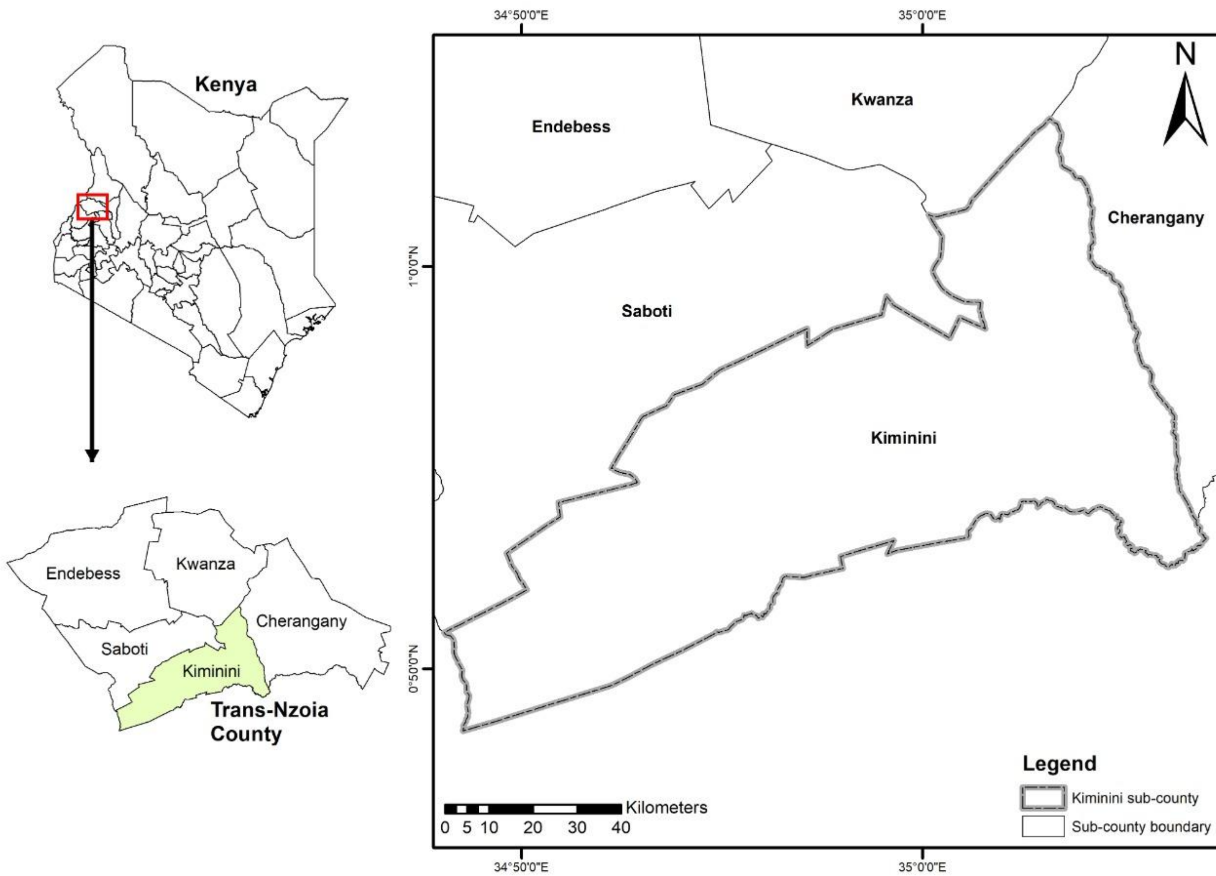

Figure 2: A Map showing the location of the Study Site

Source: Adapted from IEBC

3.2 Conceptual framework

Figure 2 shows a scenario where farmers in the face of devastating incidence such as FAW infestation will respond by adopting mitigation strategies to manage the pest. This is necessary because FAW infestation presents the danger of deteriorating farmers' livelihood if not effectively managed by causing high damage levels. Consequently, the uptake of FAW practices is influenced by the magnitude of maize yield loss due to FAW infestation, their perceptions on the available FAW control practices, and other factors such as; institutional support services, socio-economic characteristics of the maize producing households. For instance, besides the education level of a farmer influencing a perception towards FAW control practices; it will also inform whether the farmer will resolve to the continued use of the control practices.

The use of various available control practices thus has a direct impact on the quality and quantity of actual maize yield obtained. This, therefore, influences the farmers' perception of the control practice used, with regard to its effectiveness in FAW control. Consequently, the diagnosis of these perceptions will enable address the major constraint of establishing an effective integrated FAW management approach for maize farmers.

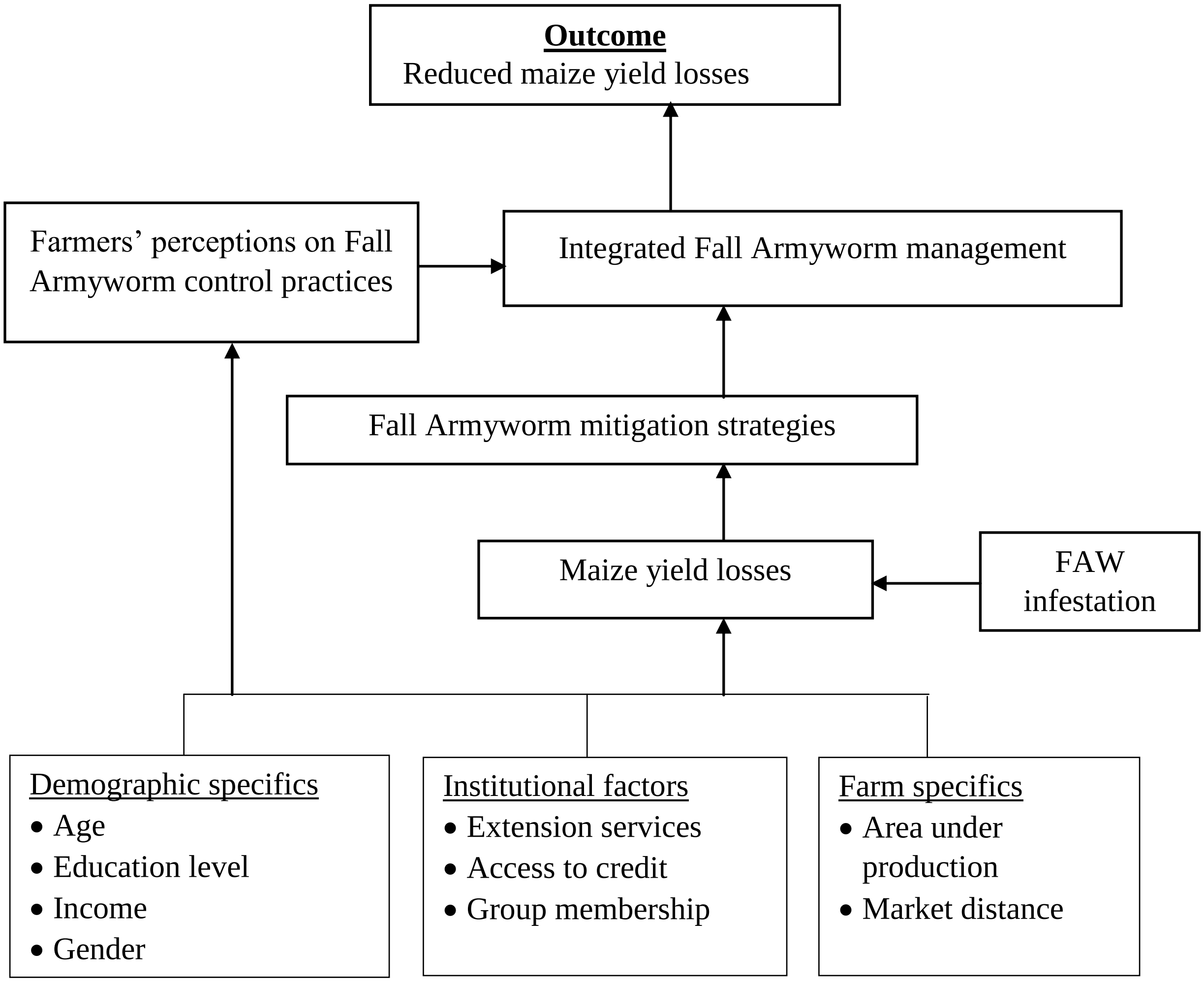

Figure 3: Conceptual framework illustrating the interactions among factors hypothesized to influence maize losses and farmers' perceptions on FAW control practices

Source: Authors' conceptualization

3.3 Data Analysis

Field Survey data were collected on maize loss estimates due to FAW, the drivers to these losses, farmers' perception of FAW control practices, and factors likely to influence these perceptions. Statistical Package for Social Scientist (SPSS) version 22 and STATA 15 was used to generate descriptive statistics such as mean and percentages. Descriptive statistics were used to analyze the general characteristics of the respondents and respondents' perceptions of FAW control practices. To condense and classify farmers' perceptions', the Principal Component Analysis model was run using SPSS which was also used in estimating regressions of hypothesized variables likely to influence farmers' perceptions' and drivers of maize losses.

3.3.1 Estimation of yield loss due to FAW infestation

The economic importance of a pest is determined by the magnitude of losses resulting due to pest infestation. When FAW infestation occurs, the quality and quantity of maize yield decline from the attainable yield in the absence of FAW, *ceteris paribus*. Characterizing declining maize yield entirely to FAW infestation is difficult in the view that, there exist other constraints that together may influence poor yields from the expected. However, based on farmers' experience and overtime field observations, given that the pest is easily visible and identified, farmers, can aptly establish good estimates on crop yields in the absence or presence of the pest (De Groote 2002; De Groote *et al*., 2016). Consequently, the study adopted an indirect measurement approach, which is a more definite way to assess the maize yield loss due to FAW infestation. To achieve this, perceived farmer-based loss estimates were compared with estimates obtained from an iterative bidding approach. The iterative procedure observed a starting value that was derived from a focus group discussion made up of key informant farmers. This was used to elicit the maximum value that farmers accepted as the loss incurred due to FAW. Thereafter the mean sum of loss incurred as established from the approaches was derived by considering the yield loss stated by each farmer. The mean accepted loss incurred was estimated as shown in equation (1).

$$\mu_{1z}^{n} = Yl_1 + \cdots\cdots + Yl_n/n \quad (1)$$

Where μ_{1z}^{n} is the mean loss from the total number of respondents, Yl is a farmer's estimate yield loss and n is the total number of observations.

3.3.2 Bidding procedure

Estimation of the value or amounts farmers accepted as the incurred loss was assessed on maize farmers who were sampled and had been affected by FAW infestation. The questionnaire provided for a bidding procedure to elicit the amount producers were willing to accept as the magnitude of yield loss, as well as a direct perceived approach to estimate the losses. The initial value of 11 bags of 90 kg bag per acre was an average value, which was derived from a FGD.

Among the two approaches, the perceived direct farmer estimate approach has a higher likelihood of resulting in bias estimates as farmers relied on recall data from the previous cropping seasons to state a yield loss estimate due to FAW. This gives rise to the possibility of farmers making inaccurate estimates, resulting in nonrandom measurement errors which may be of economic significant size. This is different in the case of the iterative bidding procedure, as the bidding starting point obtained from a FGD was followed by a validation exercise with sampled respondents. Therefore, to correct for bias estimates, follow-up certainty questions were essential as affirmed by Blumenschein *et al.*, (2008). Therefore, given the possibility of recall bias (Beegle *et al*., (2011); Wollburg *et al*., (2020), this study assumed the use of yield loss estimates established through the use of an iterative bidding approach.

Iterative bidding procedure was used, with the perspective of encouraging farmers to keenly take into consideration their preferences through the provision of rounds of discrete bids. This bidding game assisted in the valuation process, to elicit farmers' maximum accepted loss values.

Respondents were asked if they were willing to accept a series of amounts that increased or decreased from a specified starting value (11 bags of 90 kg bag per acre). The iterative bidding process eventually arrived at the respondent's maximum accepted value (Wattage, 2002). The loss on maize that the study intended to address was clearly elaborated to the respondents before the bidding game started.

A bid of ±one bag of 90 kg bag per acre was used to elicit the maximum value that the farmer was willing to accept as the lost value. In the scenario where a farmer's response was a YES to the initial bid value, an increment of one bag of 90 kg per acre followed up subsequently until the maximum value the farmer was willing to accept was attained. On the contrary, if the farmer's response was a NO to the initial bid value, equal decrements of one bag of 90 kg bag per acre followed up subsequently until the value the farmer was willing to accept was revealed.

3.3.3 Addressing bias in the estimation of yield loss procedure

Despite contingent valuation being used in the valuation of estimates, it suffers from controversies concerning various problems such as strategic behavior, information effect, and elicitation format. Considering such problems of the contingent valuation approach is critical in the carrying out of efficient estimation of the welfare measures stated by respondents (Halkos, 2012). However, (Samuelson, 1954) affirms that contingent valuation is less likely to suffer from strategic behavior when used on a private good, as is the case in public goods. This behavior is geared towards an attempt to influence the provision of a public good. On the contrary, this is not a concern for private goods that consumers have to pay for.

