GENDER ROLES AND ENVIRONMENTAL RISK FACTORS ASSOCIATED WITH FALL ARMYWORM MITIGATION PRACTICES ON MAIZE IN BOMET COUNTY, KENYA

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A Thesis Submitted to the Graduate School in Partial Fulfilment of the Requirements for the Doctor of Philosophy Degree in Environmental Science of Egerton University

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been presented in this university or any other for the award of a degree.

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Recommendation

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

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DEDICATION

The research work is a dedication to all smallholder farmers in Kenya whose efforts go all out to meet their families' basic needs through agriculture.

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ABSTRACT

Advent and meteoric rise from the fall armyworm (FAW) *Spodoptera frugiperda* (J.E Smith) as an invasive pest within Africa possesses grave implications to smallholder agriculturalists with reference to decrease on maize yield loss. The estimated loss ranges between 4.1 million to 17.7 million tons annually, notably equal to US$ 12.8 billion annually. In Kenya, the first FAW invasion detection reported in Bomet County in 2016 prompting the indiscriminate use of synthetic insecticides that could undermine the environmental and food security. Based on gender disparities through food supply network can obstruct the accomplishment of nutrition security with environmental sustainability. Subsequent infestation from FAW within nation, scanty research about gender roles in mitigation of FAW including how their adaptation and coping strategies may affect the environment. Three hundred and eighty four smallholder farmers from Bomet County were purposively enumerated using structured questionnaires, checklists for farmer groups and key informants. The gender roles in mitigation of FAW identified, their impact on the environment evaluated and food production before and after FAW invasion analysed. The analysis of data used descriptive statistics and chi-square. Results showed smallholder farmers' use different mitigation strategies, which are a combination of both coping, and adaptation strategies guided by their different socio-economic factors within different headed households during FAW infestation. The result further showed FAW invasion contributes largely to households' food decline whereas, FAW management practices that were likely to lead to environmental contamination were related to chemical use with either male or female farmers being concerned with control throughout FAW invasion. This outcome of goodness-of-fit test analysis signify that there were a statistically significant correlation amongst decline of crop yields due to FAW invasion and gender, (χ^2 =43.115, DF=3, p =.000). There is need for research and policy makers to create awareness for farmers on better FAW mitigation strategies mainly on the use of chemicals that are more biodegradable and less polluting to the environment. Increasing awareness creation on FAW practices that are less likely to enhance occupational exposures to pesticides and to family members. Farmers' should be encouraged to change their food preferences to alternative food crops insusceptible by fall armyworm.

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LIST OF ABBREVIATIONS AND ACRONYMS

AEZ	Agro-Ecological Zone
ASALs	Arid and Semi- Arid Lands
BCDP	Bomet County Development Plan
BCFCIDP	Bomet County First County Integrated Development Plan
B*t.*	Bacillus *thuringiensis*
CABI	Centre for Agriculture and Bioscience International
CDD	Crop Development Division
COVID19	Corona Virus Disease- 2019
CSE	Centre for Science and Environment
FAO	Food and Agricultural Organization
FAW	fall armyworm
FGD	Focus Group Discussion
FPR	Farmer Participatory Research
FSR	Food Security Resilience
GAD	Gender and Development
GAF	Gender Analysis Framework
GAM	Gender Analysis Matrix
GDP	Gross Domestic Product
GOK	Government of Kenya
HFI	Household Food Insecurity
HHs	Households
HIID	Harvard Institution of International Management
IFPRI	International Food Policy Research Institute
ILO	International Labour Organization
IPM	Integrated Pest Management
IRN	International Research Network
KALRO	Kenya Agricultural and Livestock Research Organization
KCSAP	Kenya Climate Smart Agriculture Program
KIEBC	Kenya Independent and Electoral Boundaries Commission

KNBS	Kenya National Bureau of Statistics
KPHS	Kenya Population and Housing Census
KEPHIS	Kenya Plant Health Inspectorate Services
LHz	Lower Highland zone
MOA	Ministry of Agriculture
PRN	Potato Root Nematode
PPE	Protective Production Equipment
PRA	Participatory Rural Appraisal
RRA	Rural Rapid Appraisal
SDGs	Sustainable Development Goals
SPSS	Statistical Package for Social Sciences
UN	United Nations
UNEP	United Nations Environmental Programmes
UMZ	Upper Midland zone
USAID	United States Agency for International Development
WHO	World Health Organization
WID	Women in Development

CHAPTER ONE

INTRODUCTION

1.1 Background Information

The world has made significant progress in the fight against hunger, under-nutrition and extreme poverty, although a lot remains undone (Akombi *et al.,* 2017; Bonuedi *et al.,* 2020; Gassara & Chen, 2021). Severe adverse pests and diseases on the region's agricultural sector can significantly disrupt food system processes wherever they occur (Deutsch, 2018; Goergen *et al.*, 2016; Kim & Nishimori, 2019; Sultan & Iizumi, 2019). These destructive events were then followed by calls for building more resilient food crop production whereas the food crop production included food production, distribution, and preparation functions (Dhaliwal *et al.*, 2015; FAO *et al.,* 2022; Hilderink *et al.,* 2012). Food crop production have always been vulnerable to hazards like crop pests, which disrupts the smooth functioning of many interconnected components (Kaur & Kaur, 2016; Tilman, 2011).

Advent and meteoric rise from the fall armyworm (FAW) *Spodoptera frugiperda* in Africa in 2016 gravely imperiled the sustenance and finance dependability of lots of smallholder farmers (Day *et al.*, 2017; Prasanna *et al.*, 2018; Tambo *et al.*, 2020). FAW's considerable favorites for maize, a chief sustenance for a multitude of lots of African smallholder households, endangered guarantee of nutriment supply, sustenance and means of support (Day *et al.*, 2017; Goergen *et al.*, 2016; Prasanna *et al.*, 2018; Tambo *et al.*, 2020). Accomplishment of abundant food supply was a sole purpose of the agricultural zone (FAO, 2017; MOA, 2018). Sustenance freedom persists when entire society all through, accept corporal, collective, and productive access to adequate, shielded, and wholesome nutrition that link up their nourishing requirements and sustenance predisposition for maintaining a dynamic and wholesome living (Andersen, 2009; Hendriks *et al.,* 2016; Pinstrup- Nathalie, 2012; Winkler & Satterthwaite, 2017).

According to FAO (2017), Meagher (2015) and Tilman (2011) reports, demography from lately absolved "State of Food Security and Nutrition in the World" report indicated that hunger was widespread and continues to show an increasing trend. Atrophy and overloaded families' burden of undernutrition are expanding virtually entire sub-regions of Africa, as well as in Latin America, although the condition is calm in nearly all Asian countries (De Cock *et al.,* 2013; Hussein, 2002; Karr *et al.*, 2016; Maxwell, 1996; Pinstrup-Andersen & Herforth, 2008). The rallying call in food security is to end discrimination on the marginalized and to assume this stupendous test; we need to deepen our accomplishments to amplify resilience into networks for sustenance and wholesomeness (Gostin & Friedman, 2019; Meagher, 2015). Situated in the conditions of a distended world population is likely to outdo lots of population by 2050, comestible and nourishment freedom will exist as a universal problem for future generations (Boerma *et al.,* 2020; Stone, 2015; Vasan, 2019).

The Rome Declaration on World Food Security and the World Food Summit Plan incubated down foundations for varying orientation to habitual goals that is abundant food supply, at self, family circle, government, territorial and planetary levels (Aliaga & Chaves-Dos-Santos, 2014; Maxwell, 1997). In this regard, world governments have paramount authority to ensure abundant food supply to its nationals since this unswerving effect on the endemic and wealth stability of individual states (Godfray *et al.,* 2010; Kirti & Kumar, 2022; Marrero- Castro & García, 2021).

According to studies by Emongor (2014), Mohajan (2014), Ogello and Munguti (2016), and Kansiime *et al.* (2021), majority of Kenyan populations experience lack of enough food supply and malnourishment, with above two million people requiring food stamps at any given time. The Famine Early Warning Systems Network (2008) in Kenya on sustenance crisis found lots of population in countryside and about four million persons in metropolitan were not having enough food supply, as well as over hundred thousands people from other parts of the country's customarily possible cultivable zones including Rift Valley zone (Oluoko-Odingo, 2011; Sasson, 2012). Facing food shortages especially affected the impoverished and somewhat females' attributable to diminished purchasing power, costly food rates alongside lack of better crop production practices (Anderman *et al.,* 2014; Botreau & Cohen, 2020; Ivers & Cullen, 2011).

Food sustanance is reliant on brief and continuing resilience of the progressively all-inclusive food modes and its adroitness to acknowledge and acclimate to endemic, universal, and collaborating disturbances and setbacks (d'Errico *et al.,* 2018; Jensen & Orfila, 2021; Upton, *et al.,* 2016). Certifying food sustenance even with a burgeoning mortal community, alterating nutritive archetype, minimal innate expendient, ambience, individual instability, and habitat capriciousness is a dominant provocation to most household within developing nations (Ataei *et al.,* 2021; Grote, 2014; Pingali *et al.,* 2005).

Household food positioning resilience in flourishing countries whirls around accumulations or marketing of properties such as animals, kernel stores, endemic precipitation augury tools, blossoming feedback, and acclimation to nutritive criterion (Chodur *et al.,* 2018; Ericksen, 2008; Foley *et al.,* 2011; Godfray *et al.,* 2010). Food systems demands that food formulation, usage and apportionment channels act in part through all factions by discerning the aspects that devote to the capability of the comprehensive food supply chain to acknowledge and accustom to aforesaid disruptions (Heck *et al.,* 2020; Knorr, 2021; Savary *et al.,* 2020). Within any food production chain, the robustness of a food chain production system represents farmers' expertise to combat or endure shocks, while resilience is mirrored in the ability within same practices to imbibe, acknowledge, and accomodate to these disruptions and reduce any negative impacts (Gonzalez, 2011; Meuwissen *et al.,* 2019; Stone & Rahimifard, 2018; Xie *et al.,* 2021).

In 2016, FAW (*S. frugiperda),* a compulsive agricultural pest indigenous to North and South America, was first sighted on the African continent where it proliferated from West Africa across the region, causing great harm to crops and later on escalated across Asia (Kalleshwaraswamy *et al.,* 2018; Malo & Hore, 2020; Ramasamy *et al.,* 2022; Wild, 2017). From its indigenous habitat, literature indicates FAW feeds on over 80 plant species in 27 plant families including maize crops (Goergen *et al.*, 2016). When considering the food production sector like maize, rice, sorghum and sugarcane, it is been calculated that FAW could cause up to thirteen billion US dollars each year in crop losses across sub-Saharan Africa (SSA) (Abrahams *et al.*, 2017; Ahissou *et al.*, 2021; Day *et al.*, 2017; Harrison *et al.*, 2019). Moreover, due to the high consumption of these cereal crops, particularly maize, in smallholder diets, FAW could have a substantial negative impact on food security (Burtet *et al.*, 2017; Khan *et al.*, 2020; Phambala *et al.*, 2020). Latterly, FAW has broadly escalated throughout Sub-Saharan Africa (SSA) and, presently, its incidences is within fortyfour African nations including Asia (Navik *et al.*, 2021; Nyamutukwa *et al.*, 2022; Tambo *et al.*, 2020).

Consequently, instantaneous response of African governments including Kenya was to plough money into toxicant pesticides since the invasion by FAW, furthermore, the take up continues being major artifice used by farmers controlling FAW (Abro *et al.*, 2021; Kumela *et al.*, 2018; Matova *et al.*, 2020). In consonance with FAO (2018), several initiatives are being tried which include, sensitization of farmers, increasing surveillance on FAW spread and early planting and chemical spraying targeted at controlling FAW infestations on maize crops (Baudron *et al.*, 2019; Gebreziher, 2020; Maluleke, 2020).

Historically, according to Babendreier *et al.* (2020), Burtet *et al*. (2017), Rioba and Stevenson (2020) and Sisay *et al.* (2019) control of FAW in maize in the Americas', have adepted applying toxicant pesticides. Notwithstanding, the potency of this management approach has limitions by the caterpillar characteristics of the FAW pest where these caterpillars dig deep inside the maize whorl, composing it impossible to reach the kill with toxicants. According to Hall (1988), Kandel and Poudel (2020), Yainna *et al.* (2021), Yu (1991) and Yu *et al.* (2003) their studies states that FAW is a difficult to control. Smallholder farmers' only solution is to increase the spraying frequency and dosage levels of the pesticides (insecticides) whereas, they practice widespread and indiscriminate use that has contributed to pest resistance (including FAW).

The upsurge of FAW was first sighted in Bomet County, Kenya in the year 2016 (FAO, 2018; MoA, 2018). The pest spread rapidly to all major maize producing areas in the county thereby, affecting food security and trade. According to FAO (2018) if the FAW caterpillar is unmanaged it will cause up to 100 percent maize yield loss. Agricultural production is the major business activity in Bomet County with over eighty percent of the county's population carrying out farming and animal rearing (FAO, 2018). The county has 1,716.6 km^2 of arable land (over 80 percent of the county's total land area). The total county acreage under food and cash crops is 74,755 and 33,222.5 ha respectively. About 62 percent of the households are smallholder farmers, with livestock rearing being a second dominant activity, yet agriculture occupies about 28 percent of the available arable land. With respect to climate, the county has normally heavy rainfall, extending from 1000-1400 mm per annum. The average annual temperature ranges between 16 to 24°C (MOA, 2018).

The most dominant cultivation modes adepted in the county encompass both limited subsistence and animal farming with average to extensive single cultivation modes (MOA, 2018). Smallholder farmers practice agricultural production for sustenance and small number saleable crops. The major crops grown for sustenance are cereals, grains, roots and tubers, kales, and the commercial cash crops include tea, coffee and pyrethrum. These climatic conditions and crops enhance the survival of FAW (Harrison *et al.,* 2019; Maino *et al.,* 2021; Zacarias, 2020).

Even though the County is appreciative with clamorous habituations, 59% of the people are in existent beneath the governmental subsistence levels (KNBS, 2010). Notwithstanding of reasonable precipitaion and loam, food sustenance is a precarious concern in Bomet County with somewhere around 36 percent of families envisaged impoverished (Langat, 2016; Ochieng *et al.*, 2011). Different studies have shown that subsistence farming in the study area appeared presently imperiled with outbreaks of vermin notably Maize Lethal Necrosis Disease (MLND) vectored by insects such as fall armyworm (FAW), potato root nematode (PRN), bacterial wilt and potato blight (Brault *et al*., 2010; Cabanas *et al.,* 2013; Mahuku *et al.,* 2015; Wangai *et al.,* 2012). Hereunder, difficulties correlate primarily to improper cultivation, use of recycled seeds, low application of fertilizers, and lack of planting materials, diseases and lack of information (Emana *et al.*, 2015; Fischer & Hajdu, 2015; Langyintuo *et al.*, 2008; Wekesa *et al.,* 2003).

Inequalities between men and women amidst susbsistence supply sequence can disrupt the realization of nutritive sustenance and environmental sustainability requiring effective gender responsive policies (Adeyemi, 2010; Berry *et al.,* 2015). Studies by Agarwal (2003), Mengistu *et al.* (2019) and Skinner (2011) argued analysyts' inabilities close to comprehending smallholder producers in any exploration imitation, had administered to default or minor concentration on gendered families inquiry and its assumptions in food systems leading to negative implications on adaptations and mitigation on pest management. The studies further stated that men and women farmers' participation are dynamic in the postulation of any alleviation innovation with a suggestion that for good measure gender-based information on smallholder farmers' social with economic differential roles during chemical handling on food crop production should be researched (Kwenye & Sichone, 2016). The research gap addressed during this study.

The invasion of FAW within the country's farmlands made our smallholder farmers vulnerable to the excessive exposure of pesticide use (Kumela *et al.,* 2018; Wyckhuys & O'Neil, 2007). According to Carvalho (2006), Jallow *et al.* (2017), Kaur *et al.* (2019) and Wilson *et al.* (2001) their studies found out there was an abundance of new pesticide users in agricultural production. The invasion of FAW demands an overuse of insecticides thereby leading to negative consequences to the environment (e.g. soil, water, air and food contamination) and farmers' wholesomeness (Kaur *et al.,* 2019; Kumela *et al.,* 2018). This required attention and preparedness on the overuse of chemicals for FAW management practices while producing food crops. The findings exploration done during the study within the confines of five sub-counties of the County. Furthermore, uniqueness to Bomet County's all year round in crop production greatly influenced the thriving of FAW where the researcher anticipated providing contrasting information on gender roles from different headed households towards food security and environmental resilience.

1.2 Statement of the Problem

Bomet County is an agricultural county in Kenya with bi-modal rainy seasons prompting the county to have all year round crop production within smallholder framers' farmlands thereby, greatly favoring and influencing the survival of fall armyworm. Studies and documentation on the origin of FAW, spread, potential threats, crops affected are already documented (Kumela *et al.*, 2018). The FAW influences on food production (maize) within different headed female and male households is not visible. Due to societal gender roles, there is limited or no literature on how female and male farmers are coping with the pest infestation and the adaptation strategies adopted. These are bound to influence the environment, so there is need to ascertain the environmental risks associated with these practices. This information gap formed the basis of this study in Bomet County, Kenya.

1.3 Objectives of the Study

1.3.1 Broad Objective

To generate data to be used to improve strategies used towards mitigating FAW invasion in Bomet County and enhance environmental resilience.

1.3.2 Specific Objectives

The specific study objectives were:

i. To assess the coping and adaptation strategies that affects maize production during fall armyworm invasion in Bomet County.

ii. To assess gender roles in the management of the fall armyworm invasion in Bomet County.

iii. To assess FAW management practices that are likely to lead to environmental contamination in Bomet County.

iv. To assess if there are differences in maize production between female and male headed households due to fall armyworm invasion in Bomet County.

1.4 Research Questions

The study therefore used the following research questions based on the above objectives for data collection:

i. What FAW management practices are likely to lead to environmental contamination in Bomet County?
ii. What are the different gender roles in the management of the fall armyworm invasion in Bomet County?
iii. Which were the coping and adaptation strategies that affected maize production due to fall armyworm invasion in Bomet County?
iv. What differences exists within female and male-headed households during maize production due to fall armyworm invasion in Bomet County?

1.5 Justification of the Study

The emenation and brisk circulation of the fall armyworm (FAW) *Spodoptera frugiperda* in Sub-Saharan Countries possesses severe consequences on subsistence production (FAO, 2018). Smallholder farmers' food production in terms of reduction of maize yield loss has an estimated loss extending from 4.1 to 17.7 million tons per annum corresponding to dollars 12.8 billion annually (Ramasamy *et al.,* 2022). This threatens the livelihood of different smallholder farmers (Malo & Hore, 2020; Ramasamy *et al.,* 2022). Chemicals use have been the only main strategy of smallholder farmers to control FAW to date with the overuse being facilitated by the readily availability of the chemical within the local chemicals shops (Kumela *et al*., 2018; MOA, 2018). In Kenya, the first FAW invasion detection was in Bomet County in 2016 (FAO, 2017). There was indiscriminate use of pesticide insecticides as the main controlling strategy with a likelihood of undermining the environmental and food production resilience. With this backdrop of information, achieveing effective FAW management requires appropriate choices on social, economic and environmental factors, particularly when controlling FAW during zea-mays cultivation (Goergen *et al.,* 2016; Kebede 2018; Wyckhuys *et al.,* 2010). Consequently, different headed smallholder households' there is disproportion inffluence by adverse crop pest conditions (Djurfeldt *et al.,* 2013; FAO, 2017). With the invasion of FAW and its continuity of invasion on smallholder farmers' on crop fields, there is a likelihood of unsustainable environment and a widening food insecurity within different headed households. The data obtained in this study can be helpful in strengethening strategies on the SDGs goal on cessationing starvation, actualizing food supply and ameliorating health no later than 2030. Food security is also an important pillar in the vision 2030 and the national strategies can benefit from this data. The generated data can be a reference source to enhancing government strategies on subsistence production soundness together with environmental resilience.

1.6 Scope of the Study

The study implementation was in Bomet County within the bounds of five sub-counties namely Chepalungu, Sotik, Konoin, Bomet East, and Bomet Central. This involved the selection of smallholder farmer from different households and farmer groups for focus group discussions (FGD) to whom associated with food systems supply. The collection of information was from different households' heads, where solicitation of gender roles differentials and understanding FAW administration actions, enduring and modification schemes used with effects pertaining to pesticide exposure during FAW management. This led to the conceptualization of gender roles in mitigating fall armyworm through integrated pest management towards environmental sustainability and promoting food resilience.

1.7 Limitations of the Study

This investigation had limitations consequential to:

i. Due to corona Virus Disease infections (COVID 19), data collection took longer than anticipated due to government lockdown whereas interaction during Focus Group Discussions was limited.
ii. During data collection, some respondents did not recall fully the information well thus required central spokesperson (field agricultural advisor) belonging to the agricultural department, livestock and fisheries (MOALF) during actual survey to assist with brainstorming and moderating on FAW invasion issues.
iii. That the change in maize production in the sampled families is due to FAW invasion.

1.8 Assumptions of the Study

The abstraction predicated its assumptions as the consequences that:

i. Respondents recollected the fall armyworm management practices;
ii. The meeting of the study objectives regarding FAW management towards resilience in food crop production and environmental sustainability.
iii. The change in maize yields is due to FAW invasion and not other factors such as climate change

1.9 Definition and Operationalization of Terms

Access to Resources- In this survey, resources are land, income and labour whereas, the household head decides who has to access and use the available resources during FAW management towards environmental and food production resilience.

Adaptation - Adaptation in crop production by smallholder farmers in this study, were shifting of priority crop production, mixing hybrid maize seeds alongside local maize seed varieties and feeding livestock with infected plants during FAW invasion.

Amount of pesticides –In this study, the instructions on the amount of pesticide to apply during FAW management by the smallholder farmer.

Constitution – In this study, the constitution is what guides the smallholder maize farmers during resource (income, land and crop products) accessibility during FAW management.

Coping Strategy–In this study, smallholder farmers' used coping strategies included chmical use, spiritual intervention, consulting with traditional seers and manual killing in controlling FAW invasion as a mitigation strategies.

Crop production - In this study, smallholder maize farmers had to recall the yield obtained 'before' and 'after' FAW invasion in understanding if FAW invasion affects food yields within different headed households.

Culture – Culture is the cultural dimensions that reflect differences in gender roles, but also elements related to the ethics of sexual difference. The presentation of these issues from the gender perspective is the subject of this study. The study will refer to importance of communication in transmission of roles of both male and female's cultural dimensions that will reflect role differences in various farming activities.

Directions for chemical use (pesticides) – In this study, instructions for use of chemicals cogitate communications that channels genuine utilization appertaining pesticide as aftermath.

Educational Levels – In this study, education levels classifications had three categories namely: No Schooling: Primary: Secondary and Tertiary education levels.

Environment – In this study, the environment used to envisage the influence of FAW invasion and its management strategies that smallholder farmers used during food production and environmental risks.

Environmental Resilience and Risks– In this study, the environmental resilience and risks is the ability of a natural system to counter disruption withstanding damage and recuperation swiftly as well as the factors that withstands the disturbance such as invasive insects (FAW).

Extension Services in Agriculture - In this study it is the delivery of information inputs, dissemination of practical information, including on improved seeds, fertilizer application, tools, water management, crop protection, agricultural practices and application of this knowledge on the farm by farmers. The extension officers connects farmers to invaluable demands, encouraging environmental outcomes and subsisting public health challenges like poor use of pesticides.

Fall Armyworm (*Spodoptera frugiperda* J.E., Smith 1797) – FAW is an invasive agricultural pest that is native to equatorial and extremely cold regions of the Americas (FAO, 2018). In this study, FAW was a new maize pest in smallholder farmers' crops fields.

Farmers Age –In this study, FAW management being an invasive pest required technological knowledge on better management. The age of the farmer relates to the farmer being able to grasp the intricate technological requirements of management FAW invasion during crop production.

Farming Experience –In this study, the farmer's farming experience was in reference to how well the farmer was able to differentiate FAW from other crop pests.

Farming systems- In this study, the farming system encompassed the dominant pattern of farm activities within different headed households and the main technologies used during the control of FAW invasion.

Food Systems- In this study, food systems comprised the activities involved in food productionand its determinants and outcomes of food yields.

Food Security – As used in this study, food security is having enough maize production after FAW invasion for households' consumption.

Food Security Resilience (FSR) – In this study, FSR understands the differential headed households' food production for its household's members after FAW invasion.

Food Insecurity – In this study, food insecurity used when different headed households do not have enough food for their daily food requirement due to FAW invasion.