Critical biases experienced when using contingent valuation are hypothetical, vehicle biases, start point (anchoring value), and sample related. This study not having a willingness to pay component in it, the payment vehicle bias was not a potential problem. To correct for hypothetical bias, follow-up certainty questions are important as affirmed by Blumenschein *et al.* (2008).

Edwards and Anderson (1987) did assert that for field surveys and interviews, sample selection bias has been low. Sample selection bias occurs when the probability of obtaining a valid willingness to accept response among sampled elements is related to the respondent's value. Field surveys or interviews have less potential for non-respondents to be consciously self-selected thus free from biased sample selection. This study made an attempt to reduce bias problems to a lower minimum level during the design of the questionnaire and sampling approach (systematic random sampling) employed. The pre-test and FGD aided in the significant modification of the questionnaire. Additionally, enumerators were well trained to carry out in-person interviews.

Start-point (anchoring value) bias kicks in when the value selected has a marked impact on observed bids Blumenschein *et al.* (2008). The starting value transmits information to the sampled respondent on the expected or reasonable bids thus influencing the final bid amount. Supposing that the starting point is far away from the true value, the procedure terminates pre-maturely before the true bid is realized. Therefore, a well-selected starting point is critical. This study used an average anchoring value for the survey, which was arrived on after conducting a FGD with key informant farmers', where each was asked to state their incurred actual loss. Additionally, it was emphasized to them that the actual loss per acre due to FAW infestation is yet to be established in the region.

3.3.4 Assessing drivers on the stated extent of value loss

To enable determine whether or not there exists a causal relationship between the hypothesized regressor variables listed in Table 2 and the regressand variable (magnitude of maize yield losses incurred by farmers due to FAW infestation), a robust simple multiple linear regression was used. A robust regression gives room to explicitly control for many other factors that will affect the regressand and also incorporates fairly general functional form relationships (Samboko, 2011). A robust regression technique was adopted since it gives reliable results by a weighting scheme that causes outliers among the y values (regressand variable) and in the design space (regressor variables) to have minimal effect on the estimates of regression coefficients. Additionally, the robust regression is also convenient when the stochastic component of the regression is abnormally distributed (Verardi and Croux, 2009; Yu and Yao, 2017). The hypothesized regressors variables include factors such as; sex of the farmer, years of maize farming, farming system, schooling years of the farmer, household size, market distance, access to extension, credit access, group membership, income, occupation, and the area under maize cultivation.

The functional form is stated as;

$$Y = \beta_O + \beta_1 X_1 + \beta_2 X_2 + \cdots\cdots\cdots\cdots\cdots + \beta_k X_k + e \text{..........} \quad (2)$$

Where;

Y is the magnitude of yield loss incurred, $X_i$are the regressor variables, β_i are the coefficients and e is the error term.

The estimated model is be specified as follows;

$$Loss = \beta_0 + \beta_1\ Sex + \beta_2\ Years\ of\ maize\ farming + \beta_3\ Farming\ system +$$

$$\beta_4\ Schooling\ years + \beta_5\ Market\ distance + \beta_6\ Occupation + \beta_7\ Group\ membrsh +$$

$$\beta_8\ Area\ under\ maize\ production + \beta_9\ Extension + \ \beta_{10}\ Income +$$

$$\beta_{11}\ Household\ size + \ \ldots\ldots + e \ \text{..........} \quad (3)$$

3.3.5 Assessment of farmers' key perceptions on FAW control practices

This study adopted the use of factor analysis to analyze farmers' key perceptions on FAW control practices in use by farmers. Factor analysis is a multivariate statistical method that aims to condense a large number of measurements to a reduced number of variables without altering the intended information. Observed variables will then be combined to form a higher credible measure of that factor (Widaman, 1993). Factor analysis comprises two analysis frameworks; principal component analysis (PCA) and principal factor analysis (PFA) (Rao,1964; Sarbu and Pop, 2005).

PCA is an approximation of PFA when the components are rotated. The only differentiating aspect between the two methods is that PCA assumes all variability in a variable needs to be used in the analysis while in PFA, the variability used is the one in the variable that is common with other variables (Kisaka-Lwayo and Obi, 2012). Both PCA and PFA produce similar results in most cases. Despite this, PCA is preferred over PFA in data reduction method while PFA is used in detecting the structure. PCA generated smaller factors that were more logical orthogonal aggregates called principal components (Rao, 1964). These principal components are linear weighted combinations of the original variables, each with coefficients that are equal to respective eigenvectors of the covariance or correlation matrices (Rao, 1964; Kisaka-Lwayo and Obi, 2012).

Principal components obtained from PCA were arranged such that the first component accounts for the largest variation in the original variables. The consequent components accounted for the maximum that is not accounted for by the preceding and was as independent as possible from each other (Rao, 1964). As a result, Rao (1964) argues that PCA is a successful method of conducting factor analysis. The underlying assumption in the use of PCA is on interval data that is normally distributed and multivariate. In analyzing ordinal data such as the Likert scale data, PCA is suitable particularly if the goal is to achieve general clusters of variables for use in exploratory purposes provided that the correlations among variables are less than 0.6 (Kim and Muellar, 1987).

Farmers' perception of effective FAW current control practices was assessed on farmers who have information and have used these control practices. The perceptions were measured by use of a Likert scale of 1 = strongly disagree to 5 = strongly agree based on the attributes of the control practices; efficacy attributes, socio-cultural compatibility, environmental sustainability aspects, external support services, and practice design. Responses obtained were then subjected to PCA to obtain principal components that explained farmers' perceptions towards the control practices. The principal components were computed as shown in equation (4):

$$PC_n = f(a_{ni}X_i \ldots \ldots \ldots \ldots \ldots \ldots a_{1k}X_k) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4)}$$

Where *PC* is the component score of observed variables, *n* is the total number of principal components (*PC's*), *a* is the component loading of regression coefficients, *X* is a latent variable estimated along with the coefficients, *i* is the component, and *k* is the total number of variables. If the number of *PC's* is greater than one, then each principal component will be a continuous variable or quantity related to the products of the values of the constituent variables and their respective weight loading *a*. This implies an additive relationship, hence the value of the principal component is obtained by the addition of the products as depicted in equation (5).

$$PC_n = f(a_{11}X_1 + a_{12}X_2 + \cdots\cdots\cdots\cdots a_{1k}X_k) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5).}$$

Where PC_1 is the first principal component, a_{1k} is the regression coefficient for the *k*th variable that is the eigenvector of the covariance matrix between the variables, and X_k the *k*th variable.

PCA extracted uncorrelated factor scores known as principal components which retained much of the variation in the data (Jolliffe, 2002). Among the extracted factors, those which had Eigenvalues greater than 1 were retained (Kaiser, 1960; Field, 2013). Additionally, to get a better representative set of factors, factor solutions of a different number of factors were tested before the structures were defined (Hair *et al*., 2010). The average of extracted communalities was equal to 0.60, confirming the reliability of Kaiser Criterion in factor extraction (Field, 2009). Variables that did not contribute to a minimum factor structure and did not meet a factor loading of 0.5 and above were eliminated. The Kaiser-Meyer-Olkin (KMO) measure was considered to ensure sampling adequacy and a value greater than 0.5 was achieved which is the recommended threshold (Everitt & Hothorn, 2011). This indicated that the data used was adequate for PCA and that the principal components obtained were reliable (Field, 2013).

Barlett's method (Howley and Dillon, 2012; Field, 2013) was used in generating the principal components with Barlett's test of sphericity generating significant results at ($p<0.01$) level of significance. Factor scores were also generated using Barlett's method. This method generates standard unbiased estimates which have a mean of zero (0) with a standard deviation of one (1). The factor scores were used as dependent variables in determinants of farmers' perception of FAW control practices (Howley and Dillon, 2012; Field, 2013). Varimax rotation was used thus yielding completely uncorrelated principal components (Rao, 1964; Koesling *et al*., 2004; Abebaw *et al*., 2006; Asai *et al*., 2014), and only compo2nents with factor loadings values greater than 0.4 were retained (Stevens, 2002). The standardized factor scores obtained were saved for subsequent multiple regression analysis.

3.3.6 Empirical model to assess determinants of farmers' perceptions on FAW control practices

To determine whether the principal components obtained on farmers perception of the FAW control practices from PCA were receptive to socio-demographic factors as hypothesized in Table 2, multiple linear regressions were fitted as shown in Equation 6 (Green, 2002; Abebaw *et* *al*., 2006; Asai *et al*., 2014), specifying a linear relationship between the regressand and regressor variables.

The functional form with *k* regressors is stated as;

$$PC_n = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots\cdots\cdots\cdots + \beta_k X_k + e \text{ .... (6)}$$

Where *PC* is the perception score, *n* is the total number of principal components which were 5 in number, $X_i$are the regressor variables, β_i are the coefficients and e is the error term. The observed value of PC_n is the sum of two parts, a deterministic part, and a random part e.

Principal component analysis extracted five categories of perceptions (PC_n) namely; increased productivity, environment friendly, socially acceptable, promotion efforts, and availability. Regression equations were used with identical sets of regressor variables.

The estimated model equations were specified as follows;

$$PC_n = \beta_0 + \beta_1\ Age + \beta_2\ Sex + \beta_3\ Schooling\ years + \beta_4\ Household\ size + \beta_5\ Income + \beta_6\ Extension\ access + \beta_7\ Credit\ access + \beta_8\ Group\ membership + \beta_9\ Occupation + \beta_{10}\ Area\ under\ maize\ production + \beta_{11}\ Market\ distance + e \text{ .... (7)}$$

3.3.7 Description of hypothesized variables used in regressions

The hypothesized independent variables used to assess factors influencing the magnitude of maize yield loss due to FAW, farmers' perception scores on the pest control practices, and their direction of influence are as outlined in Table 2. The dependent variables are the mean accepted yield loss value and the perception scores.

Table 1: Description of hypothesized variables

Variable	Description	Expected sign on:	
		Magnitude of yield loss	**Perception scores**
Age	Age of farmer in years (Continuous)	+	+/-
Sex	Gender of the farmer (Dummy; Male=1, Female=0)	-	+/-
Schooling years	Years of formal education (Continuous)	-	+
Household size	Number of household members (Continuous)	+/-	+/-
Extension access	Access to extension services (Dummy; Yes=1, No=0)	-	+
Group membership	Member of either formal or informal group (Dummy; Yes=1, No=0)	-	+
Credit access	Access to credit services (Dummy; Yes=1, No=0)	-	+
Market distance	Distance to market (Dummy; Easy access=1, Difficult access=0)	+	+
Experience	Years of maize farming (Continuous)	-	+
Area under maize	Acreage under maize farming (Continuous)	+	+
Land tenure	Type of land tenure (Dummy; Formal=1, Otherwise=0)	-	+
Occupation	Main occupation (Dummy; Farming=1, Otherwise=0)	-	+
Farm income	Income from the farm income (Continuous)	+	+

Effect of household size direction of influence on yield loss and perception on control practices is indeterminate. Household size was determined by the number of people who depend on that household for food and had lived within the household in a six-month time frame. This variable can either posit a positive or inverse relationship. Household size is often utilized as a proxy for labor (Manda *et.al*, 2016). Therefore, larger households are expected to readily provide labor in carrying out pest control practices and other agronomic practices. This implies efficiency in farm management hence the likelihood of increased maize yield due to timely and ready labor to manage FAW. Oluwasola *et al.,* (2008) showed that household size positively related to farm income implying that larger households had more labor, which contributed to farming as an enterprise hence higher farm yield. Addai *et.al* (2014) and Osanya (2018) found out that household size had a negative effect on maize production, where larger households require more resources for their sustenance thus competing for resources required for maize production.

The education level of the household head was measured as the number of schooling years a respondent spent in formal schooling. As hypothesized, education level was expected to reduce the magnitude of losses and positively influence farmers' perceptions of FAW control practices. Respondents with a higher level of education are expected to be well informed about better management practices, hence the effective control of FAW resulting in reduced loss levels compared to those of a lower education level, since they have an increased capacity to source and utilize information in more productive ways by making well-informed decisions (Handschuch and Wollni, 2016). Additionally, Bagamba (2008) noted that households with higher levels of education have a higher propensity of sourcing off-farm income which eventually increases their net income and thus opts for hired intense labor for farm management practices. Moreover, it was hypothesized that farmers with higher total annual incomes were more likely to positively influence perception scores on FAW control practices in contrast to farmers with lower total annual incomes.

Access to extension and group membership were hypothesized to reduce the magnitude of yield loss and positively influence perception scores. These provide for important avenues of increased social capital where farmers obtain and exchange important information on farm management and their respective agro-enterprises. Therefore, farmers who had membership to groups and had been in contact with an extension service provider were expected to record lower FAW related magnitude of losses and positive perceptions on FAW control practices. Credit access is also likely to contribute to the reduced magnitude of losses and positively influence the perception scores pests control practices as farmers are financially enabled to purchase required pesticides and as well seek further private extension services.

Studies by Radjabi *et al.,* (2014) and Despotovic (2019) on aspects influencing the use of pest control and integrated pest management package showed that age, social corporation, farm size, level of farmers' education, experience and average yield obtained do affect adoption and perceived benefit of using the management measures. As the average yield increases, farmers will tend to use measures that prevent loss reduction since the cost of loss that would be incurred is huge, hence farmers positively perceive the management practices as they help reduce the magnitude of losses as hypothesized. Nonetheless, age can be a less accurate measure of a farmer's experience in farming because it assumes the farmer started farming at a younger age whereas some farmers begin farming after retiring from employment. To correct for this, farming years (experience) were used and was hypothesized to reduce the magnitude of losses.

Distance to the market inversely affects efforts on effective pest management. Therefore, as distance increases, a farmers' transaction costs increase. For instance, transaction cost likely to be incurred is loss of time in search of information on effective pest control practices. An increase in distance is thus hypothesized to negatively affect farmers' perception of pest management practice and increase the magnitude of losses incurred, this is because an increase in market distance affects the availability and adoption of new farming technologies, information, and credit institutions (Kassie *et.al.,* 2013), aspects which are deemed essential in enhancing effective farm management practices. The area under maize cultivation is hypothesized to have a positive effect in increasing the magnitude of losses and subsequently on farmers' perception of the control practices (Muchiri, 2012). That is, the larger the area under maize cultivation, the higher the level of yield loss due to pest infestation. This could be attributed to farm managerial weaknesses arising with increased production area.

3.4 Methods and procedure

3.4.1 Study design

This research was quantitative and executed through a household survey using a semi-structured questionnaire anchored on an android aided platform (Survey to go). Face-to-face interviews were done between trained enumerators and the maize farmers. The questionnaire included an introductory segment, giving an elaborate description of the objectives of the study and the intended use of the outcomes achieved.

The questionnaire provided a bidding procedure in which the initial bid of 11 bags of 90 kg bag per acre, obtained from a FGD with key informant farmers. The bidding procedure and its execution has been elaborated in section 3.4.2. The questionnaire also provided a means of eliciting farmers' perceptions on FAW control practices in the study area. The questionnaire additionally enabled the collection of the respondents' socio-demographic characteristics.

3.4.2 Sampling procedure and sample size

This study purposefully targeted maize farmers in Trans Nzoia County. A multi-stage sampling technique was incorporated to identify the respective target population to be interviewed. In the first stage, Trans Nzoia County was purposively selected because the area is characterized by a high population of maize producing farmers who heavily rely on the crop to sustain their livelihoods. In the second stage, the choice of Kiminini Sub-County was purposive based on the high incidence of FAW infestation as was first confirmed in the area early the year 2017 (GoK, 2017). In the third stage, due to time and budgetary constraints, two wards; Sirende and Hospital were selected with the help of Sub-County Agricultural officers (SCAOs).

A sampling frame of potential study households was compiled with the help of Sub-County Agricultural Officers. A list of 1,073 maize producing households was generated. Following Cochran (2007) formula, determining a sample size from a known population is as specified below:

$$n_o = \frac{Z^2 pq}{d^2} \qquad (8)$$

Where n_0 is Cochran's sample size, Z is the standard normal deviation set at 1.96 corresponding to 95% confidence level, p is the proportion of the population target estimated to have a particular observable characteristic, q is 1-p, and d is the desired level of precision (set at 0.05 corresponding to 1.96).

$$1.96^2 \text{ x } 0.40 \text{ x } (1\text{-}0.50) / 0.05^2 = 385 \text{ farmers}$$

$$n = \frac{n_o}{1+\frac{n_0 - 1}{N}} \qquad (9)$$

Where N is the population size, and n is the new adjusted sample size calculated as follows:

$$\frac{385}{1+\frac{385-1}{1073}} = 284$$

$$\frac{N}{n} = k^{th} \text{ farmer}$$

$$\frac{1{,}073}{284} \approx 4$$

Systematic random sampling was used to select the k^{th} farmer at an interval of 4 from the list hence arriving at a representative sample size of 257 respondents. Absent or non-responding households during the survey were replaced by the immediately following household from the sampling frame list. Systematic random sampling eliminates the aspect of bias selection, giving every household that forms part of the sampling frame an equal chance of being selected.

3.4.3 Data collection

Primary data was collected with the aid of a semi-structured questionnaire, which was mounted on computer-aided personal interview platform (SurveyToGo) software. The data was collected between February and March 2019 by trained enumerators. The interviews were conducted in Swahili and where possible in vernacular dialect. During the survey, enumerators prompted farmers with a picture presentation to confirm if farmers could identify FAW that the pest had infested their maize plots. Interviews then proceeded only on farmer confirmation of the pest as FAW and had been spotted in their farms. The effectiveness of the questionnaire was examined through conducting a Focus Group Discussion (FGD). Feedback obtained from the FGD was used to revise the questionnaire and inform the data analysis and interpretation process in the future.

3.4.4 Data types

The study obtained cross-sectional data, which was collected from maize producing farmers in Trans-Nzoia County. Information gathered included farmer demographics characteristics, socioeconomic characteristics, production levels, maize yield losses due to FAW, and farmer perception of the pest control practices. Additionally, information on institutional services such as credit and extension which are sought from and rendered by the county government and other value chain actors were collected. This study targeted farmers who have been impacted by FAW infestation.

3.5 Diagnostic tests

3.5.1 Multicollinearity

Multicollinearity refers to a scenario where a variable is a linear function of another. Occurrence of multicollinearity results in inefficient OLS estimates (Farrar and Glauber, 1967). This affects cross-section data such that there exist wide confidence intervals leading to Type 1 error (Woolbridge, 2009). According to Gujarati (2007), multicollinearity renders OLS estimates and standard errors sensitive to small changes in the dataset. To test for multicollinearity, Variance Inflation Factor (VIF) was used (Dormann *et al*., 2013). This study used both methods to test for multicollinearity. Kleinbaum *et al*., (1988) noted that a VIF greater than 10 indicates a problem of multicollinearity. A Pearson correlation matrix was performed to determine whether there existed a strong linear relationship between the regressor variables (Gujarati, 2007).

3.5.2 Heteroskedasticity

Heteroskedasticity occurs when the variance of the error term is not consistent, resulting in an inefficient and invalid test of hypothesis (Woolbridge, 2002). If present in the data, the estimates will not be Best Linear Unbiased Estimates (BLUE) (Gujarati, 2007). It is a common problem in cross-sectional data and it violates the constant variance assumption of the error term (homoskedasticity). It renders the estimated beta inefficient and thus invalid to use in making predictions about the independent variable (Nzuma *et al*., 2001). To test for Heteroskedasticity, the Breusch-Pagan/ Cook-Weisberg test was used.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Socioeconomic profile of sampled households

The summary statistics of variables utilized in this study are presented in Table 2. The descriptive statistics results for demographic and household characteristics indicate that, on average, the farmer's age was 55 years. This finding is in line with a report by FAO (2014) and Government of Kenya (2008), stating that the average age of a Kenyan farmer is approximately 55 years which is a concern as farming systems in Kenya are labor-intensive. It was apparent that farming was the main economic activity, a majority of the respondents identified it as the main primary occupation with an average of 18 years of maize farming (CIDP, 2018). Taking farmers' average experience and age into consideration, maize farming is depicted as an enterprise mainly practiced by the elderly in the region having surpassed the youthful Kenyan context of 35 years (Olila, 2014).

The average household size was 6 persons with a dependency ratio of 0.87, indicating the existence of high pressure on resources available and the productive population. Larger family sizes especially when the dependency ratio is high, present a scenario for the competition of resource allocation. Therefore, resources meant for farm management practices are redirected to cater to other family needs like nutrition, medical care, and school fees (Addai *et al.,* 2014). Further analysis showed that the ratio of male to female farmers was approximately 2:1 where 66 percent were male. However, the male to female household head ratio was 9:1. This is depictive of the socio-cultural setting of a typical African household where males are the primary decision-makers (O'brien *et al*., 2016).

Table 2: Summary statistics of variables on sampled households

Variable	Min	Max	Mean	SD
Household characteristics				
Age	26	96	54.82	12.80
Sex	0	1	0.66	0.48
Occupation	0	1	0.79	0.41
Experience	2	60	18.29	11.21
Household size	1	20	6.39	2.80
Education	0	19	11.37	3.71
Market distance	1	25	6.61	5.21
Dependency ratio	0	7	0.87	0.89
Farm income	0	322000	73312.84	60864.14
Off farm income	0	200000	6610.90	21937.33
Farm Characteristics				
Land size	1	35	6.82	5.99
Area under maize	0.5	30	4.60	4.28
Land tenure	0	1	0.89	0.32
Yield harvested	0	2.97	1.48	0.45
Farming system	0	1	0.53	0.49
Pest management	0	1	0.96	0.19
Aware of FAW	0	1	0.99	0.09
External support services				
Group membership	0	1	0.17	0.38
Credit access	0	1	0.31	0.47
Extension access	0	1	0.52	0.50

***Note*:** SD – Standard deviation

Source: Survey Data (2019)

Predominantly, it was observed that land ownership was freehold with a majority (89 percent) having ownership to a registered title deed. Additionally, the mean average land size of the sampled households was 6.8 acres[1], on which the average proportion of land area allocated to

[1] 1 Acre = 0.405 hectares

maize production was 4.6 acres which corroborate with Kumela *et al*., (2019). These results are in tandem with those of Kiplimo and Ngeno (2016) in the study area who noted that land size holding was 7.2 acres with land allocated to maize being 6.7 acres. The decline in the area allocated to maize production could be attributed to the effect of over time land fragmentation. Maize yield per acre (tones[2] per acre) for the sampled households ranged between 0 to 2.97 tons per acre. The average yield was 1.48 tons per acre for the 2018 crop season, implying that farmers did not attain the optimal yield regardless of using commercially purchased improved seeds (Odhiambo, 2012; De Groote *et al*., 2020). This could possibly be attributed to risk factors such as pests and diseases, price risks, and weather variability.

Education level is considered an important aspect that impacts a farmer's ability to acquire process and utilize agricultural related information. The average years of formal schooling completed in the study area were 11 years. Further analysis showed that 27 percent of the respondents had acquired primary education, while 72 percent had acquired post-primary education and the most educated farmer had completed tertiary education with a master's degree. Therefore, with a bigger percentage having attained secondary education indicates that most of the households can make use of newly acquired information for incorporation into farm management practices.

Membership to groups both formal and informal was considered less important as the majority of the farmers (61 percent) had no group membership. Lack of interest (57 percent) was cited as the main reason for not joining a group. Out of those who have membership to a group, 44 percent belonged to an agricultural related group with a majority citing access to input supply as their main reason for joining (Sawenda & Liverpool-Tasie, 2012).

[2] 1 Tonne = 1000 kilograms

Credit access was found to be very low, with only 32 percent of the respondents indicating to have accessed credit. Of those who accessed credit, 46 percent sourced the credit from groups while 35 percent obtained it from financial institutions. Further analysis indicated that 48 percent of those who did not have access to credit cited no need for credit, while high-interest rates and credit risk involved were 27 and 26 percent respectively. This is supported by the finding of Olila (2014) who noted low credit access of 30 percent being attributed to the risky nature of agriculture, making financial institutions skeptical to offer credit.

Results indicate that 52 percent of the farmers had contact with an extension service provider in the last 12 months. It was observed that 84 percent of the farmers received extension services from the County extension officers, while only 24 percent was through broadcast media (radio and television). This was enabled by the new Kenya constitution dispensation that was promulgated in the year 2010, which gave rise to the existence of devolved County governments whose primary focus was to decentralize resources at the community level where agriculture is among the devolved dockets (Orina-Nyamwamu, 2010). Information obtained from accessed extension services mainly included pest management and maize crop production at 57 and 50 percent respectively. With exposure to extension which is an intellectual capital service, it can be said that most farmers were able to gain access to new skills, information, and technologies to enhance the quality and productivity of their produce (Handschuch & Wollni, 2016).

4.2 Fall Armyworm identification

Most of the farmers (99 %) were aware of Fall Armyworm having observed it in their maize plots in the 2018 cropping season. The majority of the farmers (66 %) gained privy information on the pest's existence and form through broadcast media (radio and television). Moreover, approximately 54 percent of the farmers reported having noticed FAW in their maize plots between the months of March to May, in the 2017 cropping season. Apart from the stalk borer and rodents, Fall Armyworm was reported as the most troublesome pest in the 2018 cropping season by 94 percent of the farmers. Farmers also noted the pest preference host was the maize crop.