Food Availability – In this study, food availability referred to maize production availability for households' consumption after FAW invasion.

Food Accessibility- In this study, food availability food used when different headed households have enough maize yields after FAW invasion for its household's members.

Food Utilization – In this study, food utilization used when the maize yields gotten after FAW invasion was enough for each household members and there was extra for income generation.

Food Stability - Relating to this study, food stability was the state where the household was not at risk of losing access to food because of the invasion of FAW.

Food Safety – In this study food safety referred to handling of chemical during FAW management in reducing the risk of individuals becoming sick from pesticide exposure.

Frequency – In this study, frequency referred to the application frequency of pesticide insecticides by smallholder farmers during FAW management in Bomet County.

Gender – In this study, gender is an understanding of the gender-based roles and responsibilities during agricultural production.

Gender Analysis Tool (GAM) – In this study, GAM was used to undertand the different gender roles during FAW activities within different headed households.

Gender and Environment – the survey used men and women smallholder farmers' roles used different mitigation strategies in controlling FAW invasion bringing the different environmental risks.

Gender Equality –In this study, gender equality used when both women and men smallholder labourers shared activities during controlling FAW invasion towards families's food supply and ecosystems continuality.

Gender Mainstreaming – This study's gender mainstreaming used in ensuring that female and male smallholder farmers' concerns and experiences during the management of FAW invasion were equally benefitial and inequality not perpetuated.

Gender Perspective –In this study, gender perspective looks at smallholder farmers' different roles and their involvement, behaviour and activities during handling of FAW invasion.

Gender Roles – This survey, gender roles ensured different female and male smallholder farmers' responsibilities and tasks assigned during mitigation of FAW invasion.

Hazards – In this study, hazards referred to risks involved during the physical and chemical use towards the control of FAW invasion.

Human Health- In this study, pesticide use with additional environmental interference might potentially have unswerving effects on human wholesome by way of bringin about disorders, indisposition, or expiration. When an environment becomes contaminated, deranged or discomposed, men and women smallholder farmers' helping hand possibly reduce, giving rise to unfavourable consequences.

Household- In this study, members of the household related by FAW management strategies, environmental impacts and the roles played by each family member during the management of FAW. The study assumed that the economic role of family members within households were often different during FAW management and that each household member had definitive role to play.

Household Hunger Scale – In this study, Household Hunger Scale (HHS) was determined on the differences of maize yields gotten after and before FAW invasion within different headed households.

Information sources – In this study, the information sources was solely related to FAW as a pest and its management which included radio, television, printed materials and interpersonal sources such as extension officers.

Integrated Pest Management (IPM) - In this study, notion of integrated pest management on crops included the mitigation strategies used by smallholder farmers during FAW invasion.

Integrated Strategies - In this study integrated strategies were strategies used by smallholder farmers which were either coping or adaptation strategies.

Labour- In this study, the researcher segregated the different FAW management roles by understanding how the male and female farmers' labour allocated during FAW management.

Land Ownership - In this study, land ownership is the piece of land that the maize farmers owns legally or leased in and has full right to use without granting access to usage.

Literacy of household head – In this study, literacy of the household head referred to the farmer's ability to read and understand the implications pertaining to the FAW management.

Mitigating of FAW invasion- In this study, the mitigation strategies of FAW invasion entails both coping and adaptation strategies which have been described above.

Perspective- In this study perspective used together with gender (male or female) in focusing and understanding the differential status within smallholder farmers' different headed households during FAW invasion management.

Pesticides – In this study, pesticides were chemicals that used to kill or control FAW invasion in smallholder farmers' crop fields and which were classified chemical structure, physical state and application methods.

Pesticide Application- In this study, pesticide application referred to how the assiduity modes of toxicants during the restrain of FAW invasion by smallholder farmers in Bomet County.

Pesticide Packaging and Containers –In this study, smallholder farmers were required to dispose the chemical containers properly after the pesticide used in minimizing latent peril of exposure by the applicator within surrounding ecosystem.

Pesticide usage instructions– In this study, the pesticide instructions are the usage guidelines that shows the amount and how the smallholder farmers is supposed to use and apply the chemical. The instruction can have either pictorial or wording instructions for the smallholder farmers to follow.

Policy – In this study, policies governing the use of chemical pesticide handling used in relation to FAW management towards better human health.

Precaution –In this study, the precaution was the PPEs measures that smallholder farmers used to protect themselves from harm during FAW management.

Research Questions – In this study, the researcher used the inquisition cross-examination to define the range within research project and derive guidance during information acquiring and scrutiny of information whereby, researcher used descriptive studies and open-ended questions in nature.

Resilience – The this study the researcher looked on the FAW management strategies that were used bybsmallholder farmers and were sustainable to the environment and how efficient and fast these farmers bounced back to balancing their households' food security after the invasion of FAW.

Roles- In this study, roles used as the way farmers participated and the part each person (between male and female farmers) played during FAW invasion management.

Socio-economic of farmers' characteristics - In this study, a socioeconomic of farmers' characteristics defined as the economic, social (or family) and management unit of the individual households' during agricultural production.

Smallholder farmers - Smallholders are small-scale farmers, whose land ownership is less than one hectare to 5 hectares. Smallholder farmers' conditioned by family with focused motives such as favouring the stability of the farm household system, using mainly family labour for cultivation alongsise utilizing portions of yield for nuclear family sustenance.

Smallholder farmers' income change- In this study, the researcher indicated that smallholder farmers are diverse both in terms of their level of commercialization, their farms' characteristics and the conditions under which they grow food crops.

Socio-economic demographics –In this study, the researcher used age in referrence to the households' respondents' age at the time of the study.

Storage and disposal of used containers – In this study, storage and disposal of used containers referred to the statements that explained where and how to properly keep and throw the pesticide containers after use.

Sustainability - In this study, the researcher borrowed Newton (2003) definition who described sustainability as a way of understanding the smallholder farmers' community, income generation system, and their daily roles (activities) in reaching a sustainable threshold of the environment in a profitable and indefinite state with no degradation. This study used sustainability as both ad hoc and lasting repercussions appertaining to pesticide handling during FAW management leading to healthy smallholder farmers.

Target pests – In this study, target pests refer FAW as pests controlled by pesticide insecticides.

Timing – In tis study, timing referred to the period or time during pesticide application to manage FAW by smallholder farmers in Bomet County.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin and Spread of the Fall Armyworm to Africa

The fall armyworm (FAW), which has the scientific name of *Spodoptera frugiperda* (J.E. Smith 1797) (Lepidoptera: Noctuidae), is a paramount pest of staple crops as cited by Hruska and Gould (1997). Studies by Demissie (2017) and Early *et al*. (2018) pointed out that FAW remains an insect indigenous to equatorial and semi-equatorial countries of North and South Americas. It embodied with wide host range with over 80 plantae phylogenetic among 27 boraginaceae including major inclination towards zea mays main basic food around the world (Goergen *et al.*, 2016). As reported by FAO (2018) FAW also attacks non-graminaceous crops such as potato, soybean, groundnut, and cotton with different type of weeds known to serve as hosts. This polyphagous feeding behaviour and ability to survive on diverse alternate host plants make FAW a challenging pest to manage (Prasanna, 2017). In addition, the polyphagous characteristic is a challenge to the pest management strategies in intercropping systems practiced by agriculturalists within Africa including Kenya (Demissie, 2018; Pitre *et al.*, 1983; Wiseman & Davis, 1979).

A study by Hall (1988) found out that lepidopterian is a financial significant and viable migratory and polyphagous plague within the Americas, where it remains adept of bringing about considerable yield damages within crops with larvae (caterpillars) being the most destructive and injurious stage because it feed on plant leaves. Farm Radio International (2017) reported that FAW causes significant yield losses if not well controlled. The first report of FAW in the region broadcasted amidst January 2016 in Nigeria consequently spread to other West, Central, South and East African countries causing widespread damage in maize (Tindo *et al*., 2017). Studies by Abrahams *et al*. (2017) and Stokstad (2017) confirmed FAW dispersed into over fortyfour countries inside sub-Saharan countries by end of 2017, causing serious damage to staple food crops especially maize noticeable in Figure 2.1 (FAO, 2018).

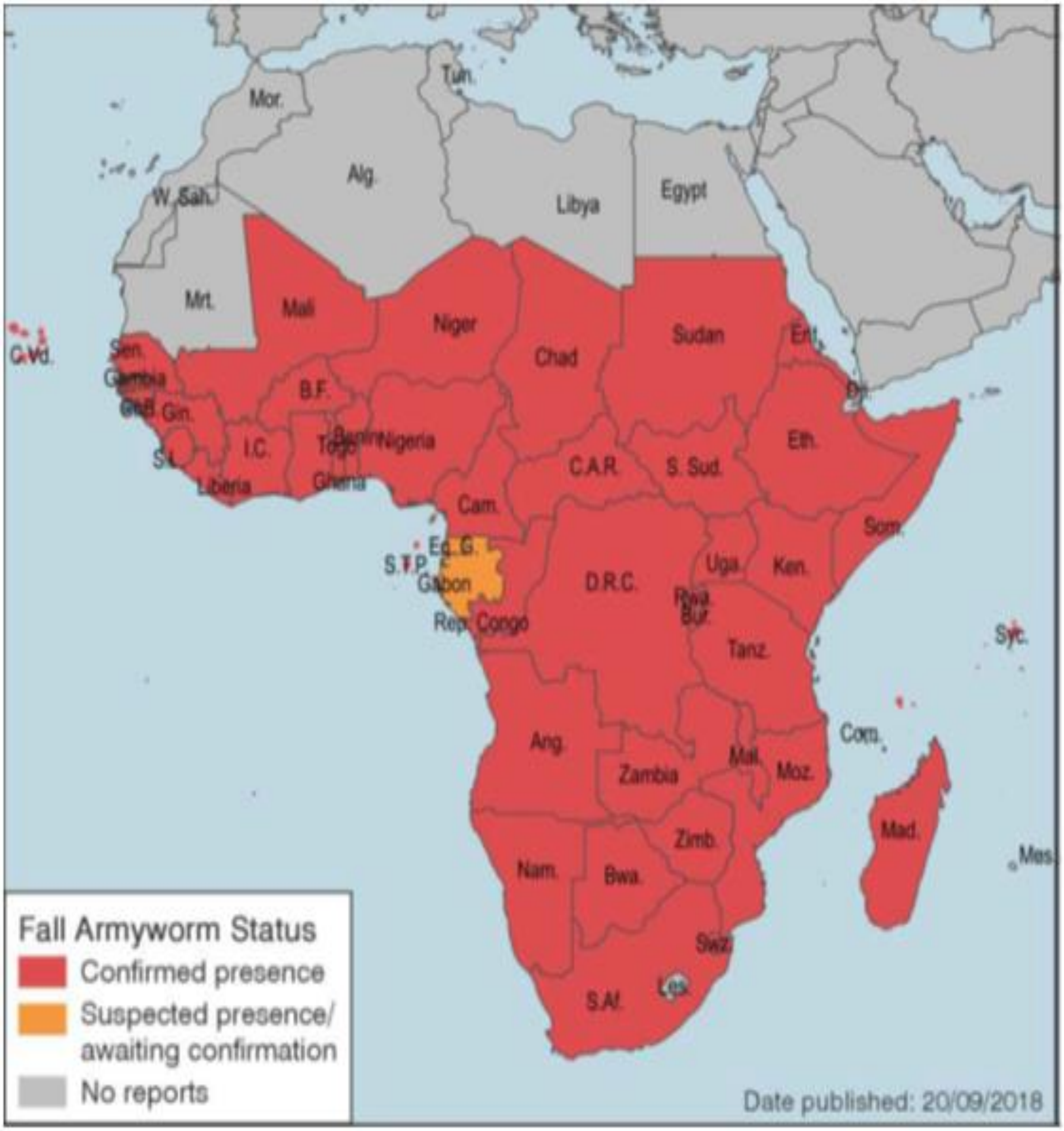


Figure 2. 1: Map of African Countries affected by Fall Armyworm (FAO, 2018)

FAO (2018) confirmed that FAW is currently within countries of sub-Saharan Africa and has caused a lot of damages and yield losses to staple foods affecting food security and trade in Figure 2. 1 (FAO, 2018). The damage to maize estimation is to be between US Dollars 2.5 to 6.2 billion per year (Stokstad, 2017). According to Kopke (2018), agricultural products from countries with confirmed FAW outbreaks have chnaces of facing import bans as the pest (FAW) classified as a quarantine pest resulting in degenerative domestic revenues. As Abrahams *et al*. (2017) confirms that in the recent studies, the maize yield loss estimates in Africa might be between 20 to 50 percent, with a likelihood of triggering some severe impact on smallholder livelihoods since most farmers cannot afford already recommended FAW costly management options of chemicals.

2.2 Current Status and Distribution of Fall Armyworm in Kenya

In Kenya, FAW rudimentary reported in Western Kenya region Trans Nzoia, Bungoma and Busia counties) in February and March 2017 (FAO, 2018). Eventually, at year-end, FAW escalated to 44 counties, covering all the major maize producing regions of Kenya, causing significant damage by reducing yields by about 80 percent (FAO, 2018). According to FAO (2018), an estimation of about 7 million bags of maize may have been lost due to FAW damage.

Ascending dangers from the FAW has acute reverberations to smallholder farmers concerning decline of earnings as consequences of food harvest setback or even entire crop dereliction (Jeger, 2018; Niu, 2009; Togola, 2018; WHO, 2014). Food security and livelihoods threatened by FAW in the country, as maize is the major paramount food crop for many smallholder farmers (Amusan *et al.,* 2018; Devi, 2018; FAO, 2022; Padhee *et al.,* 2019). Pestilence possesses enormous potential to promote circulation to other crops like sorghum, wheat including rice, thereby, alarming the sustenance of farmers and economic damage. According to Shiferaw *et al.* (2011) and Skoufias (2003), the mitigation of crop losses through effective management interventions could aid in meeting food, nutrition and income security especially the needs of people in Kenya and its recent appearance in Kenya leaves knowledge gaps.

2.3 Environmental Suitability for FAW in Africa

Capricious adding strikingly to environmental appropriateness are the average temperatures of the brisk month of the year, and the extreme of the precipitating seasons

(Goergen *et al*., 2016). Arboraceous canopy is also important with appropriateness basis of fifty percent expectation that almost all African regions is suitable for FAW all year round (FAO, 2018). Findings from Ghana and Zambia envisaged that FAW does not imply conscripted with unspecified distinct disposition nature at this contigency, but eventuate chiefly with the parts where primarily maize is cultivated (Goergen *et al*., 2016).

Comprehending the native affluence and collision of FAW involved sampling in addition to FAW numbers, but geomorphology appearances, optional hosts, as well as regulator modes used. It would also be important to study the endemic dispersion of FAW, as there could be same species of local population partially isolated or indigenous intensity influencing native supply at geomorphology extent, including the numbers considered natives or transient (Day *et al*., 2017; Prasanna *et al*., 2017; 2018). Similar survey undertaken in regions whither with greater aberrations in appropriateness like Kenya suitable for FAW (FAO, 2018).

2.4 Food Crops (Maize) Damage and Economic Yield Losses

Maize (*Zea mays L.*) primarily dominant principal sustenance nutrition in Africa, abundantly cultivated by smallholder farmers (Abrahams *et al.*, 2017; FAO, 2017; Midega *et al.*, 2018). The farming of this crop and for that reason the sustenance of the cultivators vulnerable by the encroachment and boundless affliction FAW infestation, leading to substantial maize yield losses (Abrahams *et al.*, 2017; Andrews, 2016; Casmuz, 2017; Clark *et al*., 2007; Goergen, *et al.*, 1988; Knipling, 1980; Pashley 1987; Pogue 2002). According to Midega *et al.* (2018), cultivation of food crops accordingly, the nutritive sustenance of the farmers in Africa periled by the affliction and boundless influx of FAW (*S. frugiperda*) initiated to significant maize harvest decrease.

Studies by FAO (2018) and Midega *et al.* (2018) noted that maize was exceedingly salient food crop in Africa entirely cultivated by smallholder farmers. Goergen *et al.* (2016) further reported that plants were susceptible to FAW onslaught throughout the growth period of the plant’s growing stages, and grave destruction occurred during destruction of whorl lessening actimycosis region thereby jeopardizing the granule harvest. Fall armyworm attacked the advanced part of the ear, dismantling the granule or abetting disease by germs (FAO, 2018).

Africa in accordance with Goergen *et al.* (2016) stated that FAW was creating enormous decemation to maize crop hitherto big caterpillars imitate cutworms by absolutely fragmenting the stalk base of young maize plants. The result concur with Midega *et al.* (2018) who found out that damages on maize anthers depended on progression phase. The scale of injury, nonetheless, be conditional on elements for instance sowing time, soil, cultivated variety and convention application innate on everyside of the farm. FAW was very destructive as the larvae can proliferate mainly due to wind dispersal and on host plants from eggs laid by flying moths (Goergen *et al.,* 2016; Rwomushana *et al*., 2018). It caused crop flactuations of about 73 percent and it becomes difficult to control with insecticides once it is at an advanced larval development stage. Owing to favourable ecological circumstances, FAW (*Spodoptera frugiperda*) is likely to increase rapidly and worms give every indication of being destructive to maize in West and Central Africa than most other African *Spodoptera* genus (CABI, 2018; FAO, 2018; Goergen *et al.,* 2016). Investigations by Rwomushana *et al.* (2018) divulged that catching pest invasion prior to causing financial destruction was solution to its control. On condition that invasion detections were behind time, consequences of injury might be beyond recall (Rwomushana *et al.,* 2018).

Current approximation by CABI (2018) within twelve countries harvesting maize proved FAW brought about maize yield wastage ranging from 4.1 to 17.7 million tons annually, commensuarate to an approximated wastage between $1088 million to $4661 million annually in the absence of constraint. In dearth of apt management procedures, FAW had the prospective to root food harvestes wastage of eight thousand three hundred kilograms to twenty thousand six hundred kilograms per annum, within twelve African countries predorminant with maize cultivation (FAO, 2022). Findings was compounded by both Day *et al*. (2017) and Prasanna *et al*. (2018) who reported the representation crop loss range of maize cultivated yearly amounted to over twenty one to fifty three percent in these countries for three-year period. The merit of these reductions approximated at betwixt two billion four hundred seventy eight million to six billion one hundred nine million dollars. In addition, considerable seed businesses in Non-Mediterranean Africa have devulged noteworthy destruction to their maize seed production acreage finished previous year, conceivably influencing both accessibility of seed to cultivators over the forthcoming planting time and the remunerative feasibility of Africa’s turning up exclusive grain industry.

Other recent studies by Baudron *et al*. (2019) have informed of harvest wastage of approximately twelve percent because of FAW injury in smallholder maize farms in Zimbabwe, proportionately depreciated than discerned wastage communicated by smallholder farmers in various countries for instance Ghana and Zambia. Superitendence reaction by governments of

African countries promptly the appearance of FAW invasion was the championing of massive spraying programme of toxicants (Abrahams *et al*., 2017; Prasanna *et al*., 2018). However, according to FAO (2018), nearly no smallholder farmers in Africa be in a position to meet the expense of replicated sprays of toxicants, whereas, *Bt.* maize is unobtainable in Africa.

A study conducted by CABI (2018) on family circle's communal finances investigation within Ghana together with Zambia, where the investigation inquiry scrutized farmers' understanding of wastes specifically caused by FAW realized. Comprehensive planting period found an approximated country's average reduction of maize fortyfive percent within Ghana span from twentytwo to sixtyseven percent, and forty percent in Zambia range from twentyfive to fifty percent (CABI, 2018). The findings further showed a likelihood of possible national yield decline by FAW together with income with additional ten crucial maize growing regions including Kenya (CABI, 2018; FAO, 2018). This was possible to be an occurrence in the cereal-growing period, supposedly FAW escalating across every zone with prediction of survival (Rwomushana *et al*., 2018).

The sceptical argument by Abrahams *et al.* (2017), Rwomushana *et al*. (2018) and Yu (1992) argued that immoderate utilization of toxicants eliminated possible innate rival, adversely influencing people and animal sustenance led to withstanding growth in purpose pestilence and increased cereal cultivation inputs. Generally, the immoderate consumption of toxicants with related dangers elevated food sanitation and acceptable apprehension. Rwomushana *et al*. (2018) further argued that FAW being a recent alien within African region, findings on parasitoids related with FAW not well chronicled. This highlighted the necessity for growth of comprehensive protection in form of IPM techniques appropriate for African smallholder farmers' as a requirement.

2.5 Strategies in Mitigation of Fall Armyworm

Relatively immeasurable research reports on FAW handling in North and Latin America, where the FAW pest is endemic are available (Day *et al.*, 2017). Although maize is a major plant grown in the humid and sub-trpoical countries of the Americas, whereas, ordinarily uncultivated using current or comprehensive protection (IPM) plans focusing at reducing financial inputs and decreasing risks hitherto ecosystems' well-being. The common FAW handling strategy within the Americas incessantly firstly depends on pesticide utilization exploiting conservative non-natural poisons. Nevertheless, cultivation modes, artificialization agriculture and family-resource status (such as land ownership, harvests, and access to capacity training) within African countries are dissimilar compared to Americas, thereby, the particular handling choices may not automatically be pertinent for African circumstances (Kansanga *et al.*, 2018; Pender *et al.*, 2004; Thornberry, 2013). Stationing FAW handling choices called for acumen of present-day pest containment techniques and procedures were constrained by farm handling together with sustenance elements (Altieri & Trujillo, 1987; Kebede, 2018; Wyckhuys & O'Neil, 2010).

African smallholder farmers are aforetime satisfied by different types of crop pests, inclusive of assorted indigenous noctuid moth caterpillars (Kfir *et al*., 2002; Rose *et al*., 2000). Before appearance of FAW, approximated insect pests, injuring plants at different growth ahead of harvest together with after-harvest, stemming dimished harvests just about thirty percent covering Africa, in spite of the fact that specific pest occurences debar aftereffect in absolute food decimation (Grzywacz *et al*., 2014). FAW containment techniques needed desegregation within an expansive vermin eradication outlook, through a focal point along intercedes which generated vermin eradication interests covering considerable amount of pests that were advantageous to a dissimilarity of food plants and cultivation modes (Abate *et al*., 2000; Wyckhuys & O'Neil, 2007).

Current knowledge about smallholder farmers' strategies on pest management also informed blue print interposes better approbation (Abate *et al*., 2000; Altieri & Trujillo, 1987; Wyckhuys & O'Neil, 2007). Some of the mitigation strategies used in the Americas included agronomic and cultural practices, biological control, host plant resistance FAW monitoring using pheromones traps, application of pesticides and bio-pesticides (Abrahams *et al.*, 2017).

2.5.1 Agronomic and Cultural Practices

Agronomic with convention applications is a salient module of FAW vermin eradication approach (Hailu *et al.*, 2018). A study by FAO (2018) recommends early planting of maize crops allows the crop to escape FAW attack. Farmers should avoid late and staggered plantings of food cropping systems in reduction of food base and FAW spread. According to Hailu *et al.* (2018), intercropping maize with food legume crops such as bean, soybean and groundnuts in reduces FAW damage levels by 30, 21 and 31 percent respectively. A study done in Cuba by Andrews (1988), alley cropping during maize accompanied by sunflower stemmed in nether invasion by FAW with elevated harvest collating against corn mono-crop. The push-pull method where intercropping maize with repellent plants reported materialized effectual antagonistic towards FAW within Kenya (Midega *et al.,* 2018). The impel-tug method involved intercropping with the repellent plant *Desmodium inortum*, while using Bracharia to create an attractive wall around maize (Midega *et al.,* 2018).

Utilizing minimum tillage methods minimized FAW gyrus destruction by approximately thirty going to sixty percent compared to the conventional planting according to an investigation done within Dominican state by Del Rosario *et al*. (1981) and Kudsk (2017). In Nicaragua, van Huis (2009) reported FAW influx pertaining to maize occurred twenty up to thirty percent nether once intercropped alongside legumes contrasted to cultivating maize separately. Polyculture methods are inclinedly aid additional FAW natural enemies, thus reducing the multiplication and spread of the combination of plants, using hands and killing of caterpillars, administration of wood ashes and sods onto the plant whorls (Tsedeke *et al*., 2000). A study done between Ethiopia and Kenya showed that fourteen and thirtynine percent of the farmers practiced traditional techniques (such as picking by hand) in favour of FAW control (Teshome *et al*., 2018). Ploughing fields exposes FAW pupae in the soil, to natural mortality factors such as sun baking death, birds and ants who feed on the pupae (Tsedeke *et al*., 2000).