The damage level caused by Fall Armyworm had varying descriptions by farmers as shown in Figure 1. Damage level was described as negligible, that is, less than 25 percent by 2.4 percent of the farmers. Most farmers (43%) described the damage caused by FAW as high, having damaged approximately 75 percent of the crop while 8 percent of the farmers described it as severe. Maize is infested by FAW at nearly every developmental stages. The pest population mainly at the larval stage, was noted to be high during the vegetative "knee-high" stage, at tasseling, and throughout the production cycle by 49 %, 25 %, and 16 % of the farmers respectively. At advanced development stages, the FAW larvae also feeds on the tassels, destroy the kernels and burrow into the cobs, as well as exposing the cob to infection by microorganisms, such as mycotoxin producing fungi. Such cobs are 100 % damaged hence non-harvestable (FAO, 2020).

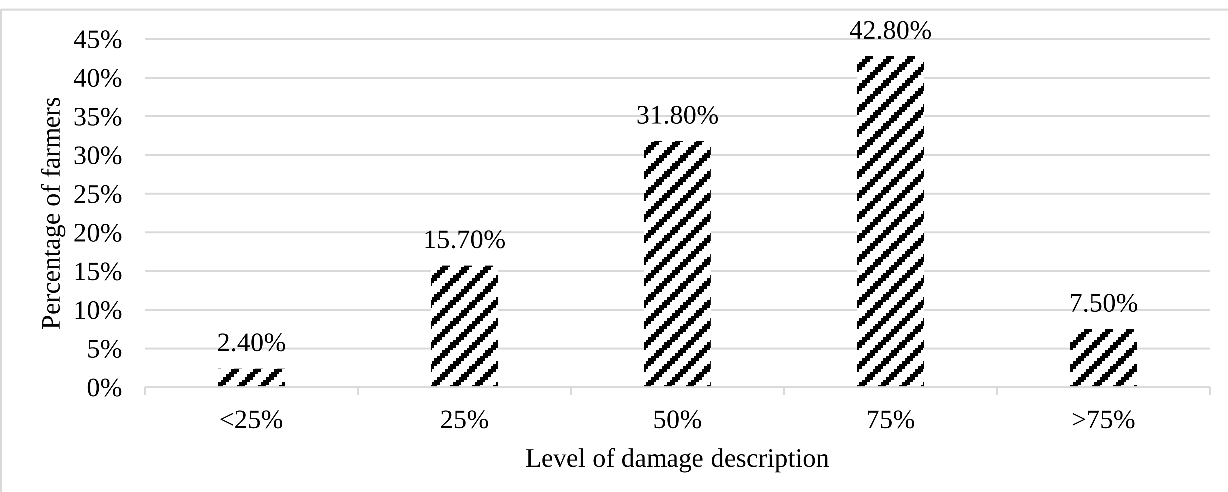

Figure 4: Farmer's description of FAW damage levels

Source: Survey Data (2019)

4.3 FAW mitigation practices

In an effort to control for the damage caused by FAW, 94 percent of the farmers did carry out a mitigation measure to manage the pest. Figure 2 shows the number of FAW control practices used by farmers. Approximately 4 percent of the farmers did not adopt any of the existing FAW control practices, whereas, about 90 percent of the farmers used at least one or more of the practices. The control practices used were grouped into four, these included: Synthetic pesticides, cultural control, botanical control, and push-pull technology.

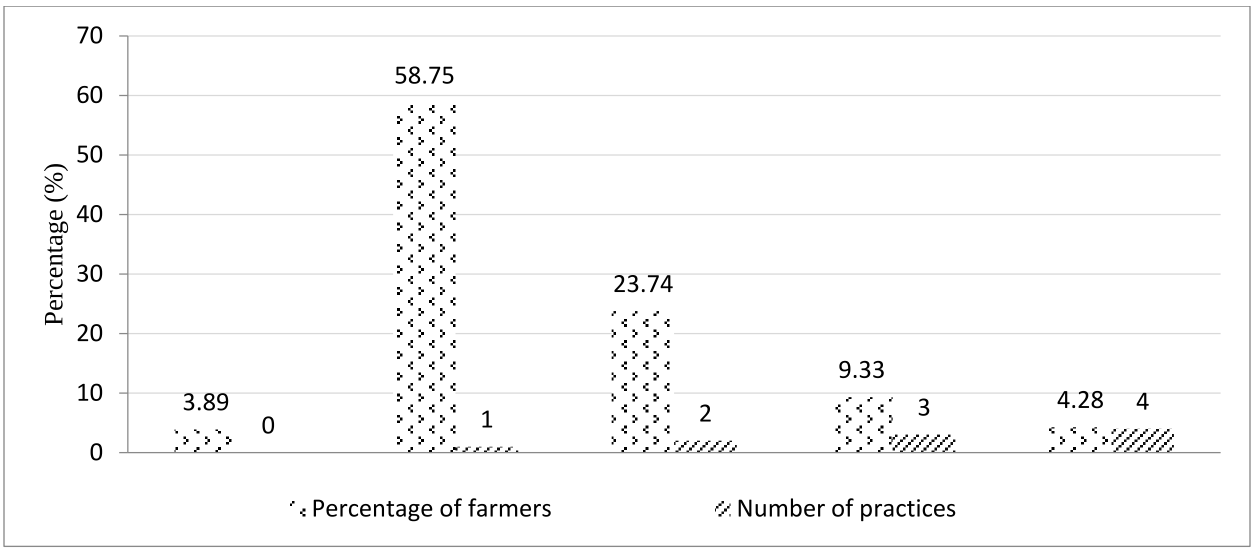

Figure 5: Use of different combination of FAW control practices

Source: Survey Data (2019)

Farmers used numerous chemical pesticides. These included; Voliam Targo 063 SC, Match 50 EC, Coragen 20 SC, and Profen 10.8 EC, which were sprayed on maize stands. Cultural control methods include; handpicking and squashing of caterpillars, synchronized early planting, and deep ploughing. Botanical control strategy involved the use of plant extracts which were mixed together forming a concentrate that was applied on the maize field. The plant extracts included;

blackjack, tithonia, chili pepper, aloe vera, neem, and wood ash that was placed on the maize whorl where the large larvae are usually found.

Indiscriminate use of pesticides was noted, as it was the dominant control practice used by 88 percent of the farmers. This was because the government provided a free supply of chemical pesticides, in an effort to help curb FAW invasion. Moreover, the use of pesticides in larger volumes has been reported to have a high potential to severely impair human health and the environment. The cost benefit analysis of the pesticides is coherently negative when the externalities on public health and environmental degradation are well-thought-out. In the case of developing countries and economies in transition where proper risk mitigation measures, such as protective clothing or properly maintained application equipment may not be in place. Lower risk FAW control measure such as bio-pesticides exists, but are not readily available to farmers in Africa (FAO, 2017). However, 78 percent of the farmers perceived pesticides to be the most effective control practice.

The push-pull technology involved intercropping maize desmodium and surrounding it with a perennial fodder grass of either Napier or brachiaria grass to repel away FAW. The technology has previously been used in the control of parasitic Striga weed and cereal stem borer moths (Khan *et al.,* 2014; Pickett *et al.,* 2014). The push-pull technology and a maize-legume intercropping pattern provide maize with protection from FAW and other pests by increasing crop diversity providing habitats for natural enemies (Day *et al*., 2017; Midega *et al*., 2018).

4.4 Maize yield losses due to FAW infestation

From the sampled farmers, the estimated magnitude of yield loss was obtained as shown in Table 3 using the two approaches (bidding procedure and perceived direct estimates respectively). Results from both approaches depict varying yield loss estimates. Elicited estimates through the bidding procedure revealed an average magnitude yield loss of 0.703 tonnes per acre with a standard deviation of 0.386, whereas, in perceived direct estimates farmers stated an average yield loss of 0.665 tonnes per acre with a standard deviation of 0.357. A two-tail t-test confirmed the existence of a statistically significant difference between the two estimate approaches with a *p-value* of 0.016, indicating a yield loss difference of 0.038 from the bidding procedure approach.

Among the two approaches, the perceived farmer estimate approach has a higher likelihood of resulting in bias estimates as farmers relied on recall data from the previous cropping seasons to state a yield loss estimate due to FAW. This gives rise to the possibility of farmers making inaccurate estimates, resulting in nonrandom measurement errors which may be of economic significant size. This is different in the case of the iterative bidding procedure, as the bidding starting point obtained from a FGD was followed by a validation exercise with sampled respondents. Therefore, to correct for bias estimates, the follow-up certainty questions were essential as affirmed by Blumenschein *et al.*, (2008). Therefore, given the possibility of recall bias, Beegle *et al*., (2011); Wollburg *et al*., (2020), this study assumed the use of yield loss estimates established through the use of an iterative bidding approach.

The validation exercise basing on the initial bid value obtained from the FGD, depicted minimum variation from the average yield loss revealed by sampled farmers. The minimum quantity revealed as yield loss by farmers was 0.09, while the maximum quantity was 2.7 tonnes per acre. This provides a range of 2.61 tonnes per acre, an indication of statistical dispersion of yield loss among the sampled farmers. This provides a range of 2.61 tons per acre, an indication of statistical dispersion of yield loss among the sampled farmers. The yield loss is indicative of a range between the minimum and maximum stated yield loss, that could be attributed to the varying intensities and forms of farm management practices (Day *et al*., 2017; Lobell *et al*; 2018; Midega *et al*; 2018) which are mainly influenced by the demographic, socio-economic as well as external institutional linkages. Considering this, it is worthwhile to note that estimates obtained by the present study were under natural infestation conditions, which are not consistent over space and time hence the range recording of minimum and maximum yield loss estimates.

Table 3: Estimated magnitude of yield loss through iterative bidding

	Valid n	Mean	Std. D	Minimum	Maximum	t-value
Elicited estimate	255	0.703	0.386	0.09	2.7	
Perceived direct estimate	255	0.665	0.356	0.18	2.7	
						2.426 **

Source: Survey Data (2019)

The beginning of 2018 was characterized by an early dry spell (UNICEF, 2018), however, rainfall precipitation for the period March-May resulted in significant yield improvement than the preceding season. De Groote *et al*., (2020) established that high-potential zones in Kenya experienced a reduction in yield loss attributed to FAW for the 2018 long rain season as compared to the 2017 long rain season, implying the adverse damage from the sudden arrival of FAW. This could be explained by the heavy rains experienced during the 2018 March-May long rain season which probably hampered the larvae survival of the FAW lifecycle (FAO & CABI, 2019). This however contradicts the findings of Sparks (1979) and Flanders *et al*., (2017), who noted that heavy rainfall creates a suitable environment for the propagation of FAW which may cause severe damage to crops. In Zambia, Kansiime *et al*., (2019) through the use of farmer-based estimates established a 28% yield loss attributed to FAW, from the season preceding FAW incidence. This is a lower estimate compared to that of De Groote *et al*., (2020) for the same season (2017 long rain). However, FAW being a case of natural infestation, it is rational to believe that farmer estimates obtained by the aid of carefully designed and executed questionnaires, while observing standardized survey protocols produces best loss estimates compared to other sources of loss reporting.

Despite the yield losses incurred, farmers managed to obtain a mean yield of 1.48 tonnes per acre after harvest. This implies that yield loss reduction due to FAW impedes the attainment of optimal maize yields of more than 2.5 tonnes per hectare (Odhiambo, 2012; De Groote *et al*., 2020). This has contributed to the effect of other pests in stagnating it to an average of below 2 tonnes per hectare (Kirimi, 2004; Olwande, 2012; Munialo, 2020). The mode accepted yield loss was 0.45 tonnes per acre (Table 3). This was recorded by 18% of farmers from the total sample. Cumulatively, 58% of the sampled farmers recorded a yield loss value lower than the average mean of the sampled farmers.

4.5 Econometric analysis of drivers on magnitude of yield loss

Fall Armyworm (FAW) control is a farm management facet, that is affected by a farming household's socioeconomic aspects. To investigate their effect on FAW related maize losses, a simple linear robust regression was fitted to determine their direction of influence. The farmers' accepted values obtained from the iterative bidding elicitation procedure form a continuous dependent variable. This was regressed against independent variables hypothesized to influence yield loss, which includes; farmer, farm specific, and institutional variable (Table 2).

The regressor variables were tested for the existence of heteroscedasticity and multicollinearity before running the model. It was established that the regressor variables were weakly collinear. To test for multicollinearity, the variance inflation factor (VIF) was used to determine the extent to which the variance of the estimated regression parameters is increased due to collinearity. Considering Greene (2002) who stated that VIF greater than 5 depicts the existence of high multicollinearity, as a rule of thumb variables, whose VIF values were less than 5 showed non-existence of multicollinearity and were included in the model. Additionally, the model was tested for heteroscedasticity using the Breusch-pagan/Cook-Weisberg which was corrected by the use of robust standard errors.

To test the null hypothesis which assumed that regressor variables had no direction of influence on the magnitude of yield loss, *p-values* as the lowest significant level at which a null hypothesis can be rejected or fail to reject were used to determine this (Gujarati, 2004). The robust regression on the parameter estimates resulted in a direction of influence on the accepted magnitude of yield loss are presented in Table 4. The F-statistic was significant at 1 percent level of significance ($p<0.01$), implying that regressor variables fitted in the regression did significantly contribute to the maximum value farmers were willing to accept as the magnitude of yield loss. The coefficient of determination (R^2) for the model was 41.01 indicating that the regressor variables included in his model explained 41.01 % variation in the regressand variable.

Table 4 shows factors that were found to have an increasing (positive direction of influence) effect of FAW related yield losses. These include; group membership and household size. Among those that had a decreasing (negative direction of influence) effect of FAW related yield losses were; utilization of extension services, years of formal schooling, distance to market, a farmer's main occupation, and farm income.

Table 4: Divers on magnitude of maize losses at farm level

Explanatory variables	Coefficient	Robust std. errors	t-value	
Experience	-0.004	0.003	-1.43	
Sex	-0.045	0.094	-0.48	
Schooling years	-0.146	0.077	-1.89	*
Household size	0.260	0.090	2.90	***
Area under maize	0.102	0.055	1.87	*
Farm income	-0.021	0.012	-1.70	*
Credit access	-0.025	0.064	-0.38	
Group membership	0.199	0.076	2.63	***
Extension access	-0.180	0.065	-2.78	***
Market distance	-0.030	0.007	-4.23	***
Occupation	-0.088	0.074	-1.19	
Intercropped	0.015	0.064	0.23	
Pest damage intensity	0.285	0.036	7.87	***
Constant	-1.054	0.323	-3.27	***
No. of observations		255		
F (13, 240)		42.81		
Prob > F		0.0000		
R-squared		0.4101		
Adj. R-squared		0.3781		
Root MSE		0.4752		

Note: *** *p<0.01*, ** *p<0.05*, * *p<0.1* (denote significance at 1, 5 and 10 percent respectively)

Source: Survey Data (2019)

Education of the farmer which was measured in terms of formal years of schooling was found to significantly influence (p<0.1) the magnitude of FAW related yield losses. Precisely, an increase in one year of formal schooling was associated with a 14.6 percent decrease in the magnitude of FAW related losses suffered by farmers. The education level of an individual plays an essential role in receiving, sourcing, and utilization of new information that will enhance his or her farm management skills in curbing FAW infestation (Nyagaka *et al*., 2010). Moreover, FAW management practices are knowledge-intensive (technical know-how) thus requiring a considerable level of knowledge in practice implementation. Alston and Murray (2014) noted that educated farmers are likely to possess a better understanding of pest situations including; early signs of eminent pest problems, absence or existence of natural enemies, and the right stage of the pest life cycle to introduce a specific management strategy.

Group membership coefficient was positively related ($p<0.01$) to the magnitude of FAW related yield losses incurred by farmers, where belonging to a group increased the likelihood of a farmer incurring an increased yield loss. This contradicts the *a priori* anticipation that, belonging to an agricultural group capacitates farmers to adapt to better farm management practices and access to relevant information needed hence achieving higher yields (Fischer & Qaim, 2012; Mwaura, 2014). This can possibly be attributed to; information gained through the groups on FAW management was not effective or the group activities did not relate to FAW management. Agricultural group membership is expected to provide a platform through which information on pest (FAW) management could be relayed timely to farmers, hence improving their approaches in managing the pest resulting to reduced yield losses. Kabunga *et al.,* (2012) noted that a farmer belonging to an agricultural group confers benefits such as obtaining disseminated information through various organizations and access to farm management inputs which significantly result to achieving higher yields.

An increase in area under maize production, increase the likelihood of higher reported FAW losses. This implies that an increase in area under maize by 1 acre was associated with a 10.2 percent increase in the magnitude of FAW related yield losses. This can possibly be attributed to the aspect of managerial weakness that arises with an increase of area under production. Fall Armyworm monitoring and control is a highly laborious practice (Prasanna *et al*., 2018), therefore, challenges in the much time and labor allocation requirements may lead to higher losses.

Results further indicate that an increment in farm income contributes to reduced FAW related maize yield losses by 2.1 percent. This could imply that financially well-endowed farmers are able to relax the resource constraint, thus having access to more hired labor to monitor and dispense the laborious FAW management practices hence the lower FAW maize yield losses. The Fall Armyworm damage intensity as described by farmers posited a positive significant effect on maize yield losses reported by farmers. This suggested that higher levels of FAW infestation on the area under maize production increased the probability of farmers incurring significant maize yield losses.

Access to extension services significantly reduced ($p<0.01$) the magnitude of FAW related losses incurred by farmers by 18 percent. This is consistent with what was initially hypothesized taking into account that, extension is a form of education to farmers to enhance their skills in managing the pest (FAW). This finding implies that raising awareness through training by extension personnel has far-reaching positive effects in equipping farmers with the requisite technical information for use in the adoption of techniques aimed towards reduction of the magnitude of FAW related losses incurred by farmers (CABI, 2019; FAO, 2019). Therefore, farmers who had an extension contact in the past twelve months recorded a reduced magnitude of yield loss by 18 percent compared to those who did not. This finding tallies with Muchiri (2012), who found that farmers who had accessed information regarding the control of mango pests, either through radio, workshops, field days, seminar trainings or had been in contact with an extension officer recorded lower mango yield losses compared to those who did not.

Distance to the market significantly influenced ($p<0.01$) the magnitude of FAW related losses incurred at the farm level. As the distance from the maize farm to the market increased, maize farmers incurred a reduction in FAW related yield losses by 3 percent. This is contrary to the expected, as an increase in market distance affects the availability and adoption of new farming technologies, information access, and support organizations such as credit institutions (Kassie *et al.,* 2013). Farm management practices more so FAW control is a highly laborious practice requiring a substantial investment of field labor (Prasanna *et al.*, 2018), moreover, efficient and routine monitoring of pests demands noteworthy on-farm time allocation (Owusu and Abdulai, 2019).

Therefore, the longer distances to markets increase transaction costs involved in the search for the requisite information and farm management inputs. This thus serves as an incentive to efficiently utilize the little time available to markets in sourcing the required information and inputs, leaving significant time to on-farm allocation to tend to the laborious farm practices, hence the effective management of FAW infestation levels. Moreover, with most of the farmers noted to have had access to extension services which reduced FAW related losses by 18 percent, implied the presence of geographically highly mobile and institutional arrangements in terms of extension access which could be attributed to relatively lower yield loss to distantly located farmers (Zanello *et al*., 2012). Additionally, it was extensively observed that maize fields far from market places were within arboraceous landscape environments that experience minimum-zero tillage, which provide habitats for natural enemies leading to increased parasitism and predation which subsequently reduces infestation levels thus reducing FAW related maize losses (Murrel, 2017; Harrison *et al*., 2019).

Household size was found to significantly influence ($p<0.01$) the magnitude of yield losses experienced by farmers. Larger households increased the probability of experiencing a high magnitude of FAW related yield losses. Household size was hypothesized to reduce the magnitude of yield losses, as larger households are ascribed to provide sufficient human capital in farm management practices. Marenya and Barrett (2007) and Agula *et al.,* (2018) noted that larger family sizes provide for labor availability free of possible moral hazards (supervision), playing a critical role in the adoption of integrated soil fertility management components and use of ecosystem-friendly irrigation farm management practices respectively. The contrary relationship shown in Table 4 can be attributed to the fact that an increase in family size posits a higher dependency ratio (0.87) as shown in Table 2. This has the effect of increased family budgetary allocations on essential goods and services such as medical care and clothing reducing the amount of disposable resources available, to be used on input and information sourcing (Addai *et al.*, 2014).

4.6 Key farmers' perceptions of Fall Armyworm (FAW) control practices

The study collected farmers' responses on their perceptions towards the functioning and use of FAW control practices, in relation to their efforts to manage the pest causing havoc to their maize production activity. The results of principal component analysis (PCA) on perceptions among farmers in the study area are shown in Table 5. The Kaiser-Meyer-Olkin measure of sampling adequacy for the sample was 0.741 which is above the recommended threshold of 0.5 for factor analysis, indicating the suitability of factor analysis in yielding definite and reliable factors (Everitt and Horthorn, 2011; Field, 2013). The reliability of Kaiser Criterion in extracting factors with eigenvalues is confirmed by the average value of extracted communalities which is equal to 0.60 with a sample size of more than 250 observations (Field, 2009). Factor loadings with values greater than 0.4 were retained on the component matrices (Stevens, 2002). The Bartlett's test of sphericity for the sample was significant at 1 percent ($p<0.01$). Varimax rotation a form of orthogonal rotation strategy was used hence no existence of correlation between the components.

Considering the Kaiser's criterion, five principal components were retained which accounted for 59 percent of the variance in the original variables. The principal components (perceptions) 1 50 5r were labeled as increased productivity, environment friendly, socially acceptable, promotion efforts, and availability. The proportion of variance explained by the first component is 18 percent of the total variance, the second accounted for 12 percent of the variance not explained by the first, and the third accounted for 11 percent, while both the fourth and fifth components each explained 9 percent of the total variance. A total of seven variables were removed from the analysis since they did not contribute to a simple factor structure as they did not attain the minimum criteria of 0.5 KMO measure.

Farmers strongly believed to have experienced increased maize yield of better quality after putting into use the various control practices. The ultimate outcome was increased farm income compared to that obtained in the previous main season (the year 2017). This corroborates with their strong belief that the practices greatly reduced Fall Armyworm infestation levels in their maize fields thus playing an essential role in addressing Fall Armyworm, a pest they ranked as a major challenge. Furthermore, they described the FAW control practices as effective technologies which provide real-time positive results. This further influenced them to perceive the practices as a better solution in constraining FAW infestation in their farms.

Perception of environment friendly was best explained by four main items that load heavily. Farmers perceived the practices not to have any harmful or unintended effects on non-targeted beneficial organisms such as bees and wasps. This is a positive perception since bees play an essential role in pollination processes while wasps are FAW natural enemies (Khan *et al.,* 2018; FAO, 2020). However, Kumela *et al*., (2018) reported the negative effect of FAW control insecticides on bees. Moreover, the farmers perceived the practices not to be human friendly especially for the chemical insecticides that may result to irreversible harm to human health (FAO, 2016: Kumela *et al*., 2018). This thus justifies the utilization of a combination of control methods that are sustainable, cost-effective, and ecosystem friendly alluding to the preferred FAW integrated pest management approach (Day *et al.,* 2017).

Under the perception socially acceptable, farmers affirmed that FAW practices were socially acceptable as they did not go against any of their culture aspects of the society. However, they did not see it necessary for further research and development, to further innovate and improve the practices technically as they deemed them effective in managing FAW. This is a negative perception since FAW has been noted to develop resistance over time (Carvalho *et al.,* 2013). Additionally, farmers perceived extension services necessary to aid them in the fight against FAW which could enhance the effective use of FAW practices as it was a new pest to them. This is evident in Table 4 as it is shown that extension services contributed to reducing FAW related losses by 18 percent.

The perception promotion effort has two items that load high. Farmers perceived promotion efforts of creating awareness to have contributed to the effectiveness of the practices. This is a positive perception since farmers obtained important information on FAW control from extension programs, National Agricultural Research Centers, and private sectors involved in pesticide distribution. This could additionally have played a role in encouraging farmers to combine practices since they perceived combining practices as an important formulation in managing the pest effectively. This can contribute to the modeling of a sustainable management approach considering the mutation aspect of the pest, thus providing a platform for the formulation of an integrated pest management approach that poses a minimum risk to the ecosystem (Day *et al.*, 2017).

The perception availability was best explained by three main items. Here, farmers asserted that the FAW control practices were not easily available. This thus confirms their strong affirmation of there being a price or cost that is involved in accessing and using the practices. Additionally, the farmers perceived the use of the practices to be laborious in nature and thus requiring additional labor for their use (CABI, 2019).