2.5.2 Biological Control for FAW management

Natural control is a strong instrument additionally amongst paramount choices for control measures providing environmentally shielded and imprishable plant defence (Reddy & Capinera, 2017). The favourable outcome of natural control anticipates on deriving alterations and inception of petitioned natural control means within farming biome. Biological control especially bacteria germs and using living natural enemies successfully controlled pests in farming of crops (Molina-Ochoa *et al.,* 2000). The strategy is invulnerable for non-tangible organisms whereas considering ecosystems, with input expenses on production notably lessened due to its quantity production (Mahmoud, 2016). In biological control, achieving FAW suppression, there is encouragement of natural enemies (predators) in the maize crop (MoA, 2018). Introducing or encouraging natural enemies, the population of FAW pest declines making the strategy viable (Molina-Ochoa *et al.,* 2000).

FAW posseses many hereditary adversaries, hunters, parasitism and bacterium which attack FAW in different life stages of its lifecycle (CABI, 2018; Luginbill, 1928; Vickery, 1929). These biological control strategies reduces the pest infestation becoming less effective on crop injury (Ruiz-Najera *et al.,* 2007; Sisay *et al.* 2018). Among the predators noted as important on

FAW are various ground beetles, birds and cuniculus paca who feed on instars (caterpillars) and chrysalis of FAW. According to a study done in Georgia by Pair and Gross (1984), predation may be quite important as it demonstrated that sixty upto ninety percent reduction FAW chrysalis are destroyed because of predatory. FAW has enemies including pathogens attacks, nucleopolyhedrovirus (NPV) and Bacillus thuringiensis that causes heavy mortality in FAW natural populations during applications of flowable or damp granules using variations of soil dwelling bacterium in corn at spiral phase of plants (All *et al.,* 1996; Gardner & Fuxa, 1980).

Similarly, most of sustenance cultivators in Africa terminate practising toxicants onto corn reducing FAW infestation though, farmers exercise indirect techniques detering lest killing vermins, including companion planting, physical choosing alongside smothering instars, administrating powdery burnt wood remains and mould to plant whorls (Tadesse *et al*., 2000). Exploration administered in Ethiopia and Kenya exhibited that between fourteen to thirtynine percent cultivators practiced indirect techniques (such as handpicking) concerning FAW managements (Kumela *et al*., 2018).

2.5.3 Host Plant Resistance for FAW Management

Shelter herbage timorousness is an essential, ideal and sustainable option for FAW management. Shelter herbages impendance investigations done in case of FAW in cereals complicated assaying, growing and discharging of germ plasm (Davis, 1980) nevertheless refrained issueing entire preventive. van Huis (2009) disclosed within Nicaragua various crossbreed cereal plants types remained immune regarding FAW in comparison with native heterogeneities. Wiseman *et al*. (1996) identified two cereal classes that possessed each of two metabolic association impact on FAW instars. Some rice cultivars reported by Pantoja *et al*. (1986), showed resistance to FAW. According to Rwomushana *et al*. (2018), some promising CIMMYT maize inborn with a bacterium identified and validated in Kenya using diverse sources showed resistance of FAW damage during maize production. The introduction of cry protein, known to occur in the soil worldwide, is capable of producing crystal proteins, and is resistant to FAW infestation (Hellmich & Hellmich, 2012).

In Kenya, there are attempts to develop FAW resistant maize crossbreed alongside genome from bacterium found in the soil suchlike cyphering toxicant polypeptide (Mugo, 2001). Williams *et al.* (2002) reported that corn crosses alongside indigenous and exogenous genome manifested intransigence toxicant polypeptides. However, there is concern about appropriateness of genealogical manipulation for smallholder farmers in Africa, considering successful modulation lessening imperils concerning FAW commencing resistance as highest corn crosses in Brazil as reported by Fatoretto *et al*. (2017) showed loss of ability to control FAW.

2.5.4 FAW Monitoring by use of Pheromone Traps

The consideration of pheromone traps is an effective as an early warning tool in detecting the arrival of FAW (FAO, 2018; MoA, 2018). Olfaction pheromones and smell used to supplement existing pest management practices for insect control (Ghewande & Nandagopal, 1997). Increase in libido and reproduction smell catches are an indication of infestation of FAW moths into maize fields (MoA, 2018). Detection of presence of FAW is fundamental judgement within sustentation approach (FAO, 2018). FAW control organised during the apprehending the airbone lepidopteran marked by reproduction smell uses libido behaviour for accumulation seizure and causing turmoils of lepidopteran. Libido behaviour produced by female FAW moths showed eventual advantageous instrument scanning masculine ecotype with outlining chemical utilisation to controlling vermin (Adams *et al.*, 1989; Mitchell *et al*., 1989).

Canopy zeniths suspends smell traps within coil phases in maize plants whereas, net snares establishes occuring or lacking of vermin (Starratt & McLeod, 1982). The moth identifier, eggs and larvae are searched and percentage infestation assessed by sampling fair number of plants in different locations following the traverse of the farm area (Andrews, 1988). The calculation done on the achieved cusp and synthetic pesticides (insecticides) applied (Flanders, 1995). In Nicaragua, van Huis (2009) determined wealth poor cultivators ought to record aggregates concerning FAW damaged coils within twenty sequential vegetation approaching any five indiscriminately designated locations and use twenty percent invasion of corn just when the verge pre-initiate insecticide application.

2.5.5 Application of Pesticides for FAW management

Pesticides act as significant control choices in FAW administration and they represent tools of convenience that were developed with the sole intention of killing or repelling pests (Conceição *et al.,* 2016). Considering the ceiling of the global warfare two, synthetic pesticides turned out to be highly instrumental helping increase crop productivity and reducing, hunger worldwide (Amekawa *et al.,* 2010). FAW can be controlled using selective and non-selective chemical insecticides. Selective insecticides are preferable because natural enemies are not badly affected (Chattopadhyay *et al.* (2017). There is therefore preferable that one may apply vermin eradication strategy in a judicious combination of pesticides (insecticides) and biological regimes that is less environmental risks and human health friendly.

2.5.6 Bio Pesticides

Crop pests including FAW indicated an attack by a number of pathogens that are likely to cause significant level of their survival thereby reducing their populations (Chaurasiya *et al.,* 2021; Gardner *et al.,* 1984; Hall & Papierok, 1982). Bio-pesticides control agents' success use in crop production is safe for drift aerosols and the environment. The costs incurred during bio-pesticides use showed a significantly reduction due to the quantity of the bio-pesticides produced (Kergunteuil *et al.,* 2016; Maurya, 2020). Other alternatives for less hazardous synthetic insecticides approaches to habitat and the anthropoid robustness are the development and utilization of alternative life-pesticides with desirable approaches for FAW control (All *et al*., 1996; Garrdner & Fuxa, 1980; Goettel *et al.,* 2001; Rwomushana *et al*., 2018).

2.5.7 Botanical Insecticides

Botanical insecticides are extracts from some plants such as neem plants with beneficial insecticidal properties used for ultimate development of commercial formulations (Amoabeng *et al.,* 2020; Fernández-Grandon *et al.,* 2020; Isman, 2020; Miresmailli & Isman, 2014). The botanical insecticides are preferred over the more potent synthetic insecticides because they are environmental friendly, biodegradable, nontoxic to humans and animals and do not affect hereditary adversaries within crop habitat stated by Chattopadhyay *et al.* (2017), Rajendran *et al. (*2018), Rwomushana *et al*. (2018) and Sisay *et al*. (2019). Indeed, botanical insecticide plants are easily available in the local environments (Hikal *et al.,* 2017; Luiz de Oliveira *et al.,* 2018). Smallholder farmers' use these plant extracts especially neem plant for the control crop pests including the invasive FAW in Africa (Nega, 2014; Stevenson *et al.,* 2017).

2.5.8 Synthetic Insecticides

Toxicants are significant crop operation options especially geared toward FAW restriction in the Americas where corn grows in large acreage (Andrews, 1988; Bateman *et al.,* 2021; Bateman *et al.,* 2018; Bhusal *et al.,* 2019; Houngbo *et al.,* 2020; Lamsal *et al.,* 2020). Impressively, Americas use toxicants against FAW during agricultural production, towards the protection of both the fruitful and seminal phases of their herbages (Bhattacharyya *et al.,* 2016; Sisay *et al.,* 2019). FAW being a stubborn pest to control requires high volumes of solution toxicants to acquire enough perforation and execute instars ruminating cavernous in the curve inside maize plant (Deshmukh *et al.,* 2020; Foster' 1989). Research with Malo *et al.* (2004) and Hardke *et al. (*2011) indicates different conventional synthetic insecticides used to control FAW in different countries during maize production are readily available in the agro-chemical stores worldwide.

Different studies by Sangle *et al.* (2020) done in Brazil and USA with large production of corn showed new classes of insecticides used were effective in controlling FAW. The result concured with a study by Suganthi *et al.* (2022) indicated a good control of FAW larval instars feeding in the whorls of corn during the use of new classes of insecticides. Agricultural pesticides have made it possible to increase production in crop production in Africa (Abate *et al.*, 2000; Carvalho, 2006; Gianessi, 2013; Oerke & Dehne, 2004). Africa's population currently estimated near above one billion three million people anticipated binary by 2050, positioning immeasurable oppression on continent's nutritive supply procedures, of which are afflicted by diminished fecundity (Bremner *et al.,* 2013; Cohen, 2003; Koul *et al.,* 2004; Ray *et al.,* 2013). A few benefits of toxicants utilisation in Africa include increased yields, which have helped improve nutrition, provide additional household income, and facilitate local and international trade (Cooper & Dobson, 2007; Meinzen-Dick *et al.,* 2012; National Research Council 1989; Pingali & Rosegrant, 1995).

Toxicants typify enormous acclimatised within major categories pertaining to farming output either avert or stop wastage through vermins (Abate & Ampofo, 2000). The pesticides improve yields in conjuction with attributes of hatvests, pertaining to superficial allure, determined frequently to consumers (Oerke *et al.,* 2004; Cooper *et al.,* 2007). Toxicants additionally ameliorate the dietary worthness of food and sometimes its well-being (Boxal, 2001; Mengistie *et al.,* 2017). There exists inter alia numerous extra genres of advantages frequently disregarded by public at large (Carvalho, 20017; Cooper, 2007; Damala, 2009; Gianessi, 2013). It is from this point of view, that this study envisaged the handling and use pesticides by smallholder farmers who considers the pesticides as a money reduction, labour-cut, and effective mechanism of vermin eradication alongside substantial traction in comprehesive categories within farming output. According to Assefa with Ayalew (2019), Banson *et al.* (2020) and Chimweta *et al.* (2020), before any implementation for pesticides use, small-scale maize growers recommend full assessments of the complications, and management strategies for adoption. The assessment should apply to all African Countries including in Kenya, with the importance of considering pitfalls and any complications likely to arise during the use of synthetic insecticides during the FAW management occasioned by food growers (Feldmann *et al.,* 2019; Huang, 2021; Overton *et al.,* 2021).

2.5.9 Negative Effects arising from Pesticides use in FAW control

Smallhlder farmers' main strategy in controlling FAW is dependent on insecticides (Shad *et al.,* 2012). Lepidopterian possesses developed resilience to contrasting usage of toxicants requiring continuous and high level dosage of insecticides (Saleem *et al.,* 2008; Tong *et al.,* 2013; Yu *et al.,* 2003). Studies within assessing utilisation of toxicants for maize unfavourable to lepidopterian in Argentina culminated lessening FAW populace alternatively abridged evidence towards parasitism helped in pest population reduction (Berta *et al*., 2000; Carvalho *et al.,* 2018; Yu, 2003; Zhao *et al.,* 2020). In the Americas, FAW management is with insecticides use and genetically modified crop (*Bt.* Maize) but at significant cost (Boaventura *et al.,* 2020; Chilcutt *et al*., 2006; Tindo *et al*., 2017; Yu, 1992). However, lepidopterian boasts developed aversion towards both a few toxicants and transgenic maize, thus, to mitigate the negative effects of FAW, assimilated control techniques (IPM) known presumptively paramount possibilities (Abrahams *et al*., 2017; Adamczyk *et al*., 1999; Gutiérrez-Moreno *et al.,* 2019; Hardke *et al*., 2015; MoA, 2018; Tindo *et al*., 2017).

Toxicants posture prospective perils towards individual robustness alongside ecosystems whilst erroneously utilised despite their benefits in crop protection (Ajayi & Akinnifesi, 2007; Aktar *et al.,* 2009; Oluwole & Cheke, 2009; Patibanda & Ranganathswamy, 2018). There is accelerating distress regarding abuse and overexpose of toxicants within emerging economies whereas extra three million people beared harsh intense toxicants adulterating (Damalas & Koutroubas, 2016; Ecobichon, 2001; Sharma *et al.,* 2012; Tijani, 2006; WHO, 2014).

The introduction of sustained use of insecticides for FAW control will increase the costs of production and increase significant risks to human health (Carvalho, 2006; Macharia *et al.,* 2013; Mokhele *et al.,* 2011). Consequences of insecticides will be more on the men and women farmers responsible for application (Tarar *et al.,* 2019). The chances of ill health and direct exposure of the entire households can be experienced (Oluwole & Cheke, 2009).

FAW is difficult to control as it feeds deep inside maize plant whorls, and farmers' only solution is to increase the spraying frequency and dosage levels of the insecticides (FAO, 2021; Jallow *et al.,* 2017). The Kenyan farming systems' compatibility with pesticide use is minimal since the average land size is about two acres, which leaves no space for line of demarcation (Macharia *et al.,* 2013). The important precautionary measures and mandatory for all pesticides required to start from five meters around the farm (Larson *et al.,* 2014; Zaehringer *et al.,* 2018). There is a likelihood of assumed and neglected during insecticide spraying (Larson *et al.,* 2012; Mengistie *et al.,* 2017). Insecticide overuse facilitation is by their wide availability in the local agro-chemical shops (Baba *et al.*, 2012; De Bon *et al.*, 2014; MoA, 2018; Warra & Prasad, 2020). This requires attention and preparedness on the threat of FAW while producing food crops and the overuse of chemical for management practices.

Africa bodies proliferating a dependency on farming toxicants (Denkyirah *et al.,* 2016; Reynolds *et al.,* 2015). Innumerable years, volumes of toxicants vended in African markets (below four percent of universal pesticide commerce) is largely ignored (Warra & Prasad, 2020). Conversely, lately, extension acquisition of farming toxicants due to FAW in many farms facilitated pesticide manufacturers alongside traders gain access to enlargening African barter (Goeb *et al.,* 2022). Simultaneously farming toxicants evolved into increased regular, unsurpassable dangerous facets include: (i) feeble or lacking protocols with (ii) deficient understanding towards pesticide perils amidst clientele. Africa's extensive authorisation of toxicants is distressing for the reason that suggests one will find a plethora of recent clientele commonly ignorant of the repercussions from toxicant utilisation, albeit acclimatised suitably. Lacking protocols and sufficient tutelage and knowledge enhancement for farmers, Africa is susceptible of extensive toxic marring (Adamu, 2020; Adekunle *et al.*, 2017; Berhane *et al.*, 2016; Mengistie, 2016; Mensah *et al.,* 2012; Tambe *et al.,* 2019).

Toxicants shifts out of the way singularly pollute streams thereby percolating into aquifer damaging unintentional lifeforms in addition to sullying earth alongside with air and have significant impact on human health (Aydinalp & Porca, 2004; Casara *et al.*, 2012; Loewy *et al*, 2011; Tanji, 1991; Tiryaki & Temur, 2010). Different studies showed that about 75 percent of all deaths associated with poisoning due to pesticides occur in developing countries (Eddleston, 2000; Eddleston *et al.,* 2002; Koul *et al*., 2004; Litchfield, 2005). Developing countries use averagely 15 percent of global pesticide supply. This has necessitated the application of extra insecticides during pest management due to pests' developing insecticidal resistance (Hrabetz *et al.,* 2013; Konradsen, 2007; Wilson & Tisdell, 2001).

Pesticide use and farmers health's documentation within various segments of the globe including Kenya, showed each empirical surveys rested on a snapshot of partial investigations with no comprehensible tendency concerning adulterating (Abedullah & Ali, 2016; Asfaw *et al.*, 2009; 2010; Macharia, 2015). In addition, the research glanced at the causation of pesticide-related drastic poisoning diagnostics amidst agriculturalists and not the gender perspective per se (Isah *et al.*, 2020; Macharia *et al.*, 2013; Ohayo-Mitoko *et al.*, 2000; Okello & Swinton, 2010). Nonetheless, remarkable hindrance is that toxicant-lacing consequences neither haphazardly rather supposed alternative unnoticed attributes in particular hereditary attributes of the pesticides (Mequanint *et al.*, 2019; Rostami *et al.*, 2019; Tambe *et al.*, 2019; Tindo *et al*., 2017).

2.5.10 Integrated Pest Management (IPM)

IPM is active agriculture that culminates in a total systems approach to the suppression of pest populations to a level where high quality yields can be obtained which provide the farmer with a maximum economic return with minimal applications of chemical pesticides (Barzman *et al.*, 2015; Bottrell, 1979; Dent, 2000; Lewis *et al.*, 1997; Prokopy & Kogan, 2009). The aim is not to eradicate pests, but to manage them, maintaining their populations below economically injurious levels (Birch *et al.*, 2011; Chellemi, 2010; Gray *et al.*, 2009; Tonnang *et al.*, 2017). Putting this vision into practice would reduce not only farmers', consumers', and the environment's exposure to toxic compounds, but also problems caused by pesticide-resistant pests.

Sub Saharan Africa has a favourable climatic conditions for FAW to thrive which is an indicator that FAW is likely to remain in smallholder farmers' fields for many days in the future (Day *et al*., 2017; Kebede & Shimalis, 2018; Li *et al.*, 2020; Nagoshi *et al.*, 2019; Zacarias, 2020). Consequently important to advance efficacious, synchronized, pliable perspective to handle lepidopterian throughout the earth. The aforementioned techniques supposed to be primed with strong empirical proof, derived from previous experiences different zones of the globe in controlling FAW, remain assimilated in the flexible African contexts (mainly by smallholders).

Studies by Barzman *et al.* (2015), Kogan and Heinrichs (2020) active agriculture is a cautious reflection amidst each one aaccessible vermin eradication approaches whereas ensuing amalgamation of suitable standards. Other further understanding is that active agriculture that discourages the growth of pestilence numbers and maintain vermins with different intercessions towards situations found financially deserved and lessen or lower chances to peoples' wholesomeness and the sorroundings (Bottrell, (1979; Dent, 2000; FAO, 2017; Lewis *et al.*, 1997; Prokopy & Kogan, 2009). IPM insists increase of flourishing harvest with minimal feasible interference to cultivation aids native vermin handling machinery while minimizing risks to peoples's wholesomeness alongside habitat (FAO, 2021; Lamichhane *et al.*, 2016).

Objectives concerning active agriculture is financially suppressing vermins numbers utilising methods that decrease injury to the sorroundings, including human beings (Bajwa & Kogan, 2002; Hubert *et al.*, 2021). Due to comprehensive essence and the need to combine a diverse of approaches and regimens, active agriculture is viewing infrequently uneasy to handle solution (Dara, 2019; Gleeson 2007; Prasanna *et al.*, 2018). Active agriculture beseeches that the farmer or agricultural mentor possess significant farming and vermin control understanding to execute functional initiative predicated towards indigenous cultivation situations (Gray *et al.*, 2009). The worldwide organizations such as the UN Food and Agriculture Organization (FAO) and the Organization for Economic Co-operation and Development (OECD) views IPM process as an embracement of minimizing environmental degradation and contamination.

The preferred FAW control option in Kenya requires an active agriculture outlook, based on utilising mixtures of handling strategies tolerable, inexpensive and causes negligible harm towards environment with humans (Day *et al*. 2017; FAO, 2018). From investigations conducted worldwide on FAW management, there is great potential for integration of pest control measures on different crops including maize (Abdollahzadeh *et al.*, 2016; Hashemi & Damalas, 2010). FAW can be controlled using selective and non-selective chemical insecticides which are preferable not able to harm biological nemesis along with sorrounding (Arthur *et al.*, 2021; Bhattacharyya *et al.*, 2009; Machado, *et al.*, 2019; Maino *et al.*, 2019; Useinov *et al.*, 2020). From literature findings, smallholder farmers are encouraged to apply a pest management strategy that is environmental friendly and not blended chemical compositions (Useinov *et al.*, 2020).

Studies by Arthur *et al. (*2021) and Maino *et al.* (2018) showed an effective FAW control through IPM strategies employs different integrated approaches including botanicals, biological control, cultural control, and safer synthetic insecticieds. The essence of these strategies to safeguard crop against financial damage conversely reducing invalidating consequences upon human and habitat (Umina *et al.*, 2019). The comparative benefits between IPM options and usage of synthetic pesticide is the economic trigger mainly on not achieving the threshold of the required FAW control during food yields (Damalas, 2016; Horrigan *et al.,* 2002; Midingoyi *et al.,* 2019). Other investigations indicated achingly IPM's basic control options fails to limit FAW's damage despite being economically viable as the lowest hazards towards individuals together with habitat (Mwungu *et al.,* 2020). IPM strategies should enhance FAW control measures with minimum input and with no or less environmental hazards (Wilson & Tisdell, 2001; Wyckhuys *et al.,* 2020; Zayan, 2019).

2.6 Incorporating Resilience into Food Crop Production

Determination term holds elevated possibilities to advance to nutritive sustenance alongside acceptable food structures, whereas, many surveys investigated at edible crop production and their constituents from suppleness viewpoint mainly adaptability and transformability (Naylor, 2009; Prosperi *et al.,* 2014). These focuses are conditioned towards attaining agricultural production yields towards achieving food security within different households (Apeldoorn *et al.,* 2011; Darnhofer *et al.,* 2010b; Milestad *et al.,* 2010; Pingali *et al.,* 2005; Van Soane *et al.,* 2012; Walker *et al.* 2009).

Food production resilience recognizes the importance of production timeline towards appropriate resilience in nourishment welfare (Chah *et al.,* 2014; Nyagumbo *et al.,* 2017). Resilience emphasizes outstanding occurrence regarding numerous phases for edible crop production, based ou of the household level toward public's edible crop production into worldwide food crop production (Abraham *et al.,* 2014; Barrett & Constas, 2014; Bullock *et al.,* 2017; Dhankher *et al.,* 2020; Meyer, 2020; Munthali & Murayama, 2013; Naylor, 2009; Zampieri *et al.,* 2020). What comes out clearly from these definitions of resilience is the research gap on the exclusion of the possible dangers about intensifying the durability approaches since are likely to bring out undesirable results for example undesired edibles and nourishment risks with habitat deterioration.

A food system's resilience has various dynamics that affect the production capacity of the crop production over time through robustness, replacement, disturbance and flexibility with which the food crop production recovers from emergency (Anderies *et al.,* 2013). This is achievable through the ability of smallholder farmers' adaptability and coping strategies, which determines how fast they recover from these shocks (invasion of invasive crop pests (FAW) towards attainment of food security. These various avenues build the foundation of the food production towards mitigating emergency shocks and attainment of differential household food security (Scheffer *et al.,* 2012; Simonovic & Peck, 2013).

This resilience of food crop production has a paradigm shift including learning and precautionary channels by smallholder farmers' achieving food security (de Sá *et al.,* 2019; Stone & Rahimifard, 2018; Tendall *et al.,* 2015). Regarding idea towards nutrition production's paradigm shift relates to differential households' food security and not in a mono shift rather a combination of strategies. Achieving the resilience on food production, smallholder farmers' should strife to achieve a balanced and maximum state of food crop production during FAW invasion within different headed households. This requires both male and female smallholder farmers to promote a resilient channel to reduce food insecurity and minimize environmental risks during any agricultural disturbances including FAW invasion (Abraham *et al.,* 2014; Lipper *et al.,* 2014; Munthali & Murayama, 2013; Nyagumbo *et al.,* 2017).

Agricultural disturbances affecting food productions' emphasize as negatively affecting different households' mitigation and adoption measures that have both short and long term influences towards positive food outcomes and environmental resilience (Ericksen, 2012; Garnett & Godfray, 2012; Olsson *et al.,* 2004). When agricultural disturbances occur, change is required in providing opportunities that are likely to be uneven with the standardizing goal of food security. According to studies by Grote *et al.* (2021), to achieve optimum food production requires positive change. This is an indication that incorporating resilience in food crop production during emergencies is a guaranteed to securing different households food security (Anderies *et al.,* 2013; Garnett, 2013; Milestad & Darnhofer, 2003; Vermeulen *et al.,* 2012; Zurek *et al.,* 2021).