Table 5: Factor loadings of farmers' perceptions of Fall Armyworm (FAW) control practices

Variables	**Increased productivity**	**Environment friendly**	**Socially acceptable**	**Promotion efforts**	**Availability**	**Communality**
Contributes to increased quantity of maize yield	**0.786**					0.724
Resulted to improved maize quality	**0.781**					0.690
Reduced FAW infestation in maize field	**0.707**					0.695
Results to increased farm income from maize	**0.691**					0.529
Addresses FAW as a major challenge in maize production	**0.653**					0.539
Provides real-time solution to reducing maize yield loss	**0.581**					0.508
Offers permanent solution to recurring FAW infestation	**0.552**					0.443
Harms non-targeted beneficial organisms		**0.812**				0.696
Cause harm to other beneficial organisms in the environment		**0.739**				0.571
FAW control practices are human friendly		**-0.627**				0.582
Possibility to harm other crops in the farm	4.29	**-0.596**				0.588
FAW control practices are socially accepted			**0.751**			0.623
Relative management in other pests and diseases			**0.627**			0.481
Require further technical innovation to increase performance			**-0.626**			0.507
Use of FAW control practices requires extension help			**0.581**			0.585
Use of FAW management practices reduces profits gain			**0.574**			0.629
Efforts in place to promote the use of FAW practices				**0.782**		0.674
Works in combination with other practices				**0.528**		0.422
FAW control practices are readily available					**-0.664**	0.557
Price or cost associated affects decision to use		0.433			**0.589**	0.665
Use of FAW practices requires additional labor					**0..544**	0.619
Eigen values	4.029	2.776	2.514	1.687	1.619	0.60
Proportion of explained Variance (%)	18.431	12.482	10.646	8.571	8.556	
Kaiser Meyer Olkin Measure of sampling adequacy (MSA)				0.741		
Bartlett's Test of Sphericity - Chi-Square (Number of degrees of freedom)				1704.070 (210) ***		

Factors extracted through principal component analysis, Varimax rotation with Kaiser normalization;

Source: Survey Data 2019

4.7 Determinants of farmers' perception on Fall Armyworm control practices

The perception scores, derived from principal component analysis were regressed against an identical set of regressor variables as shown in Table 6. However, the various forms of farmers' perceptions of FAW practices were predicted by different sets of regressor variables. This shows the variations of farmers' perception on the practices since all the perceptions cannot be predicted by the same set of regressor variables.

The regressions result in low adjusted R^2 values. Greene (2000) noted this as a usual observation especially when Ordinary Least Squares regressions are used on cross-sectional data. Additionally, low R^2 values are a good indication when carrying out perception studies as they are a show that the perceptions are mainly determined by differences in respondents' behaviors, actions, and attitudes. Therefore, obtaining high R^2 implies that the perceptions obtained will be providing unessential information (Pindyck & Rubinfeld, 1991; Nunes 2002; Flaten *et al*., 2005 Abebaw *et al*., 2006; Asai *et al*., 2014). The F-statistics are all significant at 1 percent ($p<0.01$) providing ground to reject the null hypothesis that the regressor variables had no significance and direction of influence on farmers' perception scores. This thus shows that the model is significant with significant explanatory powers, thus providing meaningful results on how farmer, farm specific, and institutional factors describe the latent variables underlying the observed heterogeneity of farmers' perceptions.

Table 7 shows that the perception on increased productivity was influenced by five variables; household size, the area under maize, farm income, membership to an agricultural group, and extension access. Extension access, group membership, and farm income all positively influenced the perception increased productivity at ($p<0.01$), while household size and area under maize influenced the perception negatively at ($p<0.1$) and ($p<0.05$) respectively. This implies that farmers who were members of an agricultural group and accessed extension services had a positive perception on increased productivity as a result of the use of FAW control practices, as they had gained the requisite information for effective use of the practices in managing the pest. Respondents who had experienced an increase in their farm income were more receptive towards increased productivity perception, as they had used the FAW control practices to manage the pest in their farms. Consequently, they perceived the practices as effective solutions to reduce the losses resulting from FAW infestation, hence increased incomes resulting from the abated maize losses. Reliance on extension efforts aiming at dissemination and training on the application of the practices played an essential role in reducing losses experienced in the study area (CABI, 2019; FAO, 2019). This corroborates with Kumela (2018) who noted the essence of real-time efforts on awareness creation and technological advancements from extension programs, National Agricultural Research Centers (NARS), and policymakers in developing and deploying an effective integrated pest management strategy.

Moreover, it was noted that an increase in both household size and area under maize made farmers less receptive to the perception on increased productivity. This could notably be explained by the increased competition of resource allocation within a farming household, as the proportion under maize production increased more resources were needed to address the increased need for FAW management. Therefore, larger households spent bigger portions of their resources in meeting family obligations hence the negative perception.

Perception on environment friendly was influenced by five variables namely; sex of the farmer, distance to market, extension access, area under maize, and farm income. Sex of the farmer and farm income positively influenced the perception scores at ($p<0.01$) and ($p<0.05$) respectively, while distance to the market, extension access, and area under maize negatively influenced the perception on environment friendly at ($p<0.01$), ($p<0.05$) and ($p<0.1$) respectively. Compared to female farmers, the male counterparts perceived FAW practices as environment friendly for use without any effect on man and other organisms within the farm ecosystem. Farmers who earned higher farm incomes had a positive perception on the environment friendliness aspect of the practices. This can be attributed to the farmers' capability to expend the income in sourcing for the right information and acquisition of the FAW practices, making the farmers more responsive towards the practices.

Farmers located far from market centers perceived the practices not to be environmentally friendly. This could be explained by the lack of environmental information related to the use of the practices and assurance from other farmers since most of the meetings and discussions are conducted mostly within market centers. Moreover, farmers who had access to extension services and with a larger area under maize had a negative perception towards the environment-friendliness of the practices, as synthetic pesticides were largely used which posed negative effects on both human health and environmental organisms such as bees (Kumela *et al*., 2018).

The third perception socially accepted was influenced by two variables whereby an increase in formal years of schooling positively influenced ($p<0.1$) socially accepted perception scores. This implies that farmers who had attained a higher number in years of schooling had the ability to source for and synthesize new information regarding the effective use of the practices hence the positive perception and subsequent adoption of the practices. Additionally, an increase in area under maize production had a positive influence at ($p<0.05$) on socially acceptable perception scores. This is an indication that farmers with larger portions of land under maize production provide farmers with an incentive for uptake and use of the practices in an effort to manage the pest and to prevent the high FAW related maize yield losses.

Table 6: Determinants of perceptions on FAW control practices

Explanatory variable	Increased productivity	Environment friendly	Socially acceptable	Promotion efforts	Availability
Age	-0.001 (0.006)	0.002 (0.005)	0.006 (0.004)	-0.008 (0.005)	-0.009 (0.005) *
Sex	0.143 (0.241)	0.590 (0.159) ***	-0.260 (0.218)	-0.480 (0.169) ***	-0.479 (0.216) **
Schooling years	-0.177 (0.192)	-0.042 (0.150)	0.301 (0.165) *	0.020 (0.160)	-0.083 (0.126)
Household size	-0.298 (0.171) *	-0.025 (0.137)	0.072 (0.154)	0.045 (0.155)	-0.051 (0.165)
Area under maize	-0.152 (0.075) **	-0.159 (0.088) *	0.216 (0.081) **	-0.210 (0.075) ***	0.260 (0.079) ***
Farm income	0.068 (0.017) ***	0.041 (0.021) **	0.019 (0.017)	0.042 (0.021) **	0.066 (0.022) ***
Credit access	-0.216 (0.149)	0.126 (0.141)	0.093 (0.145)	-0.108 (0.150)	-0.110 (0.138)
Group membership	0.549 (0.115) ***	-0.110 (0.146)	0.128 (0.184)	0.078 (0.156)	0.158 (0.157)
Extension access	0.347 (0.120) ***	-0.210 (0.123) *	-0.041 (0.128)	0.044 (0.122)	0.075 (0.126)
Market distance	0.027 (0.132)	-0.419 (0.131) ***	-0.021 (0.146)	-0.438 (0.127) ***	-0.447 (0.130) ***
Occupation	0.173 (0.153)	0.019 (0.145)	0.167 (0.141)	0.005 (0.156)	0.076 (0.159)
Constant	0.024 (0.601)	-0.485 (0.563)	-1.568 (0.721) **	0.741 (0.613)	1.332 (0.640) **
F - statistics	8.06 ***	4.69 ***	2.66 ***	3.67 ***	5.08***
R^2	0.178	0.142	0.097	0.121	0.187
Adj. R^2	0.141	0.103	0.056	0.081	0.150

Statistical significance: *** *p<.01*, ** *p<.05*, * *p<.1*.
Figures in parentheses are robust standard errors

Source: Survey data, 2019

Perception on promotion efforts was influenced by four factors. The sex of the farmer, distance to market, and area under maize each posited a negative influence at ($p<0.01$), while farm income had a positive coefficient significant at ($p<0.05$). Results indicate that male farmers were noted to be less receptive towards promotion efforts factor scores. Occasionally in the Kenyan setup, women are much involved in the farm management activities compared to men (Kassie *et al.*, 2014), this probably could explain the reason why male farmers negatively perceived promotion efforts. However, an increase in farm income had a positive influence on promotion efforts, as farmers who experienced higher farm incomes were more receptive to promotion efforts that disseminated and advocated for knowledge in the use of FAW control practices in managing the pest.

Farmers living far from market centers were less receptive towards the perception promotion efforts of FAW control practices. This could possibly be attributed to the high external transaction costs to market centers (Fischer and Qaim, 2012), where dissemination seminars and other meetings which are forms of promotion efforts take place. However, this could possibly be corrected by ensuring the presence of geographical highly mobile, and institutional arrangements in reducing the transaction costs (Zanello *et al*., 2012).

A bigger area under maize is an incentive to make financial investments on-farm management practices (Handschuch and Wollin, 2016; Manda *et al.*, 2016), hence the expected positive influence towards promotion efforts scores. On the contrary, farmers with a larger area under maize production expressed a negative perception towards promotion efforts. Pratt *et al.*, (2017) noted that farmers in Kenya and Ethiopia incurred higher maize losses due to IAS, which was largely influenced by the area under maize production and the extent of innovation.

The perception availability was influenced by five variables. Farm income and area under maize both positively influenced availability perception scores at ($p<0.01$), while age, sex of the farmer, and distance to market had a negative influence at ($p<0.1$), ($p<0.05$), ($p<0.01$) respectively. The positive influence of area under maize suggests an incentive to farmers on the need for uptake of the FAW control practices to manage the pest. Moreover, with increased farm incomes, farmers posited a more receptive perception towards availability score as they could afford to efficiently meet costs involved in information search and adopt the practices (Tey *et al.*,2014).

Farmers living far from the market center and who were old perceived the perception availability of practices as less important. This could be attributed to the reluctance of older people to adopt agricultural technical innovations (Manda *et al.*, 2016) as well as the high transaction costs incurred in accessing the distant located markets, for the search of information. Male farmers, who are defined as household heads in African setup societies, deemed the practices as not easily available. This could be explained by the fact that they are also obligated with the responsibility of providing to their families (O'brien *et al.*, 2016), considering their constrained pool of resources, whereas, some of the practices have an associated cost in obtaining them for use.

CHAPTER FIVE

CONCLUSION AND POLICY RECOMMENDATION

5.1 Conclusions

The study objectives included assessment of the economic importance of Fall Armyworm on maize farming by estimating the magnitude of losses as well as the socio-economic, support institutional linkages, farm, and farmer specific factors driving the losses among maize farmers. In addition, the study went further to examine farmers' perceptions on Fall Armyworm control practices and also unearth their determinants.

Findings indicated that Fall Armyworm is a significantly important pest aggravating the impacts of pre-existing invasive alien species. The pest was noted to result in an average of 0.7 tons per acre of maize loss incurred by farmers with the highest reported being 2.7 tons per acre in the study area. The study found that maize yield losses related to Fall Armyworm were aggravated by the area under maize production, group membership, household size, and Fall Armyworm damage intensity as described by farmers. The yield losses were found to decrease with access to extension services, years of formal schooling attained, farm income, and distance to market. The findings are contrary to the stated hypothesis that, farmer, farm specific, and institutional factors taken individually have no effect on the magnitude of yield losses in maize. The null hypothesis is therefore rejected in favor of the alternative hypothesis.

Farmers seemed not to harbor any reservations on the efficacy of the practices they employed to increase maize productivity by managing the pest and promotion efforts to encourage the use of the practices. This implies that farmers perceived that combination of practices as a leveraging approach towards maximizing the efforts on effective management of the pest. These findings are contrary to the hypothesis which stated that farmers have negative perceptions towards the attributes of mitigation strategies used in Fall Armyworm management. Therefore, the null hypothesis was rejected.

Each and every respective perception had varying determinants as indicated by results obtained from Table 6. Among the determinants of perception scores included institutional support services, farm, and farmer specific characteristics. Some of these determinants had a significant influence on the perception scores extracted in the analysis. These findings are contrary to the hypothesis which stated that institutional support services, farm and farmer specific factors have no effect on how farmers perceive their current control practices in Fall Armyworm management. Therefore, the null hypothesis is rejected in favor of the alternative hypothesis.

Access to extension services, formal years of completed schooling, farm income, and distance to market should be carefully given due consideration in stakeholders' joint efforts towards managing FAW infestation with the aim of reducing its related losses. Additionally, farmer perceptions who are the primary stakeholder in maize farming should be considered in the formulation and dispensation of an effective integrated FAW management approach. In order of the proportion of variance described by the obtained farmers' perception of FAW control practices, the perceptions were characterized as; increased productivity, environment friendly, socially acceptable, promotion efforts, and availability. Findings from the regression analysis revealed that despite using a similar set of explanatory variables across the perception regressions, variables that influenced the perceptions on FAW control practices did vary with respect to the farmers' perception under observation. Generally, perception scores of FAW control practices were strongly correlated with information on social capital (extension access, group membership), risk exposure (area under maize production), wealth (household farm income), location (distance to market), and farmer demographic factors.