2.7 Smallholder Farmers' Agriculture in Africa

The farming systems in SSA is majorly depended on smallholder farmers with biased practices towards subsistence farming with a low income earning (Collier & Dercon, 2014; Jayne *et al.,* 2006). In this study, defining smallholder farmers' depends on livestock and cultivated land holdings (MoA, 2018). The farmers cultivate below two hectares of land whereas own exclusive small numbers of herds (Gollin, 2014). In 2010, the UN Food and Agriculture organization reported fiftyeight percent of SSA inhabitants has depended upon farm harvests for their sustenance whereas, sixtythree percent depending on their family labour force and lived in the rural areas (Bahiigwa, 2003; Dorward, 2004; Frelat *et al.,* 2016). Smallholder female workers make up greater numbers of the agricultural labour, which provide the dominant employment regarding their source of livelihood other than other formal sectors (Boserup, 1970; Dixon, 1982; Gurung *et al.,* 2006; Jiggins, 1986).

In the African set-up, agriculture holds primary authority of labour with nearly two-third reasonably energetic African female with very few working the formal sector for their daily livelihoods (Ellis & Bahiigwa, 2003; Jiggins, 1986; Onyalo, 2019). Almost all the agricultural workforce is employed in smallholder production systems rather than large farms, although there is no conceptually clear way to define 'small farms' or 'smallholder agriculture' (Anríquez & Stamoulis, 2007; Ogunlela & Mukhtar, 2009). The African agriculture are small with land holdings of less than 2 hectares thus making it a challenge to quantify and compare with large scale farmers (Dercon & Gollin, 2014; Eastwood *et al.,* 2010; Gollin, 2014).

Smallholder farmers in SSA can be zoned by first their agro-ecological zones in which they operate their farming enterprises, secondly the farm typology and landholding and thirdly the income generated from the farm produce within each year (Abegunde *et al.,* 2019; Dessy *et al.,* 2006; Matshe, 2009; Peacock, 2004). The revenue generation based on the farm produce mainly from food crops produced and livestock reared and sold for the support of the family (Dixon *et al.,* 2003). The planning of the farm operations relies on the family's household head regardless gender identity. Coincidentally, homeowner autonomously holds individual sole responsibility towards decision making towards labour requirement for the smooth running of the farm production (Hazell, 2007). These decisions at times stretch to the different communities related as social dynamism with information sharing and networking (Dixon, 1982; Jayne *et al.,* 2006).

2.8 Kenya's Agricultural and Food Security Status

Kenya's agriculture is the pillar of its economic growth, with literature studies stating that almost seventy-five percent from Kenyans acquired total aggregate income from the agricultural category accounting to thirty-three percent appertaining to country's revenue (Awokuse & Xie, 2015; Gitau *et al.,* 2008; Kipkorir, 2020; Ouma *et al.,* 2016). In the recent years, agricultural productivity has declined with approximately 20 percent of Kenyan land being appropriate for crop farming (KALRO/ MOA 2019). The recent changes in climate and arrivals of new invasive pests (FAW) have added to agricultural and food insecurity situations of many households (D'Alessandro *et al.,* 2015; FAO, 2018).

Description on food security boasts elicited different definitions beside common broadly appreciated detail being originating at the World Food Summit of 1996 (Pinstrup-Andersen, 2009). According to Coates (2013) and Ya *et al. (*2021), food security is the state in which the country's all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.

Different studies have shown that in Africa including Kenya, many households are food insecure (Clover, 2003; Devereux, 2016; Drimie & Ruysenaar, 2010; Jarosz, 2011; Maxwell, 1996). Studies by Adeyemi *et al.* (2009), Banerjee and Duflo (2007), Olielo (2013) and Thirtle *et al.* (2003) have shown that in SSA, forty-six percent of the population live on less than one dollar a day, while 36.5 percent are food insecure and thirty-five percent of children under five are chronically malnourished. This concurs with a study by FAO (2018) indicating fifty-one percent within Kenyan people shortfall rights to requisite nourishment with food security. This closely links to poverty with an estimate of 46 percent nationally (Ayanlade & Radeny, 2020); Banerjee & Duflo, 2007). The dynamics of poverty within these SSA including Kenya are changing and directly influencing the country's food security status (FAO, 2022).

As agriculture continues to remain the main economic driver for many smallholder farmers, vulnerability to unpredictable shocks continues with unpredictable rainfall and recurring droughts contributing to the disruption of food crop production where 95 percent are under rain-fed production (Devereux, 2009; Prasanna, 2016; Shiferaw *et al.,* 2009). From literature review, it was noted that the inefficiencies in food production is exacerbated by poor networks leading to high prices and insufficient market supplies, limiting accessibility of, with rights to nourishment (Berman *et al.,* 2015; Devereux, 2001; Masunungure & Shackleton, 2018; Tendall *et al.*, 2015). This achievement will be through strengthening and improving the accomplishment of the agricultural segments and enabling an engagement regarding the smallholder farmers who are the major producers of food crops in their households towards mitigating FAW invasion for resilience of food security and environmental sustainability.

2.9 Gender Roles in the African Agriculture

Gender definitions scores the social roles with the African context, intewebbed as a socialism network that ties family and households together where the community relates and identifies itself. According to different definitions by different scholars, the general definition of gender are cultural norm with relations aforementioned binding male and female smallholder farmers with different responsibilities associated with women and men in a specific community are defined (Bhatta, 2001; Boserup, 1970; Moser, 1993; Ogunlela & Mukhtar, 2009). Gender roles vary within and between communities and culture where social dynamism thrive, the gender roles are bound to change (Moser & Moser, 2005).

In the African agriculture, gender roles are based either by the population density of the people within different community or the technology that has been diffused within that community whereas there are variations of agricultural responsibilities from one cultural community to the other. Gender roles in the agricultural African context based against the tools of food production involved. These tools have specificy designes for different gender with definitive chores. The tools are a determination of access to, control over, with the household head determing the activities required, which goods may be produced, and whether the user is entitled to use these available resources (Boserup, 1970; FAO, 2022; Jiggins, 1986; Kamara *et al.*, 2019; Sabo *et al.*, 2017; Takane, 2008)

The accessibility of these resources inclined on the household head who makes decisions over the divisions of roles within the households and its economy. A study by Lambrou *et al*. (2006) found out that at the family stratum, capability to contend to transformations in agricultural division relies supervision regarding land, finance, loans with instruments; minimum reliance; vibrant health and individual flexibility; family nourishment and food sustenance; safe accomodation in sacure locations; and freedom from brutality. This was further asserted by Gurung *et al.* (2006) who said that, gender prejudice within organizations regularly reiterate concepts indicating it is men who are the farmers, resulting, recent farming informations which includes the substitute of vegetation species and organism crosses with current categories deliberate for grander aridness or high temperature tolerant which are rinfrequently obtainable to women.

Women constitute an estimated 43 percent of the global labour force in agriculture (FAO 2022). As Raney *et al.* (2011) stated, some countries in non-mediterranean Africa on average, female make proximately fifty percent of the agricultural workforce for example countries such as Lesotho, Mozambique and Cote d'Ivoire, where the figure is closer to sixty percent. Despite this, there is a widespread and deep running bias against women farmers as relates to who estimates what for women. A study by Hill (2011) asserted that female agriculturalists deal with series of gender-specific limitaions result in them producing, on average, twenty to thirty percent less than their male counterparts do. However, it is widely recognized that, given the same access to agricultural resources, women farmers can be just as productive as men, which would translate into a 2.5 to 4 percent increase in agricultural output in the developing world (Hill, 2011). This was later confirmed by Mishra *et al.* (2017) who argues in their research findings on gender differentials in farming that if women were given all the inputs and support as men, agricultural output could increase by 2.5 to 4 percent in emergent nations, potentially reducing the world's malnourished by 100 to 150 million people. "This report clearly confirms that the Sustainable Development Goals (SDGs) on gender equality with poverty alongside food sustenance are mutually reinforcing.

A study by Quisumbing (1995), found that sharing farming chores amongst female and males differs regarding the crop planted, the cultivation types, the tools needed, and the resources available to family members. Barash *et al.* (2002) further confirmed that gender tasks are a set of social and behavioural norms that are generally considered appropriate suitable for either gender within a social or individual relationship. Different studies by done by Kokoye *et al.* (2013) and Quisumbing (1996) showed handling supervising yields from farming differs amongst female with male within different headed households. This finding partly reflects the differential resource control within different headed households in relation to cultural norms within different communities. This control of benefits determines the labour input during agricultural production without reflecting the use and control of produce realized (Raney *et al.*, 2011). A study by Quisumbing (1995), indicated in the african home, the suprmacy of male as the family head on any agricultural produce whether produced by female farmers in addition, thus, are eligible largest crucial reserves especially acreage and finances.

2.10 Gender and Socio-Economic Resilience

Households in developing countries especially Africa including Kenya countenance extensive intermittent and unexpected surrounding, bionomical, or socio-economic upset where the well-being costs of such upsets are often significant and draws blueprint and compassionate attention (Misselhorn *et al.*, 2012; Thompson & Scoones, 2009). According to Holling (1973), the study on resilience showed many progress agents adopting resilience ere have superior understanding towards wholesome of food crop production. Understanding smallholder farmers' capacity to adjust in the wake of agricultural upsets helps in superior planning of interposition that influence crop production shocks within the developing countries (Gunderson, 2000; Levin *et al.*, 1998; Walker *et al.*, 2004).

Description of resilience is anchored from an endemic habitat viewpoint as the aptness of socio-economic systems (for example family) hold out against any agricultural upset by way of assimilation, adjustment and transformation and become more robust to these emergency shocks (Doran & Fingleton, 2016; Folke 2006; Gunderson 2000; Misselhorn *et al.*, 2012; Thompson & Scoones, 2009; Walker *et al.*, 2004). Resilience to food crop production has specific application, according to Pingali *et al*. (2005) and Tendall *et al*. (2015). The gender and socio-economic resilience studies looked at resilience from broad context according to Pingali *et al*. (2005) and Tendall *et al*. (2015), whereas this study gave a pathway on how to individualize resilience through the gender roles during food crop production towards achieving household food security and creating a sustainable environment.

Women farmers compared to men are twice involved in agriculture related activities despite their cultural positions where sizable monetary and collective transformations are materializing within their metamorphosing household constitution and daily responsibilities (Jiggins, 1986). In accordance with Fernando (1998), occupations, assets and circumstances of society remarkably influences their own sexual category where people's income and finances with traditional dimension living as male or female is a controlling factor (Pingali *et al*., 2005).

The growing populations in the world and receding farming yield are ceding a very large indefinite number of people sans being food safeguarded requiring a need to increase food production (FAO, 2022). In the agricultural sector, women engaged with cultivation thereby, regularly related with a food supply schedule (FAO, 2022). These has created the feminization of agriculture that is likely to demand accessibility of labour towards breeding harvests, thereafter changing cultivation sequences, duties, with agricultural skills preferences (Boserup, 2013; Sabo *et al.*, 2017). Further Gladwin *et al*. (2001) notes that many sections of Africa, women contemplate agriculture for subsistences part of what asemble them "female" with permits them a feminine perspective specification. These intra household socio-economic differences are noteworthy to understand and contemplate in any subsistence blossoming efficiency (Boserup, 2013).

2.11 Existing Gender Policies in Kenya

Considerably Kenya, sexual category word communicated almost all policy attestation and regulatory framework. This includes the Kenya Constitution 2010 that promotes fairness, impartiality, equal opprotunities and objective. Additionally, the Kenya National Policy on Gender and Development, (2000) intent at aiding conventional obligations and anxieties of male with female within total regions in the growth channels of the country (Owano, 2014). Contrasting basic policy excerpts with a gender dimension include the Economic Recovery Strategy for Wealth Creation 2003-2007, the Poverty Reduction Strategy Paper (PRSP) 2001, the National Development Plan 2001-2007, Medium Term Expenditure Framework (2004) as well as Kenya's Vision 2030 (Table 2.1). Nevertheless, Kenya's Vision 2030 depend on contrasting ordinances, some of which blunder to detail on the sexuality-particular character and participation in chief design. The Food Security and Nutrition Strategy supply for vital human privileges, children's entitlements and women's prerogatives, including the worldly dues to food and adequate supply countrywide continuously. Nevertheless, the strategy slightly accountered stemming in continual food scarcity. Agricultural policy contemplates at growing food sustenance with revenues, particularly for smallholder farmers however sans transforming amongst male and female.

Gender dimensionality in smallholder farmers' agricultural activities remains a mirage with remarkable policies lacking sexual insertion (Ifejika-Speranza, 2011; Kimani & Kombo, 2010; Sumberg & Okali, 2013). The policies including Environmental Management and Coordination Act (EMCA) 1999, Water Act 2002, Kenya Forest Services Act 2005 and Energy Act 2006 lacks gender mainstreaming (Govindan *et al.,* 2020; Ulrich *et al.,* 2012). Kenya's Vision 2030 fixes its primary intentions on matters concerning to better nutritive supply, availability of water, hygiene and community solutions notwithstanding (Chege & Sifuna, 2006). Achievement of entire tasks ordains participation of feminie sex entirely dynamism for ecofriendly and scrupulous blueprint, usage and sustenance freedom (Ulrich *et al.,* 2012). Gender divisions of workforce and role apprehension affect the agricultural sector thus prohibiting equal participation by both workforce of smallholder farmers (Sumberg & Okali, 2013).

Furthermore, the agricultural sector of Kenya, gender mainstreaming has very few experts on the policy implementation levels (Ulrich *et al.,* 2012). The study engaged bridging the gender disparity gap on female and male smallholder farmers' requiring participation of equal opportunities in mitigating and adapting measures to manage food crops pests during FAW invasion. The findings act as a mention for scientists engaging on agriculture's modulations and mechanism to alter their studies' perspective by reflecting who the different stakeholders in the food crops production chain are and what are their priorities and roles in terms of capacity building (knowledge), exploration with other agricultural contivances. The study will archive all agility and unparalleled agricultural practices, through sharing or replicating to other Counties within the Country (Kenya). Gathered information could accordingly shape rationale towards expediting and incorporating gender roles and environmental risks for mitigating FAW in maize production by recommending suitable intercessions within household and citizenry phase amongst positive farmers' colaborating contivances.

Table 2. 1: Summary of Selected Kenyan Policies and Legal Frameworks with Gender Considerations

Policy and Legal Documents	Implications	Gender Considerations	Shortfall
National Environmental Policy 2012	Communities have a right to clean and sustainable environment with defined duties to protect and improve its quality.	Yes	The roles of individuals and Indegineous communities mostly the poor and vulnerables are not well defined.
Food Security and Nutrition Strategy	Basic Human Rights, Child and Women's'Rights, including the Universal Right to Food , adequate supply nation-wide and at all times	Yes	Not fully implemented thereby, resulting to frequent food insecurities within the Country Kenya.
Kenya Vision 2030	Mainstreams gender equality and equity in its interventions	Yes	Relies on other Laws of which some are compromised inhibiting implementation.
Agricultural Policy	Increasing agricultural productivity and incomes, especially for small-holder	Yes	Has no specific actions tailored towards women

	farmers		empowerment
National Gender and Development Policy	Facilitate the mainstreaming of the needs and concerns of men and women in all areas in the Development process.	Yes	Lack of gender-disaggregated data and farming systems
Constitution of Kenya 2010	Changes may lead to lack of social-justices and indiscrimination.	Yes	Changing of the constitutions by politicians for political gains affects the implementation

Source: Modified from Ifejika-Speranza, 2011

The Agricultural Sector Development Strategy 2010-2020 as cited by Boulanger *et al.* (2018) is the comprehensive national policy document for the agriculture sector. The strategy profiles the discharge of a national agricultural strategy in Kenya (Alila & Atieno, 2006; Kimenyi, 2002; Ongugo *et al.,* 2014). The Constitution also has a formulation of adaptation and mitigation legislation, policies and strategies to guarantee the right to clean and healthy environment under the bill of rights (Ifejika-Speranza, 2011). The Kenya Vision 2030 blueprint mentions among others the Environmental Management and Coordination Act (EMCA) 1999 and Water Act 2002 but does not address the threats and opportunities presented by smallholder farmers through gender roles. Therefore the only achievements the study tackled the missing gender roles gaps within smallholder farmers households and community levels was citing recommendations and suggestions on the possible causal measures.

2.12 Existing Agricultural and Environmental Policies in Kenya

Kenya's agricultural policy centres its main goals on the augmenting fecundity and wealth growth, more so for agricultural farmers (Alila & Atieno, 2006). Studies by Argwings-

Kodhek *et al.* (2019), Mwadalu and Mwangi (2013) indicate policies have enhanced food security and introduced stability in agricultural output, commercialization and intensification of production especially during agricultural schocks. The smallholder farmers are required to practice positive human activities that are appropriate towards formulation of policies that are participatory and attaining environmental sustainability.

The many agricultural and human activities that degrade the environment invariably occur at the level of the smallest unit that is the household level practiced by smallholder farmers (Abernethy, 2001; Buttel & Taylor, 1992; Dietz & Rosa, 1994; Holton, 2011; Sadoff & Grey, 2002). It is within that smallest unit, which policies, cultures and destructive practices exist whereas the likelihood of environmental degeneration happened. It is in this context that, initiatives leading to the destruction and wastage or to the conservation of the natural resources due to agricultural activities will occurred (Mwadalu & Mwangi, 2013). This degradation either was from effluents emitted during farming or degeneration of the nature towards creation of more spaces for agricultural production (Cortner *et al.,* 1999; Juma, 2000; Sikazwe, 2019).

Prior to passing of the Environmental Management and Co-ordination Act, 1999 (Act No.8 of 1999), Kenya was devoid of desegregated legislation amongst national environmental regulation (Cortner *et al.,* 1999; Juma, 2000). Instead, disparate decrees passed leaving scores of different headed households being hurt (Okidi, 1988). The most affected area was agriculture and the environment that complimented each other during crop production leading to contamination of the water bodies and acidification of soils leading to decline of food production (Sikazwe, 2019). Despite the sectoral legislation being in place, EMCA (1999) provides institutional mechanisms of co-ordination towards saving the environment, in addition wide principles steers the activties of ecosystem handling within the whole nation (Bosek, 2014; Gichenje *et al.,* 2019; Haregu *et al.,* 2016; Kaniaru, 2013; Kering, 2016; Kimani, 2016; Poulton *et al.,* 2006; Watson, 2004).

Policies that affect the performance of any sector have important implications for the economy (Fei *et al.,* 2021; Himmelweit, 2002; Lundvall, 2002). In Kenya for example, policies for agriculture consist of bureaucracy opinions that influence the echelon and adherence of costs and yields, state expenses affecting agricultural production, inputs and money and allotment of resources where these policies affect agriculture either directly or indirectly (Hassan, 2010; Lundvall & Battese, 2000; Odhiambo *et al.,* 2004).

Kenya places keen interest in the improvement of agricultural production though viewing and considering the main drivers likely to lead the country from poverty to being self-reliant in food security status (Alila & Atieno, 2006; Denning *et al.,* 2009; Oluoko-Odingo, 2009). The agricultural sector strategy's key objective is to increase agricultural growth, where the rural food producers will increase their incomes and equitable distribution of each individual's food daily intake (Attah, 2012; Magesa *et al.,* 2015; Timmer, 2017). Land is a limited resource in Kenya and that compels the government to radically increase its agricultural production through crop intensification during production and increase the use of improved inputs (seed, fertilizer, chemicals and machinery) by aiding in high crop yields (Dolan, 2001; Greiner & Mwaka, 2016; Ochieng, 2007). Currently, with the invasion of FAW affecting the agricultural sector, pesticides use has been the norm for farmers to meet the threshold of nutritive supply (Asfaw *et al.,* 2009; Sattler *et al.,* 2007; Wilson & Otsuki, 2004). This study looked on how compromises within the agricultural policy and environmental sustainability have been used by smallholder farmers in an appropriately and participatory manner during their daily crop production activities (Guijt, 1998; Oni *et al.,* 2010).

2.13 Theoretical Framework

The study encompassed different agricultural pest management theories in understanding the relationship between crop pest and the mitigation strategies used by smallholder farmers towards environmental sustainability and food production resilience. Environmental sustainability was a form of obligation for future generations through the environmental and socio-economic actions taken by smallholder farmers and not diminishing the household food production. The study looked at different theories on food production resilience and environmental sustainability during FAW management by smallholder farmers' different headed households. The study emphasized on the theory of sustainable environment as theorized by Stern (2018) for environmental sustainability with the approach of looking at the environment's physical interdependencies, and smallholder farmers' health after chemical handling. The theory emphasizes long-term survival of FAW management including resiliency within different headed households and adaptability. The study cited the used theory of food crop production in agriculture by Zampieri *et al.* (2020) whose theory looks at estimating annual crop production resilience with limitations. The two theories (environmental sustainability and crop production) resonated well with the study since there was emphasis on pesticide insecticidal use, management roles during FAW management by different headed household albeit looking at the best management strategy in-terms of environmental risks during chemical handling, and households' maize yields before and after FAW invasion. The management strategies during FAW invasion brought out the distinct differential gender roles within different headed households' food security and the ripple effects of these outcomes on the environment.

2.13.1 Environmental Sustainability Theory

The study considered contributions of environmental theory and practices during FAW invasion management by smallholder farmers and the different headed households' roles towards food production resilience and environmental sustainability. The theory is relevant in that there are responses to the invasion of FAW's influence on the environment. The theory conceptualises some assumptions and incorporates environmental sustainability development (SD) through diversification of smallholder farmers' influence on environmental contamination during agricultural shocks.

The study provoked novel ideologies for environmental theory that contributes to sustainable development with less disruptive activities during FAW invasion. The mitigation strategies (coping and adaptation strategies) involved chemical use with continuous application and this may have a likelihood of contaminating the environment (Ware *et al.*, 1980). The study acknowledged that the environment encompasses everything, according to the FAO (2021) definition with all human beings and their relationship with nature requiring an understanding and functions of the smallholder farmers during decision-making processes on agricultural activities towards a sustainable environment.

2.13.2 Food Crop Production Resilience Theory

The study approach focused on different avenues of resilience by estimating the amount of food crops yield attained "during" the period of FAW invasion. The individual households and average household yield harvested "during" the good season of food crop production and "before" the invasion of FAW. The average differences of the yields that the respondents gave was the determinant of the households' food security status indicating the respondents' food unavailability for consumption by their household members. This result gave the researcher an understanding of either considering the household was food insecure during the period of FAW invasion thus requiring alternatives of individual or collective resilience to overcome the situation. The crop yield in this study related to the food crop production per person "during" the period of FAW invasion by comparing the previous season's harvest "without" FAW but with other diseases and pests held constant.

2.13.3 Reviewed Literature Gaps

The literature review discussed exhaustively by revealing that there were research gaps not addressed during management of FAW. The fact-finding will purpose answering in basic knowledge research disparity and helped in the evidence on gender perspectives during FAW management towards environmental and food security resiliency in Bomet County. The following Table 2.2 summarized the reviewed literature gaps.

Table 2. 2: Reviewed Literature Gaps

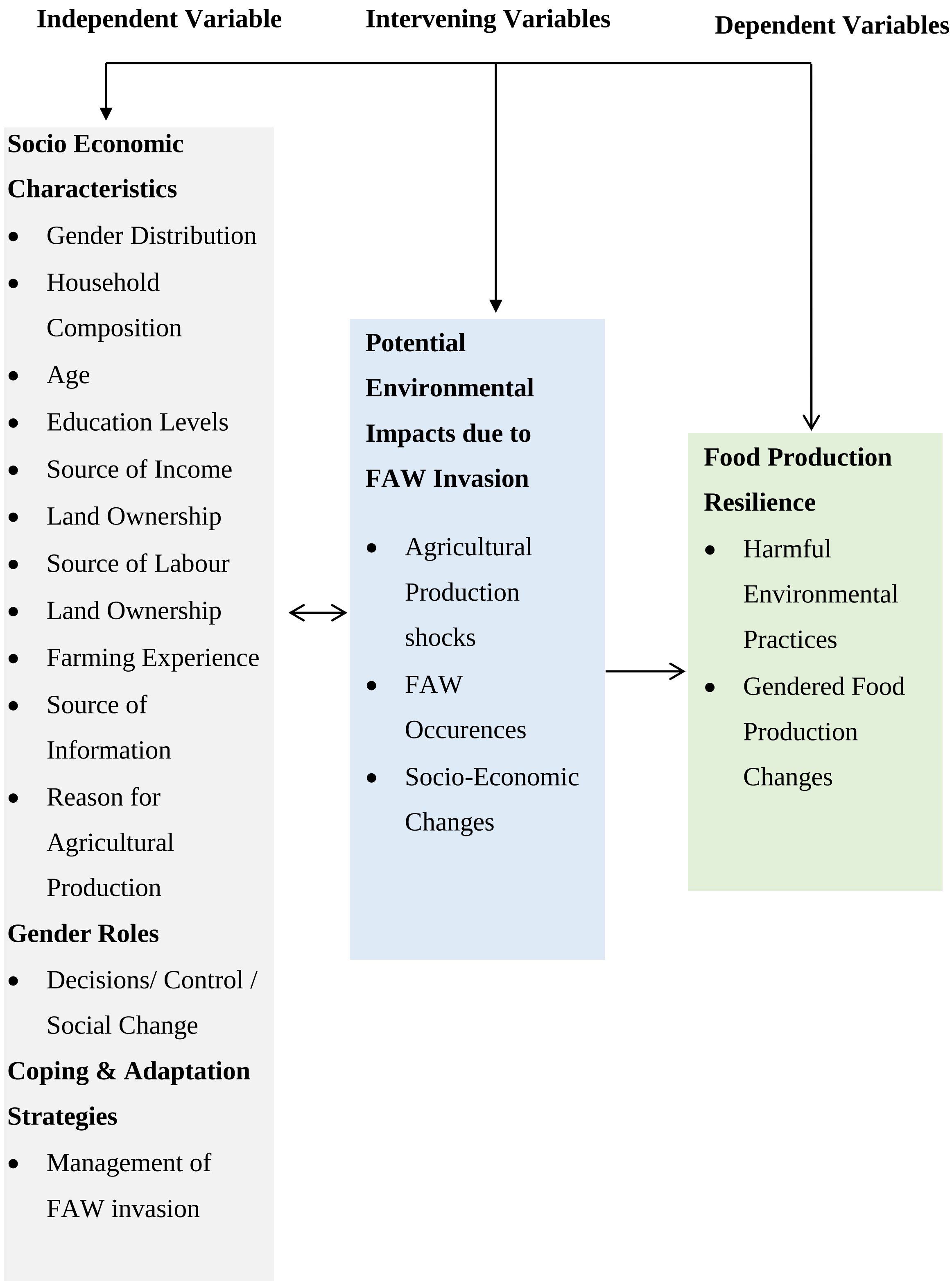
Authors, Publication and Year	Scope of Study	Research Gap
Abrahams, P., Beale, T., Cock, M., Corniani, N., Day, R., Godwin, J., Murphy, S., Richards, G., & Vos, J. (2017). Fall armyworm status. Impacts and control options in Africa: Preliminary Evidence Note (April 2017). *CABI, UK*. https://www.cabi.org.	Impacts and Implications of fall armyworm for Africa.	Mitigation strategies (Adaptation strategies) by gender due to the effects of the fall armyworm invasion.
Adger, W. N. (2000). Social and Ecological Resilience: Are they Related? *Progress in Human Geography*, *24*(3), 347-364. https://doi.org/10.1191/030913200701540465.	Relationship of Social and Ecological resilience.	Gender roles on environmental and food security resilience.
Boliko, M. C. (2019). FAO and the situation of food security and nutrition in the world. *Journal of Nutritional Science and Vitaminology*, *65*(Supplement), S4-S8. https:doi:10.3177/jnsv.65.S4	FAO's agenda on food security and nutrition in the globe.	Building resilience on nutritive sustenance within different male and female-headed households.
Boserup, E., Tan, S. F., & Toulmin, C. (2013). *Woman's Role in Economic Development*. Routledge.	Woman's role in economic development.	Socioeconomic shocks in different male and female-headed households.
Carvalho, F. P. (2006). Agriculture, pesticides, food security and food safety. *Environmental Science & Policy*, *9*(7-8), 685-692.	Use of agricultural pesticides towards food security and food safety.	Improving food security and safe pesticide handling in different male and female-headed household.

Collier, P., & Dercon, S. (2014). African Agriculture in 50 Years: Smallholders in a Rapidly Changing World? *World Development*, *63*(C), 92-101.	Smallholder farmers in a Rapidly Changing World.	Gender segregated data on household labour by gender and their effects on food security.
FAO, 2017. Food and Agriculture Organisation of the United Nations Statistics Division [www document]. URL http://faostat3.fao.org/home/E	Building resilience for peace and food security.	Building resilience on food security within different male and female-headed households'.
Foster R. E. (1989). Strategies for protecting sweet corn ears from damage by fall armyworms (Lepidoptera: Noctuidae) in Southern Florida. *Florida Entomologist,* 72: 146-151.	Strategies for protecting sweet corn ears from damage by fall armyworms (Lepidoptera: Noctuidae) in Southern Florida.	Effects of pesticides handling and use on the environment by different gender within different households.
Goergen, G., Kumar, P. L., Sankung, S. B., Togola, A., & Tamo, M. (2016). First report of outbreaks of the fall armyworm *Spodoptera frugiperda* (JE Smith) (*Lepidoptera, Noctuidae*), a new alien invasive pest in West and Central Africa. *PloS ONE*, *11*(10), e0165632.	First report of outbreaks of the fall armyworm (*Spodoptera frugiperda).*	Determination of the extent to which food systems affected by fall armyworm within different household.
Jiggins, J. (1986). *Gender-Related Impacts and the Work of the International Agricultural Research Centers* (No. 17). Washington, DC: World Bank. https://documents.worldbank.org	Gender studies.	Determination of differences in household food systems between female and male households.

Niu, J., & Yu, G. (2009). Agricultural chemicals. *Point Sources of Pollution: Local Effects and Their Control; Yi, Q., Ed*, 43. https://www.eolss.net/ebooklib/sc_cart.aspx?File=E4-11-04-02	Agricultural chemicals.	Potential influences arising from knowledge and handling practices of pesticide by gender among smallholder farmers in different households.

2.13.4 Conceptual Framework

This study examined smallholder farmers' independent and intervening variables and their interaction with the dependent variables (Fig. 2.1). On the aspect of independent variables, the socio-characteristics of the smallholder farmers (respondents' gender, household composition, age, education levels, income, labour, land ownership, farming experience and reason for agriculture) contributed to the control of fall armyworm invasion during agricultural production). The intervening variable on potential environmental impacts of the strategies saw the use of different gender roles to manage the agricultural shocks (FAW invasion) whereas smallholder farmers' with perceived exposure during pesticides handling and experienced changes in socio-economic due to FAW invasion. The results on the independent and intervening variables affected the dependent variables on food production with different headed households experiencing food yields changes during 'before' and 'after' FAW invasion. It was important to comprehend a particular gender perspective of endurance and adjustment approaches used by male and female agriculturalists during the management of pests' infestation with its effect on environmental and households' food security.



Conceptual Framework

CHAPTER THREE
MATERIALS AND METHODS

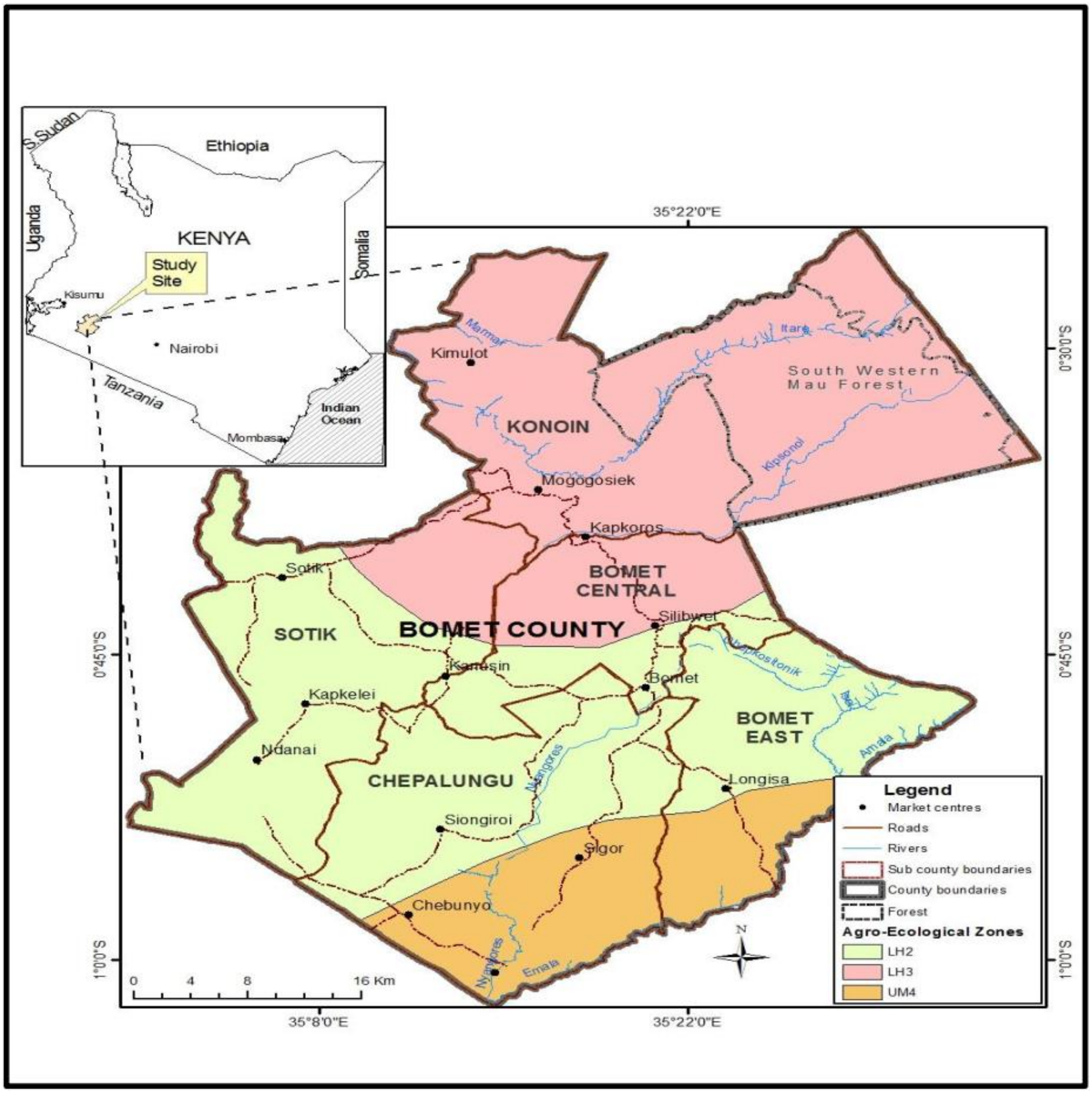
3.1 Description of Study Location

3.1.1 Study Location

A given regulation within Kenya have steadly changed with the legislation renaming deignation of diverse regulations. The current constituencies acted as provincials while the sub-counties well charted divisions, additionally, investigations adopted current executive power regulation. It intersects parallels 0 degrees 29 minutes South with on 1 degree 3 minutes South together with amidst meridians 35 degrees, 5 minutes East along with 35 degrees, 35 minutes East. Its median 1962 height above mean sea level (KPHC, 2019). Current constituencies' anchores within hilltops belonging to South Rift Valley belt of South Western Kenya.

Current constituencies' creation was from the former Kericho district through Kenya gazette supplement no. 53 of 1992 (KPHC, 2019). The county borders Nakuru territory into northeast, Narok territory appearing in south, Kericho territory into north along with Nyamira cpnstituency inside west with a land mass of 2,037.4 square kilometers. Bomet constituency also divided into five small divisions (Chepalungu, Sotik, Konoin, Bomet East, and Bomet Central) that make up Bomet County with a total population of 875, 689 and a gender proportion of 434,287 females, 441,379 males and 23 intersex persons (KPHC, 2019).

Specific sampling locations was selected pertaining to the 3 major agro-ecological zones in Bomet County (Low Highland Zone[2] (LH2), Low Highland Zone[3] (LH3) and Upper Midland Zone[4] (UM4) taking into consideration food crop producing areas especially maize production being the prominent cultivated food distressed by FAW invasion. Distinct map shows the study area (Fig. 3.1) (KPHC, 2019).



Key: LH2- Low Highland Zone[2]; LH3- Low Highland Zone[3]; UM4- Upper Midlands Zone[4]

Figure 3. 1: Map of Kenya showing Bomet County (Kenya Population Housing Census, 2019)

3.1.2 Climatic Conditions

Study constituency braves normally cold weather alongside average yearly conditions situated beneath 20 degrees Celcius across nearly the entire costituency. The area receives an average yearly precipitation rainfall depth ranging 1,000 to 1,250 milmeter and temperature varies from 16 degrees Celcius to 24 degrees Celcius. The rain seasons are bi-modal with the lengthy precipitations starting within the mid-March into June alongside a maximum within April, while the minimum precipitations occur amidst September through December (MOA, 2018). Nevertheless, county lies in a high altitude with advantageous weather environment enabling the region lasting leafy within nearly all length period, bringing land to be receptive for lepidopterian existence through the whole year.

Bomet County is characterization of undulating topography that gives way to flatter terrain in the south (KPHC, 2019). All-inclusive declination ground remains facing rare south, excluding North Eastern section rising eastwards approaching Mau Ridges, which are 3,000m.a.s.l. Dry land tilts mildly out-of Kericho escarpment with approximately 1,800m within lowland at which area exists normally horizontal having hardly any dispersed prominence within Chepalungu alongside Sigor grassland. The Countyis soil composition coprises volcanic as well as igneous and metamorphic rocks. In addition to tertiary lava, (phonolites) and intermediate igneous rocks there are basement systems (granite), volcanic ash mixtures and other pyroclastic rocks. Also present are quaternary volcanoes to the southwest parts and faults along the Mau escarpment bordering Narok County (KPHC, 2019).

The higher altitudes in the northeastern parts within constituency especially appropriate towards tea and dairy production. Each central section within constituency is apt for tea, cereals, tenacetum with coffee farming and lies within 2,300m.a.s.l. Within austral sections out from divisions similar to Sigor with sections of Longisa, major profitable activities include animal agriculture, whereas, milk yields primary profitable occupation within Sotik constituency additionally apt for cereal, tenacetum and horticulture alongside animal agriculture.

3.1.3 Socio-Economic Activities

Bomet County prides along expansive acreage pertaining to high-yielding soil with heightened precipitation. Farming remain fundamental business occupation having above eighty percent from whole society enthralling within harvest and animal yields (MOA, 2018). About 62 percent of the households are smallholder farmers, with livestock rearing being a second dominant activity, yet agriculture occupies about 28 percent of the available arable land. Farmers in Bomet County practice agriculture mainly for sustenance with minimal marketing commercial crops (MOA, 2018). Furthermore, total land holdings consist of an average farm size of 1.5 hactares for smallscale families' upto 15 hactares for largescale families. The activity allocation mainly for harvest and animal farming with a minimal allotment from land harnessed towards building place of settlement (Cheruiyot, 2020). Maize production is prominently wholesome sustenance cultivated additionally and the area's staple food. Nevertheless, major nourishment cultivated for sustenance include grains, cereals, sweetpotatoes, cabbages alongside primary commercial crops consisting camellia sinensis, rubiaceae, with dsalmation pellitory, with the altitude, average annual temperature and annual average rainfall as indicated in Table 3.1 (MOA. 2018).

Table 3. 1: Agro-Ecological Zones for Maize Growing in Bomet County (MOA, 2018)

Agro-ecological Zone	Altitude in Meters	Annual mean temperature in ^{0}C	Annual average rainfall in mm
LH2: Low Highland **(Wheat/maize/Pyrethrum)**	1900 - 2350	18.4 – 15.7	1200 - 1500
LH3: Low Highland **(Wheat/Maize/Barley)**	1900 - 2350	18.4 – 15.7	1100 - 1300
UM3 Marginal **(Coffee/ Tea)**	1550 - 2000	20.5 – 17.8	1150 - 1350
UM4: Upper Midland **(Sunflower/ Maize)**	1650 - 1950	19.9 - 18.1	1000 - 1200

With the county having fertile soils and adequate rainfall, it faced with different agricultural challenges especially new invasive crop pests (FAW) which needed address. These challenges related to using of uncertified seeds, low application of fertilizers, and diseases and crop pests (Anon, 2010; Cheruiyot, 2020).

3.2 Research Design

This investigative technique encompassed a descriptive study design that involved a survey without manipulating the behaviour of subjects and variables in the study. The design was relevant to the study since it has the potency to elicit large amount of quantifiable data from the study population and it is considerably cost-effective. This design approach enabled the researcher to collect valid data from the target population thereafter generating insightful information. The design incorporated the collection of both qualitative and quantitative data

3.3 Sample Population

The study targeted the sampling of smallholder farmers within the study area. During the household selection, Kenya Population and Housing Census (2019) documented list was the formula of selection. A population of 174,914 households including a moderate domestic formation of five folk representatives (KPHC, 2019) where 62 percent of the total population (876,689) persons are smallholder farmers. Somewhat 384 families preferred for examination from the survey frame of different households within the five sub-counties in the sampling region. The sample size estimation based on coefficient differences between span of twentyone percent nearly less to equal thirty percent and a standard error in the scope of two percent less to equal five pecent (Chuan & Penyelidikan, 2006; Hashim, 2010). Table 3.2 shows the minimum HH sample size representation inside of five divisions within Bomet territory.

$$S = \frac{x^2 NP(1 - P)}{d^2 (N-1) + x^2 P(1- P)}$$

Where:

S= the essential representative proportion, stipulated by the subsequent:

N= the populace within the survey frame (875,689)

P= the population apportionment (supposed to be 0.50), as this measure yields the maximum possible survey frame involved.

d= the degree of exactness as reflected by the amount of error that was tolerated in the oscillation of a sample breadth about the population **P**. The value of *d* taken as 0.05, which was equal to plus or minus 1.96σp.

$\mathbf{d^2}$= (0.05^2 =0.0025)

χ^2= The table value of chi square for one degree of freedom dependent to the desired level of confidence which was 0.95. (The chi-square value used was 3.841).

$$S = \frac{(3.841*875,689*0.5*0.5)}{(0.0025(875,689-1) + 3.841*0.5*0.5)}$$

S= (840,830.36225)

(136.73775)

S = 383.93203584 ~ 384 smallholder farmers.

Total of 384 Sampled Farmers plus 9 Registered Smallholder Farmers' Self Help Groups sampled. The sample size was considered appropriate and the researcher was able to derive sufficient and representative data that answered the research objectives (Neumann, 2000) (Table 3.2).

Table 3. 2: Minimum Representation of HH Sample Size by Sub-County

Study sites	Population of Sub-County (KPHC, 2019)	Sample Estimate within Sub- County (N= 384)
Bomet Central Sub-County	175,215	77
Bomet East Sub-County	144,275	63
Chepalungu Sub-County	164,837	72
Sotik Sub-County	227,855	100
Konoin Sub-County	163,507	72
Total population	**875,689**	**384**

3.4 Sampling

Respondents for the research study selected using random sampling. The survey form attained through obtaining divisions categorisation inventory out of government agricultural ministry's extension office by classifying each sub-county into AEZ strata namely- Low Highland Zone[2], Low Highland Zone[3] and Upper Midland Zone[4]. The sub-county agricultural extension crops officers were identified who assisted in selecting the sample study areas within the different agro-ecological zones in the five divisions (Chepalungu, Sotik, Konoin, Bomet East, and Bomet Central).

The MOA extension officers aided in the selection of Self Help Groups through purposive sampling. Titles regarding Self Help Groups forwarded including precedence stipulated within the referred to cluster with a goal of engaging in food farming, and officially registered with the Sacco's co-operative and number of years it had been operating. A total sample representation of 384 households (212 female households and 172 male households) and nine SHGs sampled with a gender proportion of 55 female and 45 male smallholder farmers interviewed. Ten key informants who were extension officers from the ministry of agriculture (2 key informants from each sub-county) used where selection of SHGs and enumerated done (Table 3.3).

Table 3. 3: Sampled Households and Self-Help Groups

Name of Sub-County and Self Help Group	Total HH Sampled	Total SHG Per Sub-County	Total Key Informants	Interviewed SHG Members by Gender	
				Males	**Females**
Sotik – (Ndanai / Abossi)	100HH	2SHG	2	11	16
Bomet Central – (Chesoen / Tarakwa)	77HH	2 SHG	2	7	11
Chepalungu – (Samaria)	72HH	1 SHG	2	8	10
Bomet East – (Kembu / Mobokoche)	63HH	2 SHG	2	-	12
Konoin – (Mogogosiek /Mosonik)	72 HH	2 SHG	2	19	6
Total (n)	**384**	**9**	**10**	**45**	**55**

The discussions with interviewed household respondents and Self Help Group members relied on the ability and capacity from respondents by what means interviewee brought to mind prior agricultural pursuits with additional pertinent data (Morgan, 1996; Witkin & Altschuld, 1995). There was emphasis on the different household interrelations where the nuclear family alongside community heads categorized according to married or with spouse, single men and women, bachelor, split up or detached men and women, dowagers and widowman who were practicing crop farming. According to definitions given by Udry (1995) a household consisted with persons who “worked mutually in relation to in any event single shared cultivated lands surbodinate to supervisory of individual determiner with whom drew a pertinent allowance of their principal sustenance from only or extra repository subordinate to control of that specific adjudicator". Nonetheless, once there was a need for farm work elaboration by the married man as the head of family was sought permission to interview the female spouse separately and her opinions noted in the field notebooks.

The results obtained from FGDs gave the researcher an in-depth understanding on how smallholder farmers manage FAW and whether the already sampled households gave the required answers towards achieving the desired objectives of the study. This further added meaning on the "how" and "who" regarding to gender perspective and whether households were different from each other when categorized by gender as a major determinant in assessing environmental sustainability and food systems resilience. The different survey approaches provided complimentary information towards gender perspective in mitigating FAW and the possible environmental impacts on the different households by gender.

3.5 Data Collection

A permit of study issued by the National Council of Science and Technology and Innovation (NACOSTI) (Appendix III) with relevant offices in the study area including Ministry of Agriculture Livestock and Fisheries within study County and Kenya Agricultural and Livestock Research Organization (KALRO- FCRC Njoro) used. The researcher affirmed the attesters (smallholder farmers) regarding secrecy of the data given, inclusive of individual private data. The interviewees reasoned of the intention of the survey that it was for collegiate goal solely. Aforementioned enabled respondents supply data lacking mistrust.

Data collection strategies involved secondary data sources gotten from the agricultural institutions (research institutions and Ministry of Agriculture who doubled up as key informants). Detailed identification of these data sources obtained from ground contact persons from five division within constituency. Accordingly, researcher used both questionnaires and checklists administered to selected households and farmer groups from five divisions within Bomet constituency. Furthermore, questionnaires had closed ended questions and administered by the researcher with the help of enumerators through individual interviews.

There was a classification of households to be sampled based on supply of primary food crop cultivation (zea mays, sorghum bicolor, eleusine coracana, sweet potatoes alongside napier-grass for livestock) from five divisions within Bomet territory. Considering activties between female and male agriculturalists within divergent farm workforce, their contact to farmstead wealth, whilst dominance of earnings achieved from farmstead pulled. Admissions of either male or female agriculturalists for extension advisor alongside loan amenities considered. Furthermore, suppression met with either male or female concerning sustenance cultivation ranking demonstrated in the course of both single-family surveys and farmer group conversations. Moreove, dialogue conveyed through traditional dialect with assistance of a interpreter. Alternative non-traditional that respondents were familiar or comfortable with used.

The questionnaires covered all the four objectives that guided the study (Appendix I) with a complimentary checklist (Appendix II) used on FGD for verification of the already answered questionnaires. During focus group discussion, the researcher recruited one participant from the group to take up a temporary role of moderator. Having one of the participants led the discussion to be relaxed and responses were more honest thereby increasing the chances of varied positive responses.

On community movement, a guide, a local resident, facilitated the movement around the sampled community thus facilitating beforehand introduction for a comfortable reception and a fluent conversation with the respondents in the visited households. The interviewed farmers' filled the questionnaires and any extra information given by the enumerated respondents and noted by the researcher for further analysis.

3.5.1 Pilot Study

Survey tools consisted pilot testing delighting to normalize study tools prior real data data collection survey. Furthermore, feasibility survey conducted in Kamwago Village, Njoro Sub County of Nakuru County. The pilot county has the same climatic characteristics as Bomet County. Sampling of households captured utilising straightforward arbitrarily transection. Aforementioned aided in diagnosing problems that interviewee might have to experience as well as decide whether components in the survey tools would give the essential data for the survey. Applying straightforward arbitrarily transection, investigator picked a total representation 23 individual household heads (both male and female smallholder farmers) from different households proportionate 10 percent survey representative 832 smallholder farmers with 2 farmer groups discussions (Rehema S.H.G- 11 members and Blessed 1 Acres S.H.G- 14 members). In line with Mugenda and Mugenda (2003), representative identical to 10 percent of the study proportion is sufficient for testing study tools. On that account, researcher used aforementioned pilot test towards trainning the enumerators on the tools and eluded any fears that were likely to emerge during the actual survey. Succeeding answering unto study tools, accordingly, researcher had produced the obligatory alterations with accustoming tools that increased their soundness.