5.2 Recommendations

5.2.1 Policy recommendations

Despite maize being an economically significant crop for the producing households, it is faced with the menace of FAW infestation which is likely to remain as an important pest in the foreseeable future. Consequently, farmers are subject to incur substantial welfare loss due to the reduced yield obtained, thus having an effect on their state of livelihoods. Therefore, the assessment of maize yield loses is essential for the improvement of production systems that contribute to the incomes of maize farming households and food security. The study noted that factors aggravating the stated magnitude of losses by farmers include area under maize production, household size, group membership, and pest damage intensity as described by farmers.

The proportion of farmer membership to an agricultural group was markedly low. This is an alarming concern to policymakers, considering that both government and non-government organizations highly rely on agricultural groups when carrying out extension activities. Nevertheless, tackling FAW cannot be solely done by farmers, as there is a need for concerted efforts from relevant institutions and policymakers to design policies that ensure a multi-stakeholder approach in managing FAW. Moreover, there arises the necessity to motivate farmers to organize themselves into groups related to their agriculture enterprises, which is essential as it will enhance access to relevant extension services thus contributing towards reducing FAW related losses. They will also get training on the use of control strategies and the acquisition of inputs at subsidized prices. Additionally, it will also aid in cutting down transaction costs incurred in accessing markets due to long distances covered to fetch information, as knowledge spillover from the groups will result due to the existing social capital.

Consequently, this will increase farmers' efficiency in effectively carrying out farm management practices in pest management.

The level of education and extension services as demonstrated by this study influenced the magnitude of FAW related losses. This, therefore, calls for the need to consider the different existing literacy levels amongst target farmers in packaging the approach and training material content, especially to male farmers who had a negative perception towards socially acceptable, promotion efforts and availability scores of FAW control practices. Through the various dissemination platforms, technical information on how to effectively manage FAW should be disseminated through the combined efforts of NARS, the private sector, and the Ministry of Agriculture.

The importance of extension services was shown by the findings as it was noted to contribute towards farmers' efforts to abate FAW related losses. This resulted to spillover effects as the location of a maize farming household with respect to the *a priori* anticipated outcome, had a contrary effect. This, therefore, calls for the increased efforts directed towards availing and provision of extension services aimed at FAW management. This will result to ensuring the presence of geographical highly mobile and institutional arrangements, which ultimately reduces transaction costs incurred by farmers thus reducing impediments towards reducing FAW related maize yield losses. Moreover, enhanced investment in education will play a significant role as it increases farmers' prudence levels in terms of knowledge management in the processing of knowledge obtained thus increasing their effort efficiency towards FAW control. Simultaneously, this improves the aspect of farmer resource allocation as the gross farm incomes obtained are spent diligently on-farm management aspects.

Results also indicated the effect of household size in increasing the FAW related magnitude of yield losses realized. Larger household sizes are equated to the existence of sufficient human capital for use in farm management practices. Although this was not the case as the dependency ratio was at a high of 0.87, indicating the existence of a huge fraction of individuals (both older and young ones) competing from the pool of resources leaving negligible allocation for farm management practices that are highly laborious. Therefore, there is a need to economically empower the youth on the existing agro-enterprise opportunities, a role that can be played by both the private and public sector to reduce the dependency levels which ultimately frees up resources for allocation to farm management practices. Additionally, social protection measures can be implemented to cushion the aged in the households as well.

The study noted that farmers' perceptions on FAW practices were grouped and classified into: increased productivity, environment friendly, socially acceptable, promotion efforts, and availability. This, therefore, depicts to technology developers and policymakers, the need to consider these aspects in the process of formulating a FAW IPM approach to enhance the effective management of the pest and its adoption by farmers. It is therefore critical to develop a well-coordinated, flexible and effective approach in managing FAW, which is adaptable across Kenya's agro-ecological zones where maize farming is practiced particularly by small-scale farmers.

Farmers perceived FAW control strategies as not easily available and non-friendly environmental effects, perceptions that discourage the use of these practices. These could be as a result of the cost associated with practices such as chemical pesticides, the high labor requirements in the use of the practices as well as the effects on human health and other surrounding living organisms. However, farmers were receptive to promotion efforts that were carried out by both private and government agencies on the use of the practices. Considering the importance shown by farmers on promotion efforts, there is a need to increase awareness creation to ensure farmers are fully aware and well informed of the existing various FAW control practices. This is important as awareness creation has been recognized as a vital condition to adoption and decision use by farmers. Therefore, through government institutional capacities, platforms such as broadcast media, agricultural workshops, and exhibitions should be exploited with the aim of informing farmers on the approaches to manage FAW.

In most agricultural contexts, farmers' decisions in their farms are greatly and directly influenced by national policies and regulations. For the case of FAW control measures and management, this is factual in the case of pesticides policies, regulations and programs and including financial resource allocation on FAW national response. Farmers, government and extension frameworks also need sound policy and technical advice to prevent the use or over-reliance on highly hazardous synthetic pesticides while promoting much safer alternatives. Therefore, formulation of technical working groups on FAW will play an essential role in laying down frameworks on management of the pest. The technical working groups could play essential roles in aspects such as; farmer education and communication, testing and validation of FAW management of FAW practices, monitoring, risk assessment and early warning systems, long-term research and innovations, policy and regulatory support and coordination.

5.2.2 Recommendations for further study

This study assessed the magnitude of maize losses incurred by farmers in Trans-Nzoia County and their perceptions on their existing FAW control practices. Future studies could delve into the following:

1. It is noteworthy to point out that data used in this study was cross-sectional data collected shortly after the FAW menace occurred in Kenya and government agriculture agencies and farmers were not ready and well equipped in managing the effects of the pest. As a result, with increasing knowledge over time, the extent of damage resulting from the pest may decrease. Therefore, to capture the impact of FAW infestation over time, panel data can be used to assess the damage caused and the dynamics in pest management practices used by farmers.
2. The estimation of FAW related losses in this study is the only representative of the study area and thus estimation of losses in all agro-ecological maize producing zones will avail a broader picture for the county's maize sub-sector.

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APPENDICES

Annex 1: Variance Inflation Factors, misspecification and Heteroskedasticity tests

2.1 Variance inflation factor for drivers of yield loss

	VIF	1/VIF
Area under maize	1.566	0.639
Farm income	1.290	0.775
Experience	1.283	0.779
Market distance	1.271	0.787
Intercropped	1.229	0.814
Schooling years	1.199	0.834
Credit access	1.176	0.851
Household size	1.166	0.858
Occupation	1.116	0.896
Extension access	1.111	0.900
Pest damage intensity	1.087	0.920
Group membership	1.087	0.920
Sex	1.036	0.965
Mean VIF	1.201	.

Model misspecification error test

Ramsey RESET test		
F (3, 237)	=	0.83
Prob > F	=	0.470

Heteroskedasticity test

Breusch-Pagan /Cook Weisberg test for heteroskedasticity		
chi2(1)	=	15.42
Prob > chi2	=	0.0001

2.2. VIF, misspecification and Heteroskedasticity test for determinants on perception of increased productivity

	VIF	1/VIF
Area under maize	1.350	0.741
Farm income	1.241	0.806
Market distance	1.175	0.851
Credit access	1.174	0.852
Age	1.163	0.860
Household size	1.157	0.864
Schooling years	1.149	0.870
Extension access	1.103	0.907
Occupation	1.077	0.929
Group membership	1.060	0.944
Gender of HHH	1.032	0.969
Mean VIF	1.153	.

Model misspecification error test

Ramsey RESET test		
F (3, 241)	=	0.10
Prob > F	=	0.9610

Heteroskedasticity test

Breusch-Pagan /Cook Weisberg test for heteroskedasticity		
chi2(1)	=	7.49
Prob > chi2	=	0.0062

2.3 VIF and Heteroskedasticity test for determinants on perception of environment friendly

	VIF	1/VIF
Area under maize	1.350	0.741
Farm income	1.241	0.806
Market distance	1.175	0.851
Credit access	1.174	0.852
Age	1.163	0.860
Household size	1.157	0.864
Schooling years	1.149	0.870
Extension access	1.103	0.907
Occupation	1.077	0.929
Group membership	1.060	0.944
Gender of HHH	1.032	0.969
Mean VIF	1.153	.

Model misspecification error test

Ramsey RESET test		
F (3, 241)	=	1.52
Prob > F	=	0.2099

Heteroskedasticity test

Breusch-Pagan /Cook Weisberg test for heteroskedasticity		
chi2(1)	=	2.66
Prob > chi2	=	0.1027

2.4 VIF and Heteroskedasticity test for determinants on perception of socially acceptable

	VIF	1/VIF
Area under maize	1.350	0.741
Farm income	1.241	0.806
Market distance	1.175	0.851
Credit access	1.174	0.852
Age	1.163	0.860
Household size	1.157	0.864
Schooling years	1.149	0.870
Extension access	1.103	0.907
Occupation	1.077	0.929
Group membership	1.060	0.944
Gender of HHH	1.032	0.969
Mean VIF	1.153	.

Model misspecification error test

Ramsey RESET test		
F (3, 241)	=	4.34
Prob > F	=	0.2309

Heteroskedasticity test

Breusch-Pagan /Cook Weisberg test for heteroskedasticity		
chi2(1)	=	2.13
Prob > chi2	=	0.1445

2.5 VIF and Heteroskedasticity test for determinants on perception of promotion efforts

	VIF	1/VIF
Area under maize	1.350	0.741
Farm income	1.241	0.806
Market distance	1.175	0.851
Credit access	1.174	0.852
Age	1.163	0.860
Household size	1.157	0.864
Schooling years	1.149	0.870
Extension access	1.103	0.907
Occupation	1.077	0.929
Group membership	1.060	0.944
Gender of HHH	1.032	0.969
Mean VIF	1.153	.

Model misspecification error test

Ramsey RESET test		
F (3, 241)	=	1.43
Prob > F	=	0.2339

Heteroskedasticity test

Breusch-Pagan /Cook Weisberg test for heteroskedasticity		
chi2(1)	=	1.19
Prob > chi2	=	0.2754

2.6 VIF and Heteroskedasticity test for determinants on perception of availability

	VIF	1/VIF
Area under maize	1.350	0.741
Farm income	1.241	0.806
Market distance	1.175	0.851
Credit access	1.174	0.852
Age	1.163	0.860
Household size	1.157	0.864
Schooling years	1.149	0.870
Extension access	1.103	0.907
Occupation	1.077	0.929
Group membership	1.060	0.944
Gender of HHH	1.032	0.969
Mean VIF	1.153	.

Model misspecification error test

Ramsey RESET test		
F (3, 241)	=	0.19
Prob > F	=	0.9044

Heteroskedasticity test

Breusch-Pagan /Cook Weisberg test for heteroskedasticity		
chi2(1)	=	1.19
Prob > chi2	=	0.1667

Annex 2: Questionnaire

University of Nairobi

Assessment of Economic Losses and Farmers' Perceptions of FAW Control Practices on Maize

INTRODUCTION

Dear Sir/ Madam

The University of Nairobi, Department of Agricultural Economics is interested in conducting a research survey to assess economic losses due to FAW and farmers' perception on their current control practices.

The objective of the study is to assess the magnitude of losses and their perceptions on the available FAW control practices in use. This will enable the involved stakeholders and policy formulation personnel to be efficient in resource allocation prioritization and designing of an effective integrated FAW approach.

The information you provide will be treated with ultimate confidentiality and used for academic and policy purposes only. This interview will take at least 30 minutes and your dedication and time will be highly appreciated. I would like to begin the interview now.

The respondent must be an individual who normally makes farm decisions in the household. This must be the household head or the spouse.

Respondent screening: Does your household ordinarily grow maize and has experienced FAW infestation? YES [1], NO [0]. If NOterminate the interview.

Section I. Identification

1) Date of Interview: ______________________ 2) Enumerator's name: __________________________

3) Enumerator's code: ______________________

4) County: ________________ 5) Sub-county: _________________ 6) ward: __________________

7) Village: _____________________ 8) Name of respondent: ____________________

9) Respondent's phone number: ____________________________

10) Respondent's relationship to household head:

Head [1] Spouse [2] Son [3] Daughter [4] Other (specify) [5]

11) Crop production system: Rain fed agriculture [1] Irrigated Agriculture [2]

HOUSEHOLD DETAILS

Sex of respondent (Code A)	Sex of household head if not the respondent (Code A)	Number of schooling in years	Primary occupation of the household head (Code D)	Marital status (Code E)	Year of birth

Code A:0= Female [ ] 1= Male [ ]

Code D: *1= Farming 2 = Business person 3= Casual Laborer 4 = Salaried Employee 5= Other (specify)……………………..*

Code E:*1= single 2= married 3= separated 4= widow/widower 5=none*

12) What is the total number of people living in the household? ____________________

Household members	Male	female	Total
Household members aged below 16yrs			
Household members aged between 16-59 yrs.			
Household members above 60years			

Section II. Land ownership and Maize production

13) How many years have you practiced maize farming? _________________ Years.