In addition, survey response data gotten from the pre-tested exercise was analysed using statistical software package of SPSS. Investigator authenticated pre-tested survey forms by dialogue alongside key informants from the Ministry of Agriculture (Extension officers). Any anomalies identified during the piloting study corrected and the questionnaire re-structured. The result on using the Cronbach's alpha (0.673) indicated the questionnaires had a high internal level of consistency and were measurable. This findings from the pre-test of the questionnaire clearly showed that the developed questionnaire was valid and reliable for answering the study objectives. The anomalies identified during the piloting exercise corrected and adjustments made on the survey instruments that increased their reliability.

3.5.2 Validity of the Instruments

Accuracy within suitability, truth with impactfulness for specific inference picked out for investigation outcome (Frankel & Wallen, 2008). Moreover, level of outcome gotten through information scrutiny clearly represented validity. Accordingly, exploration survey anxious aforementioned alongside subject matter legality as stated by Kothari (2004). The computing tool accountered sufficient communication of the matter within survey. In this study, subject matter accuracy of tools actuated by the lead researcher alongside consultation with the study field proficient of surveys through examining the appraisal executions and amendments of categorical field (intentions) explored through survey. Professionals at that time informed investigators articles rectified. Furthermoe, rectifications regarding recognised inquiries consolidated within tools corrected objects such as multiply the aforementioned accuracy. Accuracy determined through auditing regardless if queries were examining alleged variables presumed towards examining for example accuracy regarding phrases whereas, interviewees interpreted entire survey form alike. Accuracy ascertained from researcher through divulging sectors givinh right to uncertainity with vagueness that led into remodelling interrogations towards being comprehensible by interviewee whereas, collect consistent reactions over numerous interviewees.

3.5.3 Reliability of the Instruments

Reliability of research instruments according to Mugenda and Mugenda (2003) contemplated to bear equivalent outcome alongside replicated assays under alike circumstances, the instrument returns similar setting practiced within distinct periods. For deciding uniformity towards surveying, tools restore alike estimations whenever practiced distinct periods analyst practiced exploratory factor analysis (EFA) in-order to ascertain and understand if the research questionnaire answered the intended study objectives and the responses were measurable by a questionnaire. Hitherto eventuated prior to the pilot study, ahead of the authetic survey accomplished. Application tool result obtained subjected through Cronbach's alpha (0.664) whereas, the results indicated the questionnaires had a high internal level of consistency and were measurable (0.673). Conforming to Mbwesa (2006) if the similarity interdependent of the tools abates atop +0.6, the tool held to be dependable and therefore apt for information gathering.

3.6 Data Analysis

Information acquired through interrogations with listing analysed using the Statistical Package for the Social Science (SPSS) version 19 (Asthana with Bhushan, 2016) and EXCEL (Barreto, 2015) whereas, information accordingly both encoded with entry done for analysis. The sampled data from study area yielded both quantitative and qualitative data. Descriptive analysis done using means, percentages and frequency distribution (table charts, line charts, bar charts and pie charts). Inferential statistics done using Chi-test of independence. The inferential statistics included Chi-square (χ^2) tests (to get evidence of association or no association) and the T-test compared two averages. The collected and analysed data was regarded as being significant at 95% confidence interval with $\leq$.5% significance level. A table formulated showing the linkages between the objectives, indicators and data analysis tools used in survey (Table 3.4).

Table 3. 4: Summary of Variables and Data Analysis Tools

Objectives	Indicators	Data Analysis Tool
To assess the coping and adaptation strategies that affects maize production during fall armyworm invasion in Bomet County.	**Coping / Adaptation Strategies:** Chemical Pesticide use Cultural intervention- manual killing; crop rotation; spiritual prayers; shifting crops; hybrid seeds/local seeds; feeding livestock with infected plants	-Descriptive Statistics -Chi-square Test
To assess gender roles in the management of the fall armyworm invasion in Bomet County.	**Gender Roles**: FAW management responsibilities **Socio-Characteristics**: (household composition, age, education levels, primary source of income, labor and farming experiences)	-Descriptive Statistics
To assess FAW management practices that are likely to lead to environmental contamination in Bomet County.	Chemical handling and use practices before, during and after use. Environmental and Human effects	-Descriptive Statistics
To assess if there are differences in maize production between female and male headed households due to fall armyworm invasion in Bomet County.	Crop yields ('before' and 'after' FAW invasion) within different headed households; Trend of FAW occurrences.	-Descriptive Statistics -Chi-square Test

The collected and analysed data regarded as being significant at 95% confidence interval with $\leq$ 0 .5% significance level.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

Survey findings alongside discussions of significant analysis presented in line with the four major specific objectives. The general information about the study population socio-economic characteristics provided the basis for establishing the relationships of different study variables presented in this chapter.

4.2 Socio- Economic Characteristics of the Respondents

Results on socio-economic characterization for sampled smallholder farmers (n=384) shows the respondents' gender, household composition, age, education levels, income, labour, land ownership, farming experience and reason for agriculture contributes to the control of fall armyworm invasion during agricultural production.

4.2.1 Gender Distribution

The actual response sample size was 393 respondents from which 384 respondents were responsive and provided valid data (Figure 4.1).

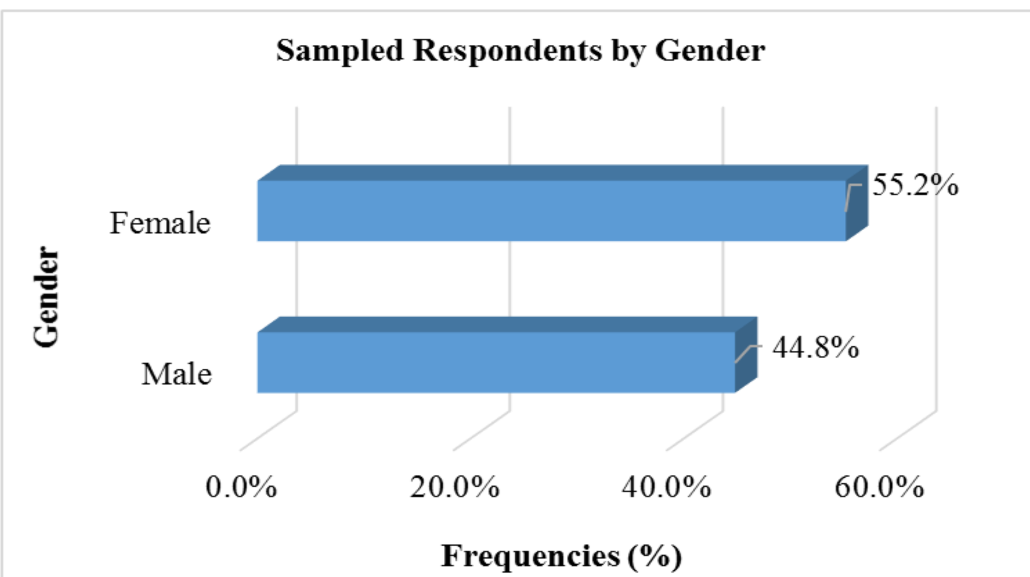


Figure 4. 1: Number of Sampled Respondents by Gender (2020)

The results in Figure 4.1 indicates a gender measure equivalent to 44.8% male with 55.2% female smallholder farmers within the five sub-counties (Konoin, Sotik, Bomet Central, Bomet East and Chepalungu sub-Counties) in Bomet County. This results show that there were more female farmers available during the study period.

4.2.2 Household Composition by Gender

The result indicates the household composition had an average of eight relations (inclusive of parents and children). Nevertheles, sampled households had a minimum of 1 to 3 household members and the highest are 12 to 14 household members (Figure 4.2).

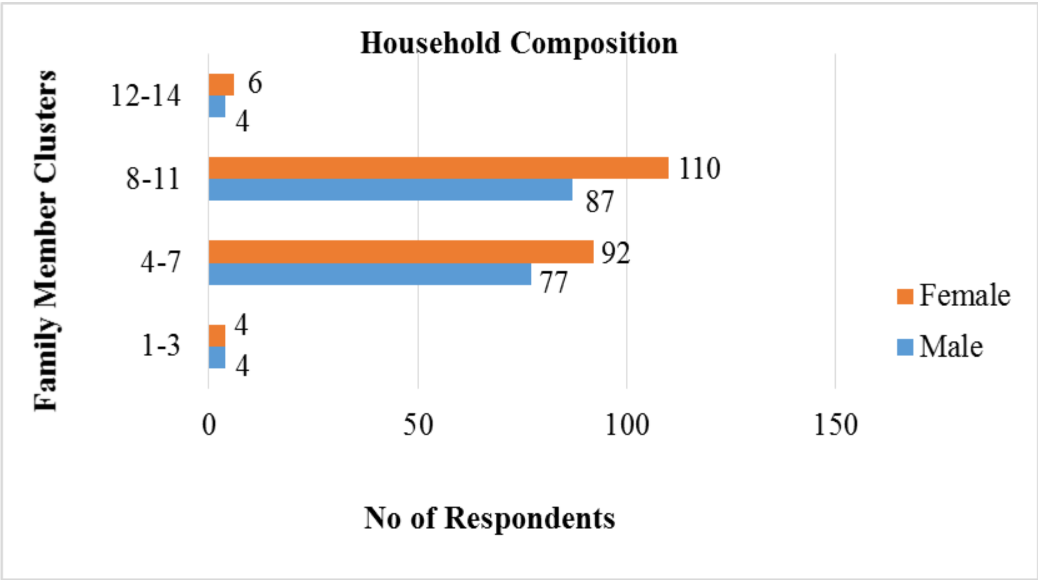


Figure 4. 2: Respondents' Household Composition by Gender

On the respondents' household composition by gender, (Figure 4.2), the majority of the households comprised between 8 to 11 family members with more female compared to male members. The results indicates despite the households with a higher number of family members getting family labour easily, the consumption of food intake is equally high making them to being vulnerable towards food insecurity and environmental risks due to fall armyworm invasion. This findings supports studies by FAO (2022) and World Health Organization (2020) stating that agricultural shocks affect households' food nutrition and production resilience differently especially with households with a higher aggregate of household family relations.

4.2.3 Age of Respondents

The results on respondents age shows an average age of 56 years with a gender mean age of 49 years for male and 52 years for female smallholder farmers. The cluster age findings shows 27.6% are between the ages of 18 to 35 years known as a youthful cluster of farmers and 29.9% are between the ages of 36 to 45 years. The results further shows 20.8% smallholder farmers are between 46 to 55 years whereas 21.7% are between the ages of 56 to 75 years (Figure 4.3).

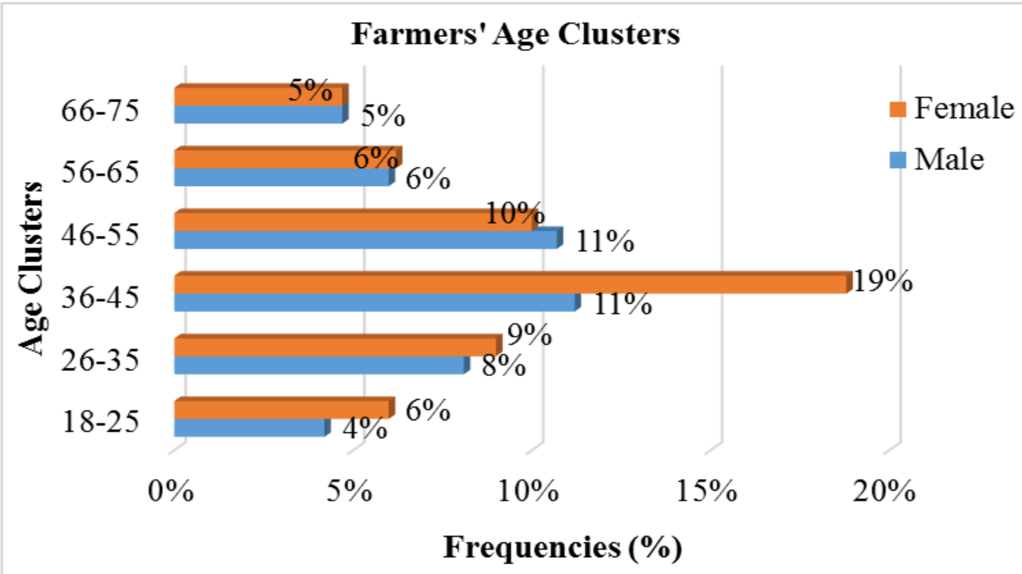


Figure 4. 3: Farmers' Age Clusters by Gender

The result (Figure 4.3) shows that female respondents (29%) were highest in the age cluster of 36 years to 55 years of age as compared with male respondents (22%). The result further shows that the age clusters of the smallholder farmers (male and female) had almost the same percentage an indication that there was not much of age differences between male and female farmers. This result is an indication that the farming communities in the study area are aging whereas the use of technologies required to controlling fall armyworm will be limited. Studies done elsewhere in the worlds by Roh (2013), Seok (2018), and Zou (2018) have shown that the farming communities in the world are aging whereas they control and make major decisions regarding agricultural production. This held that the different headed household heads' chances of compromising on the households' food production resilience and environmental risks during the invasion of fall armyworm are likely due to the age of the households head.

It is worth noting that age of the farmer determines the management of agricultural production whereas, the age progression of the smallholder farmers' exhibits limited technical knowledge and abilities during the control of invasive pests especially fall armyworm invasion. Studies by Nath and Athinuwat (2021), Sarker *et al.* (2021), and Shams and Fard (2017) have indicated that age progression of the farmer has a management ceiling threshold and once the peak is reached, the management skills starts regressing backwards thereby diminishing the technical knowledge and management abilities. This is worth noting that age of the farmer determined the management of agricultural production and if the farmers were too old and was the decision makers with chances of compromising on the households' food production resilience and poor environmental sustainability

4.2.4 Education Levels

Basic education is a right of every human to achieve universal primary education (Sachs, 2012). The study results exhibited differences among the interviewed smallholder farmers' households head with regard to educational levels (non-formal, primary, secondary and above). The result on education levels shows 68% respondents have attained primary levels of education with 16.9% secondary and tertiary education levels whereas 19.5% have no formal education (Figure 4.4).

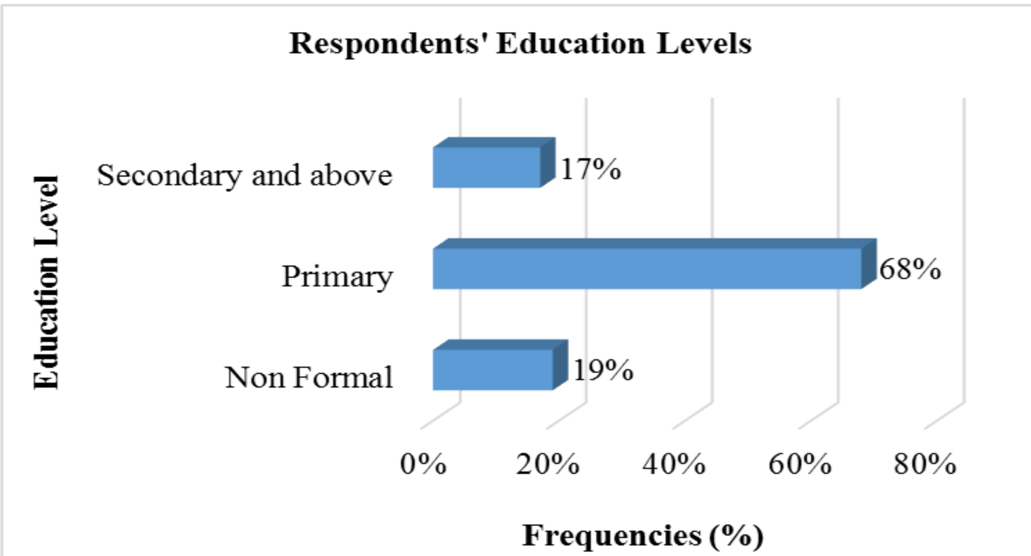


Figure 4. 4: Respondents Education Levels

On education levels (Figure 4.4), 85% of the respondents have attained primary level of education and above holding true with the Kenya Population and Housing Census (2019) which indicates that 82.62% of the Kenyan population have attained primary and above levels and can read and write simple sentences.

Results on the segregation of gender by education levels of the smallholder farmers shows 6% males and 10.8% females have secondary educational levels and above whereas 35% males and 29% females have primary levels with 5% males and 15% females' have no formal education (Figure 4.5). This implies that the strategies applied in FAW control will depend on the interpretation of the information on the characteristics of the fall armyworm infestations.

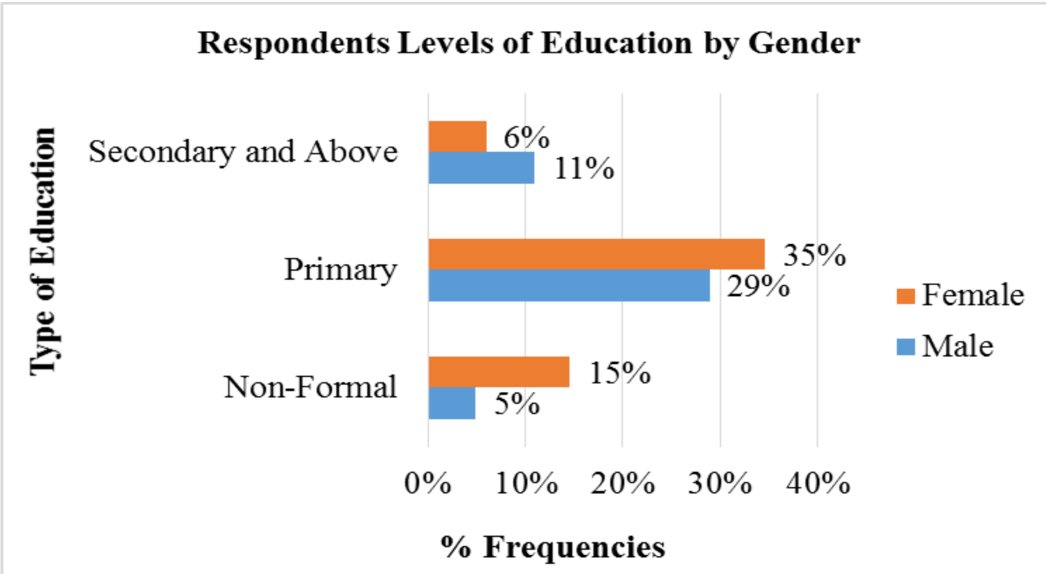


Figure 4. 5: Respondents Level of Education by Gender

The results in Figure 4.5 indicates the 19.5% smallholder farmers (male and female) who had no any formal of education are likely not to manage fall armyworm efficiently due to its newness as an invasive pest in the area while using modern control measures as compared to 81% who have primary education and above. The FAW invasion control skills require smallholder farmers to have basic education in understanding the technical complexities of the nature of fall armyworm's habitations and varietal plant feeding habits. Studies by Deshmukh *et al.* (2020), Huang (2021) and Overton *et al.* (2021) indicated that the management of fall armyworm requires technical operations and it is imperative for the smallholder farmer to have a basic education for ease of understanding the complex operations of fall armyworm management towards attainment of household food production resilience and environmental sustainability.

4.2.5 Source of Income

The findings on income generation indicate that 49% respondents rely on crop farming as a primary source of income whereas 32.3% obtained their income from livestock production (Figure 4.6). The smallholder farmers who derives their income from other source other than agriculture are 10% who runs own businesses (shop, vegetable vendors) and 9.1% are employed in the formal sector thus with a monthly salary earning.

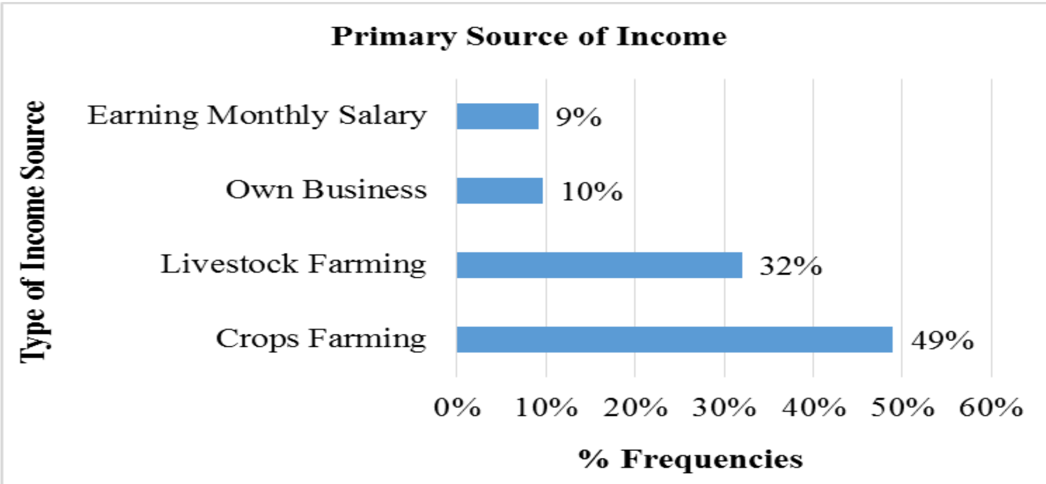


Figure 4.6: Primary Source of Income

On the primary source of income (Figure 4.6), implies that 81% respondents who rely on crops and livestock farming as their primary source of income are likely to be food insecure if the invasion of fall armyworm and other agricultural shocks like draught will affects their production.

The results on income generation by gender shows 22% males and 27% females get their source of income from crop production whereas 15% males and 17% females use livestock production as their primary source of income. Further results indicate that 3% male and 6% female earn their income from owning business with 4% males and 5% females' are employed in formal sector where they earn a monthly salary (Figure 4.7).

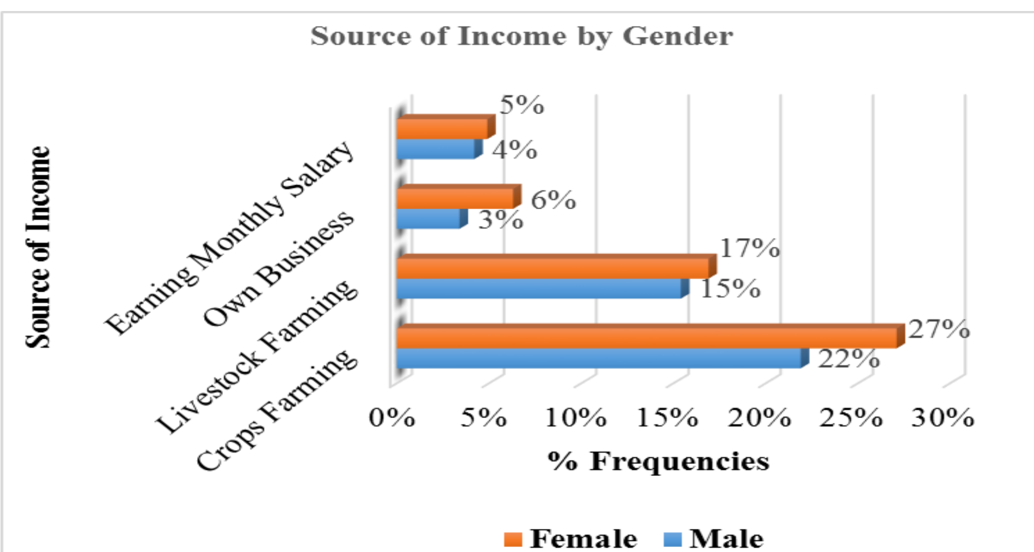


Figure 4.7: Primary Source of Income by Gender

The result (Figure 4.7) also indicates crop farming is the main source of income for 22% male and 27% female farmers. In another view, in the event of fall armyworm invasion, the acquisition and accessibility of chemicals for fall armyworm control requires income primarily sourced from crops and livestock farming and later ploughed back to agricultural production activities including mitigation of fall armyworm. This findings agrees with studies by Alobo (2015), Chikowo *et al.* (2014) and Frelat *et al.* (2016) who states that most sub-Saharan African households depends on crops and livestock for their main primary source of income and livelihoods. Any disruptions during the food production chain will reduce income thereby making different headed households to being food insecure and unsustainable environment. Second, this is another indicator showing that invasion of fall armyworm to households' whose primary source of income generation is from crop and livestock farming, are likely to lose their source of income. Studies done by Day *et al.* (2017), Jeger (2018) and Togola (2018) have shown that emerging threats from new invasive pests including fall armyworm on food crops have severe consequences to differential households' food production resilience due to income transfer towards their management.

4.2.6 Source of Labour

The labour requirement during agricultural production shows 55% households relies on family labour comprising of both spouses, children and other family members whereas, 19.8% utilize hired labour for pay with 2% both spouses opting to control FAW invasion alone. The finding further indicates 23% uses own self labour (single male and female) respectively without the help of the family or hiring labour (Figure 4.8).

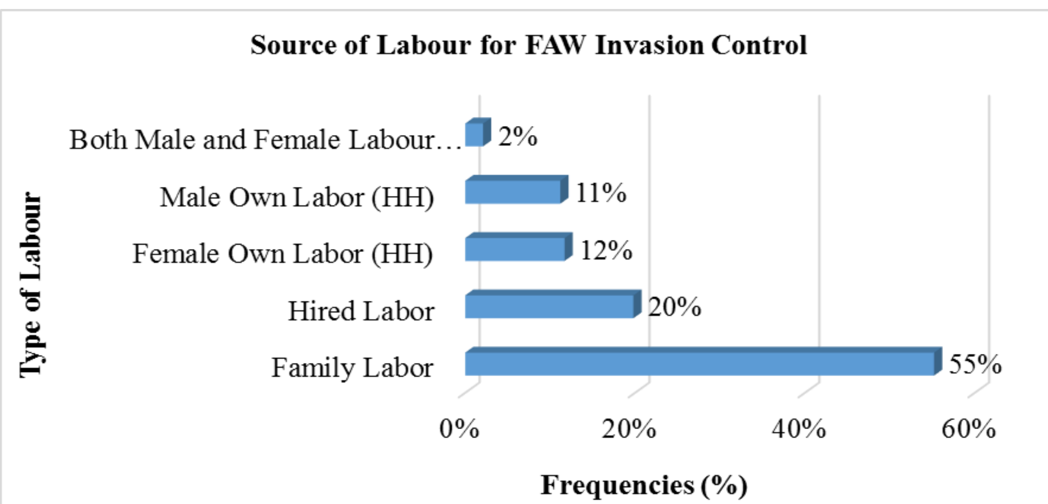


Figure 4. 8: Total labour requirement for FAW invasion control

The result on labour requirement for FAW invasion control (Figure 4.8) shows labour requirements impacts on agricultural production either negatively or positively depending on its availability. This augments the study by Ahissou (2021), who stated that agricultural activities and accessibility to labour have variation from region to region while farming decisions made by household heads requiring the family to provide most of the labour required during farm activities.

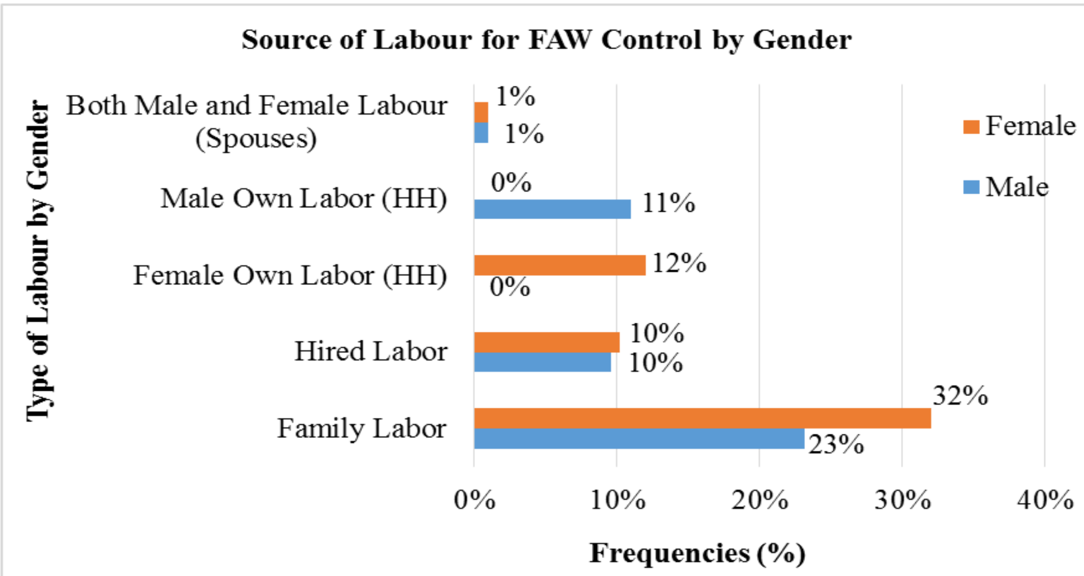


Figure 4.9: Source of Labour for FAW control by Gender

The gender labour (Figure 4.9), shows 23% male and 32% female headed households use family labour during agricultural production whereas, 11% male and 12% female use own labour without family labour or hiring labour during agricultural production with 10% on both male and female headed households hires labour during agricultural production respectively. This finding indicates that female farmers' are the main contributors of labour during agricultural production including fall armyworm invasion. A study by FAO (2022) noted that 52% of the total population of African women is responsible for about 50% of the agricultural labour on farms in Sub-Saharan Africa whereas they produce 60% to 80% of the region's consumptive foods.

The labour allocation by gender based on the agricultural activity required during control of fall armyworm invasion. Labour was a crucial requirement and determinant for any agricultural productions and as stated by Ahissou (2021), and Botreau and Cohen (2020) in their studies, household food production is reliant mainly on family labour. This is in line with studies by FAO (2021) and Frelat *et al.* (2016) who reported 64% smallholder farmers in Sub-Saharan

Africa are depended on their family labour and lacking this essential input during the agricultural production chain especially management of fall armyworm will reduce the households' food production and the sustainability of the environment.

4.2.6 Land Ownership

The results on land size ownership varied from household to household with the owned lands being parcels of family lands inherited from parents. The finding shows that 25% own less than 0.8 ha (2 acres) of land whereas 34% own between 0.8 ha to 2 ha (2.1 to 5 acres) of land (Fig. 4.10). The finding further shows that 21% own between 2 ha to 5.9 ha (5.1 to 15 acres) of land with 18% owning between 5.9 ha to9.8 ha (15.1 to 25 acres) of land whereas 3.1% own above 10 ha (25.1 acres) of land.

The findings indicated that land ownership within the study area was generational inheritance whereas prioritization of ownership was parents be-quitting their children once they became too old. The researcher adopted definitions of land ownership by Azadi *et al.* (2020), Bambio and Agha (2018), and Leavens *et al.* (2019) whose studies conceptualized land ownership as the full land rights usage including the right to farm at will, use and dispose of the produce at will. Land ownership offers decisional control towards food production stability and opportunities with the autonomous power to use and generate income for other agricultural activities thereby securing differentiated households food security status. The social structures of different headed households and the inherent disproportion of land ownerships is a likelihood of households' food insecurities and unsustainable environment.

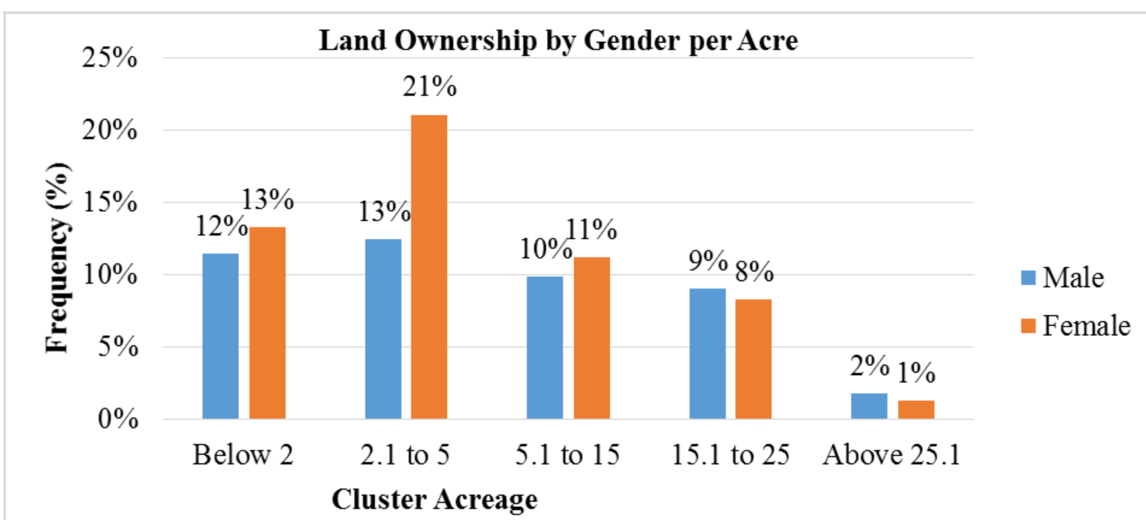


Figure 4. 10: Land Ownership by Gender

On the land ownership by gender (Figure 4.10), 59% of the smallholder farmers own below 2 ha (5 acres) of land an indicator likely to put pressure on the land during crop production thereby, compromising households' food security in the event of the invasion of fall armyworm. A study by FAO (2018) indicates that about 65% of the arable land in Africa damaged to sustain viable food production. This finding illustrates that fall armyworm invasion will put negative impacts on the land during agricultural production due to various management strategies thereby enhancing food insecurity within different headed households and a contaminated environment.

4.2.7 Farming Experience

The study results looks at farming experience as the years the smallholder farmers has been doing agricultural production. Findings on smallholder farmers' (n=384) average years in farming experience had a mean of 26 years for both male and female respondents. The study result indicates that 51.8% smallholder farmers' have farming experiences between 11 to 20 years with 24.2% having between 21 to 30 years of farming experience (Figure 4.11). The result further shows that 13% have farming experiences between 31 to 40 years whereas 7% having between below 10 years of farming experience with 4% have farming experience between 41 to 50 years of farming experience. The finding on farming experience translated with the respondents' age. This was a case cited by a female farmer aged 75 year and stated:

> *"…my first born is 55 years old and I was married when I was only 18 years old. My Husband died a few years ago and I have continued to do farming because I need to feed myself. My children are married with their own families. I use mixed plant concoctions to manage fall armyworm but at times I get help from my neighbour or my grandchildren..."*

This excerpt demonstrates that smallholder farmers are an aging farming community whereas, the management FAW invasion is through the use traditional knowledge and social dynamics. The invasion of fall armyworm is likely to compromise different headed households' food security status and environmental sustainability due to poor technological skills.

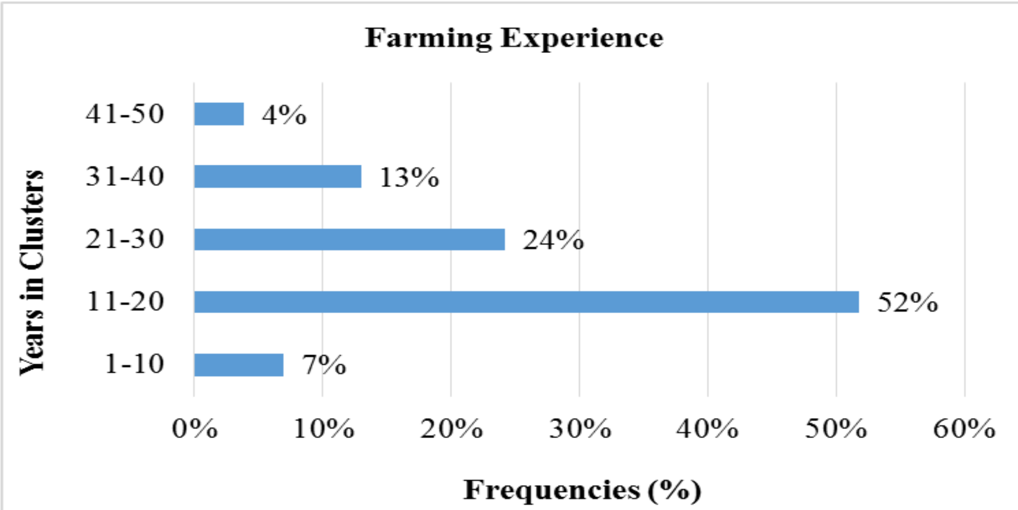


Figure 4.11: Farming Experience in Years

On farming experience in years in different clusters (Figure 4.11), 93% respondents have farming experience of over 10 years of agricultural production experience an indicator that the farming community is aging thereby putting the food security of different households at risk. This finding confirms with a study by Johr (2012) who noted that the average age of smallholder farmers is 52 years with an average farming experience of 30 years thereby there are no future farmers to grow food due to new technologies that are elusive to this aging generation thus putting the future of households' food production at crossroads.

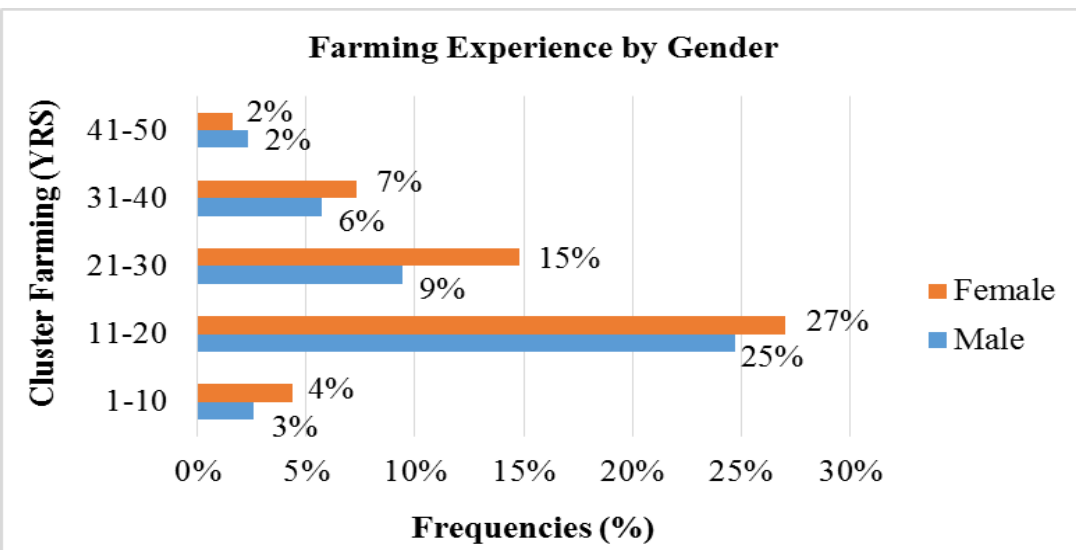


Figure 4. 12: Years of farming experience by gender

Result on years of farming experience by gender (Figure 4.12), 25% male and 27% female farmers have farming experience between clusters 11 years to 20 years. About 17% male and 24% female have above cluster 21 to 50 years of farming experience whereas 3% male and 4% female have below 10 years of farming experience. The gender perspective on farming experience by gender shows female headed households have more years on farming experience and are likely to contribute more during agricultural production (fall armyworm invasion) as compared to male headed households requiring gender specific approaches.

4.2.8 Source of Information on FAW Control

Information on FAW control during data collection (2020), 97% household respondents received information about FAW and were able to compare its larval stage signs with other crop pests. The study result shows the control of fall armyworm requires information that is reliable and environmentally friendly. The result indicates smallholder farmers interrelate socially within the community and shares information within themselves making them updated on any current news including new pest invasion (FAW) in the area.

The result on sourcing of information (Figure 4.13), 24% smallholder farmers listens to radio with 23.2% sourcing advice from extension services. About 15.6% watches television for information with 14.6% reading newspapers whereas, 8.9% smallholder farmers get their information from local agro-chemical dealers with 8.3% farmers sourcing their information from other neighbourly farmers and 5.5% receiving information from research institutions (Figure 4.13). A study by Modirwa (2019), noted that the sources of information are the primary factor determining the resilience of agricultural production and the development of countries, farm communities, and individual farmers.

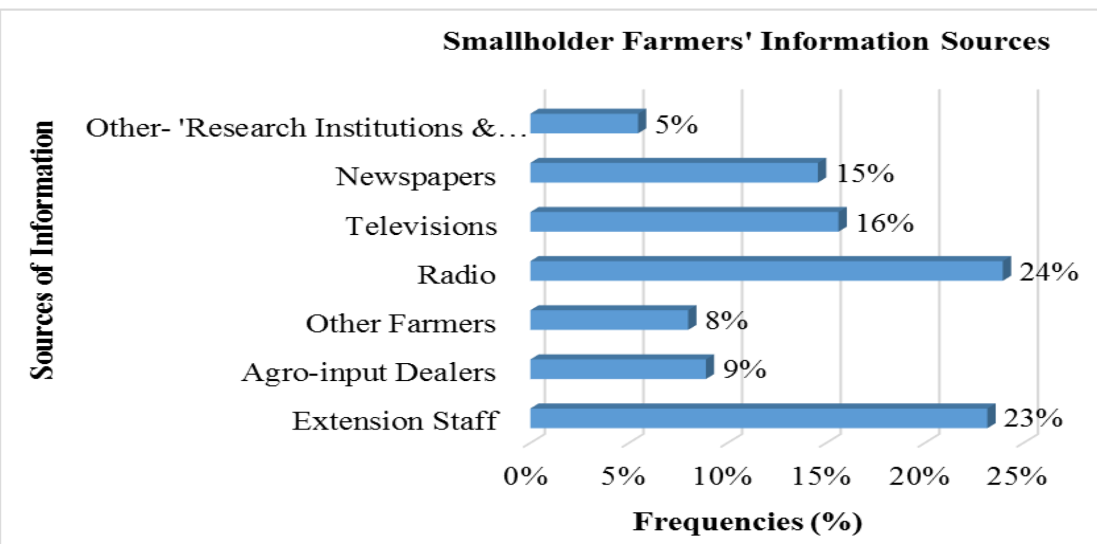


Figure 4.13: Sources of Information for control of FAW invasion

On sources of information for control of fall armyworm invasion (Figure 4.13), listening to radio (24%) and information from extension staff (23%) are the most preferred source of information as compared with other sources of information. This finding indicates that smallholder farmers' sources of information is influenced by their socio-economic characteristics like age , income, education levels and gender thereby, choosing what information is useful and achievable during the control of fall armyworm invasion. On the sources of information by gender preferences (Figure 4.14), 13% female farmers prefers either radio or information from agricultural extension staff respectively whereas, 11% and 11% male farmers preferring radio and sourcing information from agricultural extension staff respectively. This implies that the farmers prefer the two sources of information probably because of accuracy and reliability.

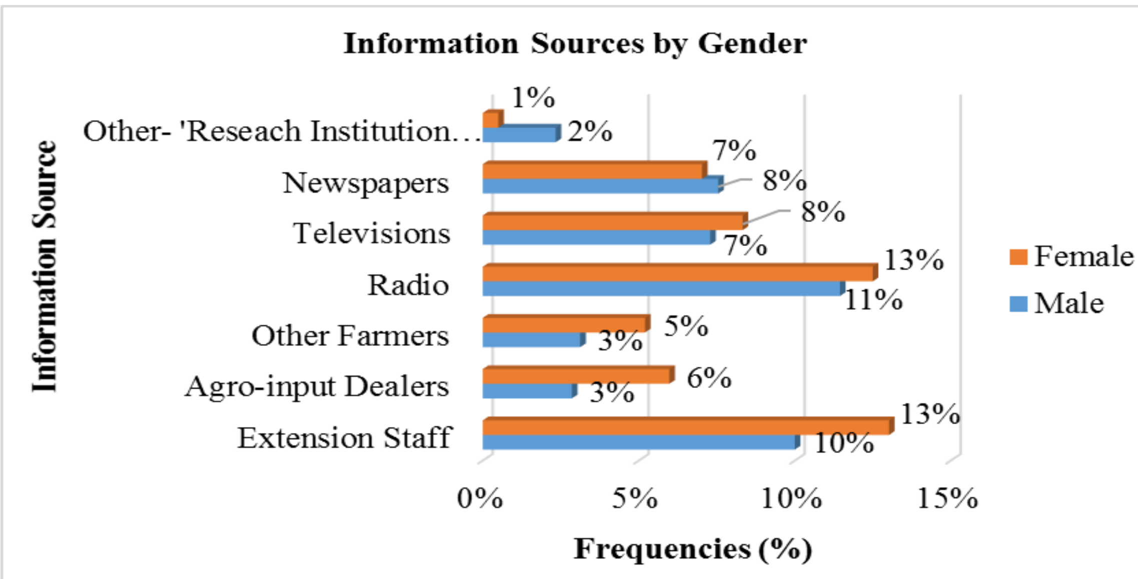


Figure 4. 14: Source of Information for FAW management by Gender

On the source of information for FAW management by gender (Figure 4.14), the result shows there are different gender preferences on the sources of information whereas, information is seen as a productive resource that can either limit or influence the efficiency of controlling fall armyworm invasion during agricultural production. This is in support with a study done by Sun and Zhang (2021), who noted that for any effectiveness during agricultural production, the information sources should be reliable towards the control of crop pests and diseases including FAW invasion thereby, enhancing household food security and environmental sustainability. The sourcing of information shows that different headed households are not homogeneous and that smallholder farmers' need to make informed decisions and have access to recent information about the management of fall armyworm invasion. The main causes of poor food yield and low production among smallholder farmers' are lack of recent information at the farm level especially during management of invasive crop pests including fall armyworm requiring technical expertise (Myint *et al.*, 2020).

The results on the type of information that is easy to understand by gender (Figure 4.15), 30% male and 21% female reads posters with 6% male and 22% female attending community meetings (baraza) for oral training whereas, 8% male and 10% female reads the leaflets or brochures and 2% male and 2% female read local newspapers.

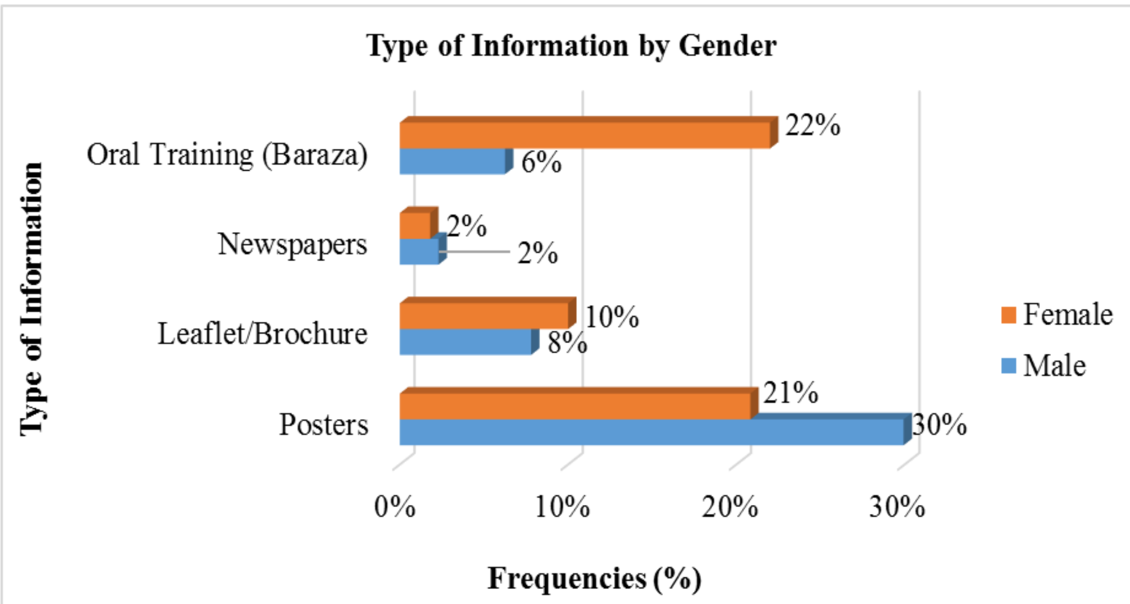


Figure 4. 15: Type of Information for the control of FAW by Gender

The result in Figure 4.15 indicates the type of information shows the literacy level of the farmers thereby, determining the management strategies to use for the control of fall armyworm invasion. However, the information in general cannot control fall armyworm unless the different headed households' acceses the right type of information and at the right time through the right channels. Msoffe and Ngulube (2016) opined smallholder farmers in the rural areas mostly engage in subsistence and are mainly illiterate. Therefore, requires access to appropriate information (local dialect) and quickest way to be able to discharge informed decisions and improve agricultural production towards different household food security and environmental sustainability. On the type of information for the control of FAW invasion by gender (Figure 4.15), the result implies that the transfer of information is a crucial pathway during FAW control with gender preferential of the type of information that communicates to the smallholder farmers easily.