14) Which maize varieties do you plant? ____

15) How many seasons do you plant maize in a year?(1= One, 0= Two)

16) What is the total size of land owned by the household in acres? ________________ Acres.

Provide the following information about each plot that the household owns or has access to. (1 acre = 4,046.86m^2).

Land inAcres (cultivated)	**Plot tenure** (CODE D: below)	**Who owns this plot:** (1=Male 0=Female 2=Joint)	**Proportion of land under maize production** **(In Acres)**	**Do you intercrop maize with other crops?** 1=Yes 0=No	**If YES what crops:** 1=beans 2=soya beans 3=ground nuts 4=cowpeas 5=other, specify (__________)	**Maize yield Quantity:**	**Unit** 1=90kg bag 2=70kg bag 3=50kg bag

CODE D: Land Tenure	
1.Holds a formal title or allotment letter 2.Owns but has no formal title/document (e.g. inherited) 3. Lease/ Rented in	4. Has communal rights to use of land (e.g. pastoral land, trust land, group land/ranch) 5. Has use of land (s)he considers own but has never been allocated (squatters)

Section III. Variable Inputs:

Provide the following information for input use on maize crop production in a normal year.

Input (excluding labor) type		**Did you use?** 1=Yes 2=No	**Units used** Quantity	Unit (Code E)	Price per unit	**Source of Input (Code F)**	**What are the constraints to input access? (Code G)**
Seeds	Improved seeds						
	Local seeds						
Herbicides							
Planting fertilizer							
Top dressing fertilizer							
Organic fertilizer							
Organic Manure							
Foliar feed							
Pre-harvest pesticides							

Code F	**Code E**		**Code G**
1. Own seeds 2. Open market center 3. Agro vets 4. Government (AFC) 5. Donations from NGOs 6. Friends 7. Others (specify)	1. kg 2. 25-kg sack 3. 50-kg sack 4. 90-kg sack 5. litre (gorogoro/kasuku) 7. 10-kg debe/bucket 8. 15-kg debe/bucket 9. Tonnes 10. Donkey carts	11. wheelbarrows 12. pick-up 13. Others(specify)	1. None 2. High prices 3. Distance to input market 4. Poor quality of inputs 5. Lack of access to inputs at the right time 6. Others (specify)

Section IV. FARM LABOR

19) Do you use hired labor in your farm? [1]Yes [0] No

Provide the information of labor requirements in maize production activities on your farm for a normal year

Maize production activities	**Man-hours**		**Human Labor**			**Machinery**			
	Family	**Hired**	**Unit**	**Cost**	**Total Cost**	**Farm Implement**	**Unit**	**Cost**	**Total Cost**
Ploughing									
Fertilizer Application									
Planting									
Weeding									
Spraying									
Harvesting									

****** Family labor* (Man-hours)*will be estimated in terms of opportunity cost***

Section V. INSTITUTIONAL SUPPPORT SERVICES

(i) Group membership _ Social Capital

22) Are you a member of any agricultural/social/association or development group? Yes [1]   No [0]. If **YES,** please fill the details in the table below: If **NO** skip to Q.23

Type of group:	**Membership duration in years**	**Reason for joining the group:**
1= Women group 2= SACCO/ credit supply 3= Farmer cooperative / input supply 4= Producer and marketing group 5= Youth group 6= Other (specify) _____________		1=produce marketing 2=input access 3=savings and credit 4=farmer trainings 5=transport services 6=other, (specify) ______________
1)	1)	1)
2)	2)	2)

23) If you are **NOT** a member of any development group/organization, why not? (1=Not available, 2=time wasting, 3=Not interested, 4=corruption in the group, 5=other, specify____)

(ii) Credit Access (*credit/loan/in kind loan e.g. planting seeds, fertilizer, pesticides, e.t.c*) _ both formal and informal

24) Has the household had access to credit in the **last one year**? [1]Yes [0] No

If **YES** in Q.24 please fill in the details in the following table: **NO** skip to Q.25 ***(when Code I is materials/ inputs, convert to cash)***

Major source of credit (Code H)	Major form of credit (Code I)	Amount (Kshs)	Purpose of the loan	Interest rate (%)

Code H 1= Government fund/agency e.g AFC 2= Buyers 3= Commercial bank 4= Shylocks 5= MFI's	6= Donor/NGO 7= Groups (farmer groups) 8= Relative/friends 9= Input dealers 10= Others (Specify)_____	**Code I** 1= Money 2= Material(s) and/or inputs 3= Others (specify)_______	**Purpose of loan** 1=farm inputs 2=school fees 3=food 4=land 5=livestock 6=offset a problem one had 7=other, specify_________

25) If you did not apply for credit what was the **main** reason?

(1=high interests rate, 2=lacked collateral, 3=too much paper work, 4=borrowing is risky, 5=not a member of the Microfinance Institution (MFI), 6=high cost of obtaining credit, 7= I don't need it 8. Other. Specify_________________________)

(iii) Extension Services

26) Did you receive extension contact for maize production for the last one year? 1=Yes, 0=No. If ***yes,*** please fill in the table below.

Source of extension service	**Frequency over the last 12 months**	**What kind of information did you receive from this source:** 1= Maize crop production 2= Pest and disease incidence, 3= Pest and disease management. 4= Markets & prices, 5= Government initiatives, 6= Good agricultural practices, 7= Training 8= other, specify(______________)	**Was this information timely?** (1= Yes, 0=No)	**Was this information reliable?** (1= Yes, 0=No)
County extension officer				
Private extension agent				
Researchers				
Farmer to farmer				
Farm Demonstrations				
Print media (magazines and newspapers)				
Television set (TV)				
Radio				
Out grower (seed companies)				
Farmer cooperatives				

Section VI. FALL ARMYWORM IN MAIZE PRODUCTION

27) Are you aware of Fall Armyworm (FAW)? Yes [1]   No [0].

If yes when did you first observe it? _________________

28) What was the source of the information on FAW?

[1] Extension staff   [2] Radio   [3] T.V. [4] Agro-input dealer   [5] other farmers **[**6] other (specify)....

29) What kind of information have you received? ____

30) What type of damage is caused by FAW on maize crop? ____

31) Are there any other crops attacked by FAW?

(i) ____________________ (ii) __________________________ (iii) ________________________

32) In your opinion, is Fall Armyworm a major maize pest compared to other pests? Yes [1]   No [0].

If ***NO,*** which other pests are major problems? **Rank 1-3**

Other pest	1.	2.	3.	4.

33) At what stage of maize production is Fall Armyworm population highest?

[1] Three weeks after germination. [2] At knee high. [3] At tasseling. [3] Cobbing stage. [4] At all above stages

VI.i. ASSESSMENT OF MAIZE YIELD LOSSES AND DAMAGE LEVELS

34) On average, what yields have you normally been achieving per acre in the past 5 years **before** Fall Armyworm infestation? ____________________________ 90 kg bags per acre.

35) What yields did you achieve per acre**in the just-ended maize crop season**? ______________ 90 kg bags/acre.

36) How would you describe the ***damage level*** caused by Fall Armyworm on maize in your farm?

[1] Negligible   [2] Low   [3] Moderate   [4] High   [3] Severe

37) About what proportion of maize yield loss would you attribute to Fall Armyworm?

[1] <25%,   [2] 25%,   [3] 50%,   [4] 75%,   [5] 100%

VI. ii.(Willingness to accept maize loss caused by FAW) MULTIPLE BOUND MODEL WITH ITERATIVE BIDDING

38) Do you agree that in the last **one year** FAW has resulted to 11 bags of 90kg maize loss per acre in your farm?

_______________ (1=Yes, 0=No)

If the bid in Q 38 is YES, increase the 11bags of 90kg bags by 1 until you reach the highest bid he/she is willing to accept as the yield loss due to FAW ______________________

If the bid in Q 38 is NO, decrease the 11bags of 90kg bags by 1 until you reach the lowest bid he/she is willing to accept as the yield loss due to FAW ______________________

***VI.iii.* RISKS AFFECTING MAIZE PRODUCTION**

Risk factor	**Did you encounter this risk factor in the last 5 planting years** (1=Yes, 0=No)	**If yes how many times did it occur in the last 5 years**	**Did you put in place any strategies to prevent the risk factor before it happens** (1=Yes, 0=No)	**If YES What risk adaptation strategy did you put in place <u>BEFORE</u> risk occurrence?** 1=change crop varieties 2=early planting 3=crop diversification 4=Savings 5= change planting sites 6= increased seed rate 7=more of off-farm employment 8=None 9=other, specify	**Did you put in place any strategies to manage the risk factor after it happens** (1=Yes, 0=No)	**If YES What risk adaptation strategy did you put in place <u>AFTER</u> risk occurrence?** 1=change crop varieties 2= pesticides use 3=early planting 4=crop diversification 5=replanting 6=Migration 7= Borrowing 8= increased seed rate 9=more of off-farm employment 10=None 11=other, specify	**How many kgs of maize did you lose due to these risk factors per acre?**
Fall Armyworm							
Other crop pests							
Diseases							
Drought							
Hail storms							
Too much rain							
Theft of crops							

Section VII. PERCEPTION ON EFFECTIVENESS OF FALL ARMYWORM CONTROL PRACTICES

39) Did you take any control measure to manage FAW infestation? (1=Yes, 0=No).

40) If ***yes***, which of the following practices did you adopt?

(1=Pesticides, 2=Cultural, 3=Pheromone traps, 4=Push-pull technology, 5=Bio-products, 6=Biological control, 7=Handpicking, 8=Other, specify ________________________________).

41) Of the practices mentioned in Q.40 above, which one was most effective? _____________

42) Please give your opinion on effectiveness of the control practice (**X**) you specified in Q. 41 above, **tick one box across per statement**:

Statement	**1=Strongly Disagree**	**2=Disagree**	**3=Neutral**	**4=Agree**	**5=Strongly Agree**
a) FAW Management					
Do you think **X** reduced FAW infestation in your maize field?					
Do you think **X** contributed to increase the quantity of your maize yield?					
Do you think **X** contributed to increase your maize quality?					
Do you think **X** offers a permanent solution to avoid the recurring of FAW infestation?					
b) Economic Aspect					
Is FAW the major challenge to maize production and **X** can address it?					
Do you consider shortage of maize in the market a challenge in production and **X** can contribute to its reduction?					
Does the price of **X** or cost associated affect your decision to adopt it (**X**)?					
Do you think use of **X** will result to increased farm income from maize production?					
Does the use of **X** reduce the profits you gain from maize farming?					
Is **X**readily available?					
c) Social, environmental Sustainability and compatibility					
Do you think **X** may cause harm to other beneficial organisms in the environment?					
Do you think **X** is a safe practice and will not cause harm to other crops in the farm?					

Do you think use of **X** deforms the maize produce obtained?					
Do you think use of **X** leads to increase in other pests and diseases?					
Do you think the use of **X** goes against any culture or belief of the community?					
d) Product design					
Do you think **X** will offer real-time solution to reduce maize yield losses due to FAW?					
Do you think **X** is a safe practice to use on maize and will not have any harmful effects on human health?					
Do you think **X** works in combination with other practices?					
Do you think **X** may cause harm to other beneficial organisms in the farm environment that are not initially targeted causing more harm than good?					
Do you think **X** requires further technical improvement or innovation to increase its performance?					
e) Ease of use					
Are most farmers near you aware of the use of **X?**					
Are there efforts in place to promote the use of **X** in maize production?					
Have you faced challenges in the use of **X** hence requiring help from extension officers?					
Is the use of **X** time consuming?					
Does use of **X** require additional labor?					
Do you think further innovation or improvement of **X** will greatly increase its ease of use?					
Can **X** be used by both genders?					

Section VIII. SOURCES OF HOUSEHOLD INCOME

Fill the table below on your household source of income in a normal year

Sources of income	**Did someone in your household receive income from that activity? (1=yes, 0=no)**	**Amount received in the last 12 months (Kshs)**
Income from selling maize		
Income from farm crop activities		
Income from livestock activities (including beekeeping, AI e.t.c)		
Income from woodlot activities (farm forest)		
Income from renting out land		
Income from selling pastures and forages (fodder)		
Wages/ salaries/ non-farm, pension and business activities		
Remittances from relatives		
Other (specify) ___________________		

Section IX. MARKET INFORMATION

43) Did you get **market information** before you decided to sell the crop? (1=Yes, 0=No)

44) If ***yes*** what was your **MAIN** source of information?

(1= farmer coop/groups, 2=neighbor farmers, 3=seed traders/ agro vets, 4=research Centre,5=extension service, 6=radio, 7= TV, 8=mobile phone, 9=other, specify)

45) What was the average price of maize in the just ended maize crop season? KShs.____________ per 90 kg bag.

46) What is the distance to the nearest market in kilometers? _____________________________ Kilometers.

END

(Please remember to thank the farmer genuinely)