4.2.9 Reason for Agricultural production and Indicators of FAW invasion

The results on reason for agricultural production shows 73.4% practice agriculture for households' food consumption and 26.6% practicing for income generation (Figure 4.16). The result on reason for agriculture by gender shows 33% male and 40% female practice agriculture for household food consumption whereas, 12% male and 15% female practice agriculture for income generation.

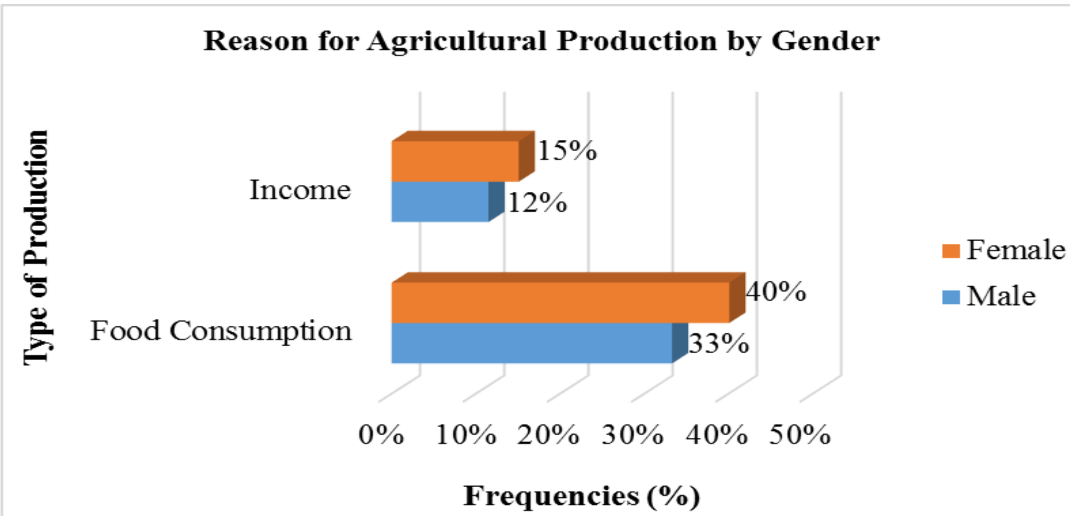


Figure 4. 16: Reason for Agricultural Production by Gender

The result (Figure 4.16) shows that female farmers produces more in food consumption (40%) and income generation (15%) as compared with male farmers (33% in food consumption and 12% in income generation) depicting a contrast in the production ability between different headed households. This finding shows that during capacity building on the best control technologies for fall armyworm invasion, smallholder farmers' reason for agricultural production taken into consideration within different headed households (male and female).

4.3 Coping and Adaptation Strategies used to control FAW Invasion

The emerging of fall armyworm in farmers' crop fields threatens the household food production resilience and income as result of crop yield loss or even total crop failure. Bomet County is an agricultural County and during the arrival of fall armyworm invasion on farmers' fields, smallholder farmers changed their agricultural food production norms tremendously. Smallholder farmers' uses different mitigation strategies with a combination of both coping and adaptation strategies guided by their different socio-economic factors within different headed households during FAW invasion. The study result shows 52% farmers use chemical pesticide spraying with 12% using spiritual prayers whereas 3% use traditional seers and hand picking through manual killing respectively (Figure 4.17).

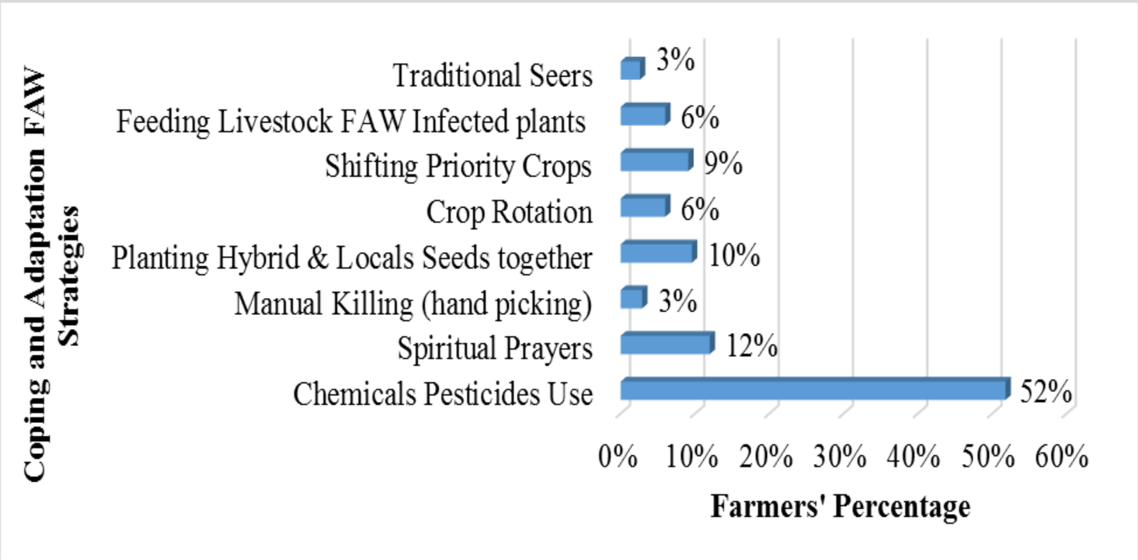


Figure 4. 17: Coping and Adaptation Strategies used for FAW Control

These findings in Figure 4.17 indicates smallholder farmers use strategies that are responsive towards FAW invasion control towards households' food security and environmental sustainability. This is in agreement with studies by Ansah *et al.* (2021) and Kom *et al.* (2020) who notes that smallholder farmers develop management strategies during agricultural stresses and shocks, which are responsive and socially acceptable within their communal surroundings towards yielding positive household food production and a sustainable environment.

The finding shows smallholder farmers have adapted to different FAW control measures that are because of continued FAW invasion in their crop fields. The strategies adapted include planting hybrid maize seed together with local seed varieties (10%), shifting of priority crops to alternative crops (9%), practicing crop rotation (6%), and feeding livestock with plants infected with FAW (6%) (Figure 4.17).

The result on the adaptation strategies used to control fall armyworm invasion (Figure 4.17) indicates planting hybrid maize seed together with local seed varieties is the most preferred adaptation strategy used by smallholder farmers as compared with other adaptations strategies (shifting of crop preferences, crop rotation and feeding infected plants to livestock). Planting hybrid maize seed together with local seed varieties ensures food security and the local varieties are resistant to FAW invasion. This result supports findings by Castells-Quintana *et al.* (2018) and Ofoegbu *et al.* (2016) who notes in their studies that farmers have their own mechanism of understanding and prioritizing the nature of agricultural production shocks thereby, prioritizing different adaptation strategies towards food production resilience and environmental sustainability.

The finding on gender and use of coping and adaptation strategies during FAW invasion shows 23% male and 29% female smallholder farmers use chemical spraying with 1% male and 2% female smallholder farmers opting for traditional seers whereas, 4% male and 8% female smallholder farmers uses spiritual prayers (Figure 4.18). The results further shows 5% of both female and male smallholder farmers prefer planting hybrid and local maize seed varieties whereas 4% male and 5% female farmers shift their priority crops. The finding further shows that 2% female and 4% male practice crop rotation with 1% female and 5% male feeding infected crop plants with FAW to their livestock whereas 2% male and 1% female opts for manual killing (hand picking) of FAW caterpillars (Figure 4.18).

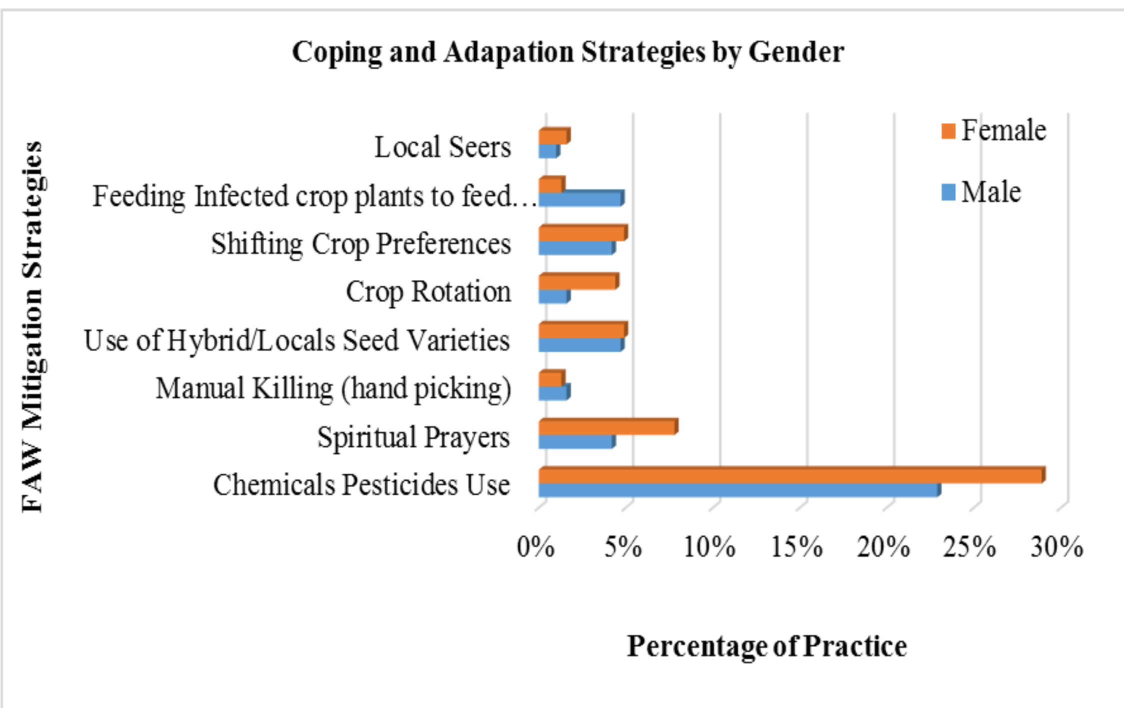


Figure 4.18: FAW Coping and Adaptation Strategies by Gender

The result in Figure 4.18 shows that planting hybrid alongside local maize seed varieties is the most preferred adaptation strategy by male (5%) and female (5%) farmers as compared with the strategies that smallholder farmers chose as their adaptation strategies (shifting of crop preference, crop rotation and feeding livestock with infected plants) during fall armyworm invasion. To determine if there is a relationship between adaptation strategies by gender using chi- square analysis, the result shows there was no significant relationship between the chosen adaptation strategies' and gender, (χ^2 =16.313, DF=7, p=.022). The finding is an indication that there are no differences within different headed households and the adaptation strategies used during the control of fall armyworm invasion not determined by gender. The result supports studies by Savary *et al.* (2020), World Health Organization (2020) and Yazdanpanah *et al.* (2021) who notes that many differentiated smallholder households in Sub-Saharan Africa are food insecure and the invasion of FAW on the crop fields will compound the food production resiliency in different headed households to being food insecure.

4.3.1 Chemical use (pesticide spraying and local mixtures)

The results on chemical spray entailed the use of synthetic pesticides and local mixtures including ash, detergent and pepper. Results on the gender perspective indicates 23% male and 29% female farmers' uses chemicals (pesticide and local mixtures (ash, detergent and pepper) as the main coping strategy towards control of fall armyworm (Figure 4.19).

The total gender percentage preference of 52% (male and female) smallholder farmers using chemical spray (pesticides and local mixtures) towards control of FAW invasion as compared with other coping strategies, indicate chemical spray is the main preferred coping strategy towards control of FAW invasion. The high usage of chemical spray by smallholder farmers is either due to free acquisition of the pesticides through the government during the arrival of FAW in the country in 2016 or the accessibility and availability of the pesticides from the local agro-vet shops and locally found mixtures. These concurs with Harrison *et al.* (2019), Hruska (2019), Kabwe *et al.* (2018) and Tambo *et al.* (2020) stated in the newness of fall armyworm in African farm crops by 2016 affected many crop fields. This left many governments including Kenya grappling for the easiest management options resulting to using subsidized pesticides for quick and easy control to remedy further crop damage (Abro *et al.,* 2021; Bannor *et al.,* 2022; Otim *et al.,* 2021).

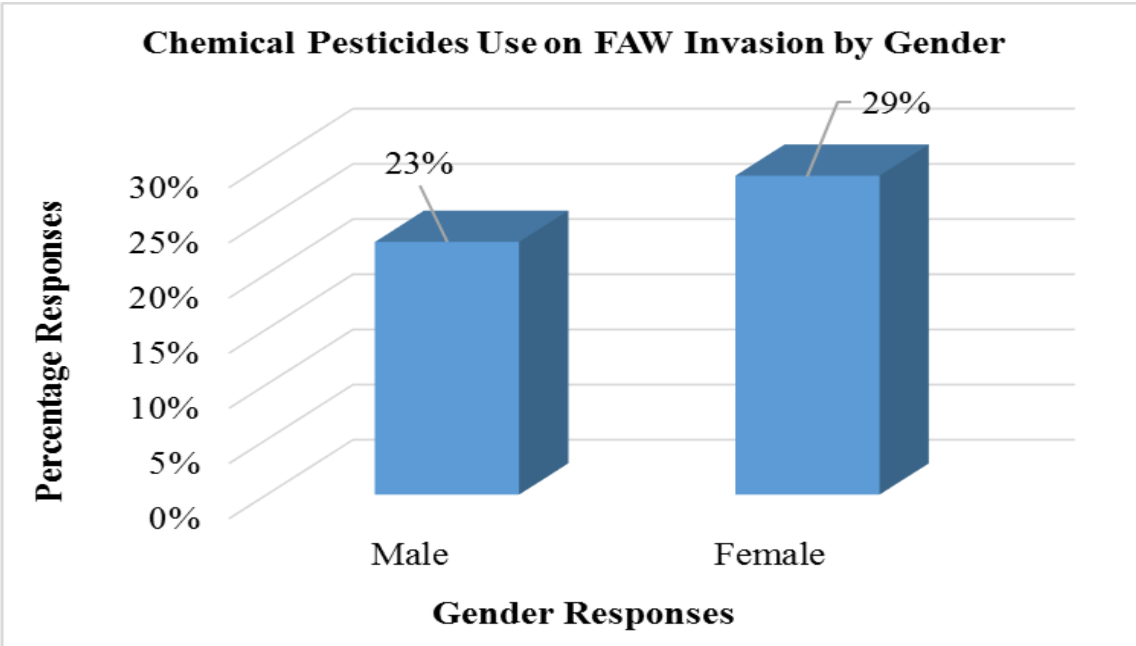


Figure 4. 19: Chemical Pesticides use during FAW Invasion by Gender

On chemical pesticide use as a coping strategy by gender (Figure 4.19), despite male (23%) and female (29%) farmers are using chemical spray as their main coping strategy, female farmers accessed chemical pesticides more as compared by male farmers with a 6% difference. Another view, despite the 6% difference between female and male farmers, the results shows a likelihood of other factors like the socio-economic factors that contributed to the accessibility of the chemical pesticides by both male and female smallholder farmers. This finding is an indication that there is a high usage of chemical pesticide spraying during the control of FAW invasion by different headed households with a likelihood of contaminating the environment leading to ill health of the households. This finding requires capacity building on safe handling of chemical pesticides and disposal of used containers on both male and female farmers so as not to be gender discriminatory. The training of both male and female smallholder farmers on the handling and use of chemical pesticides will minimize the vulnerability to the exposures of pesticides thereby not compromising the health of households' and the environment during fall armyworm management.

The findings on comparing coping strategies with households composition shows the household clusters from 4 family members to 11 family members were the highest chemical spraying users with 60% whereas, those from households clusters 12 to 14 and 1 to 3 uses 2% and 1% chemical spray respectively (Figure 4.20).

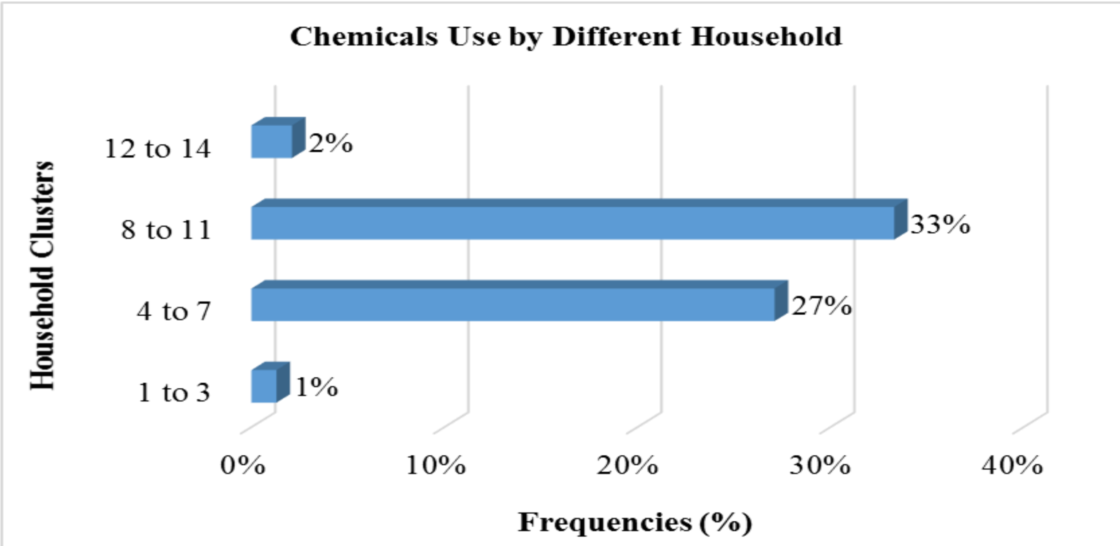


Figure 4. 20: Chemical Use as a coping strategy by Household Clusters

The result (Figure 4.20) indicates chemical spray is used more on households' clusters of family members from 4 to 11. This implies that households take advantage of the moderate number of members within the households to perform more tasks such as chemical spray. However, a high number of household members exposed to the health risks of the effects of chemical use during pesticides spraying thereby increasing expenditure on ill health of the household members.

4.3.2 Spiritual Interventions (Prayers)

Study result shows smallholder farmers (n=46) have their own social ways of dealing with agricultural shocks including fall armyworm. The result on going for spiritual intervention, 12% farmers resorted to controlling FAW invasion on their crop fields through communing with God with a gender proportion of males (n=15) and females (n=31) choosing prayers (God's intervention) as a coping strategy against fall armyworm invasion (Figure 4.21). This strategy is an indication that smallholder farmers attach spiritual relationships during agricultural production especially food crop production.

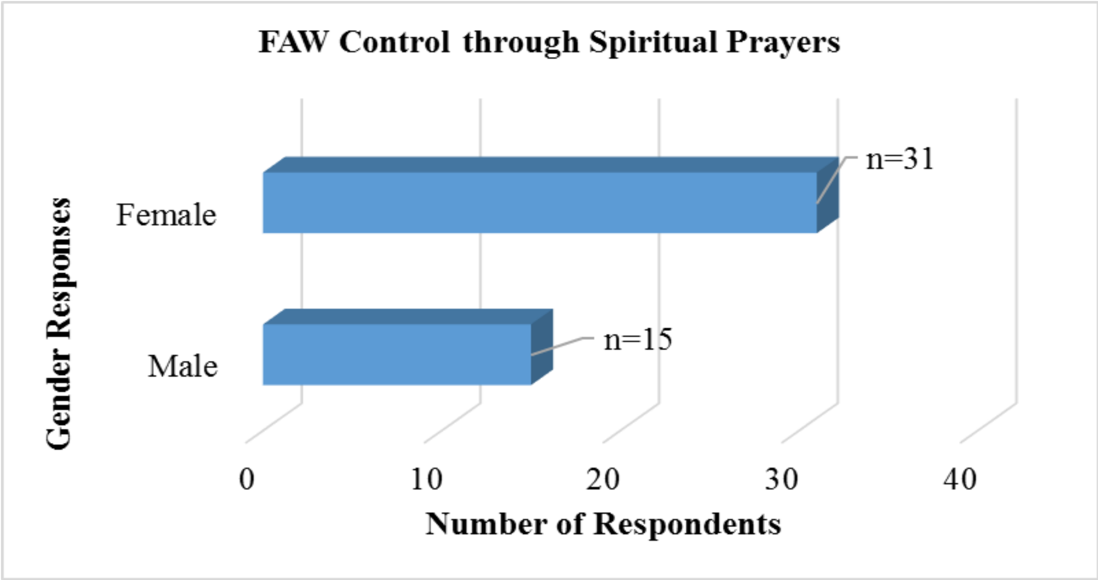


Figure 4. 21: FAW Invasion control through Spiritual Prayers by Gender

The result on coping strategy through spiritual intervention by gender (Figure 4.21) indicates the persistent of the invasion of fall armyworm in smallholder farmers' crop fields, 8% female farmers' turns to prayers for protection of their field crops compared to 4% male farmers. The finding shows that female farmers have a higher inclination trust of social belief (prayers) during agricultural production that any agricultural shocks remedied through prayers. This finding is in agreement with a study by Zhang (2022) who states that human being embodies cultural beliefs during any food production especially the traditional food crops that are gender inclined and revered in both cultural identity and spiritual angles. Spiritual intervention (prayers) during agricultural production entails the inner consciousness of the farmers and it serves as a way of communicating with the spirit of the land during food production (Figure 4.22).

Figure 4. 22: Image of Traditional Seer using Charms and Female farmer praying for her crop at Chepalungu, Bomet County

4.3.3 Consulting Traditional Seers

The study findings indicate the respondents believe the traditional seers whom they refer 'future foretellers' have mystical powers that counteract befallen calamities including agricultural shocks by transmitting their powers through use of charms (Figure 4.22). According to smallholder farmers, the respect and reverence accorded to traditional seers believes to foretell the future once befallen with calamity like the invasion of fall armyworm. The gender response shows male farmers (n=3) and females farmers (n=7) sought the intervention of traditional seers to control the invasion of FAW in their crop fields (Figure 4.23).

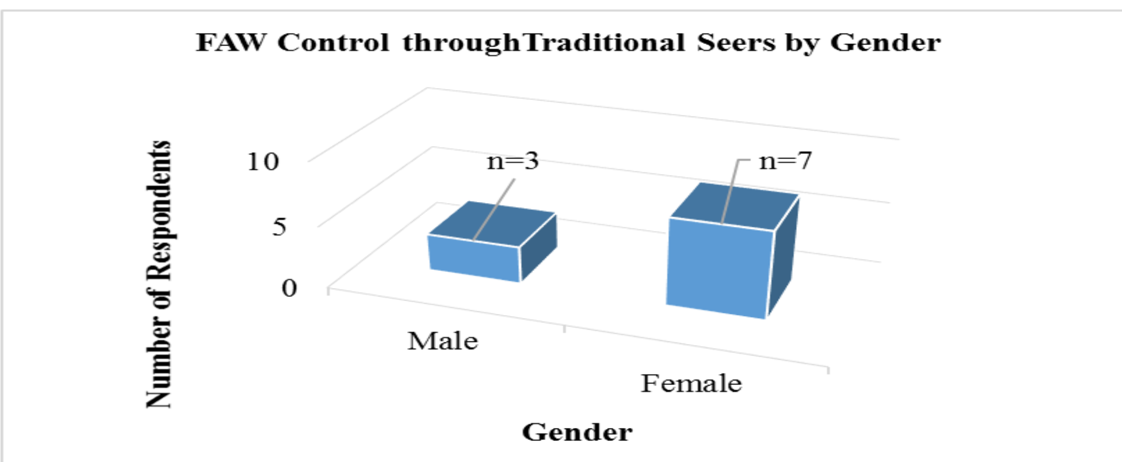


Figure 4. 23: FAW Coping Strategy through Traditional Seers by Gender

The finding in Figure 4.23 shows a gender differential percentage of 1% on engaging the traditional seers' between male and female respondents is either due to their socio-economic differences between male headed and female headed households or the respondents cultural beliefs and spiritual connections during agricultural production shocks. This finding agrees with Das (2022) and Tanko and Ismaila (2021) whose studies indicated that spiritual religion affects agricultural production and households are culturally webbed where spiritual willpower and traditional knowledge controls an individual during agricultural shocks. The finding show that the social-cultural believes amongst smallholder farmers gendered and that the spiritual and traditional seers cannot control fall armyworm invasion rather expose different headed households to being food insecure and contamination of the environment due poor FAW invasion management.

4.3.4 Manual Killings of Fall Armyworm

The result on handpicking strategy of fall armyworm caterpillar requires the smallholder farmers (n=11) to tear open the maize whorl or cob to expose the fall armyworm caterpillar that has burrowed deep into the maize to hide and feed (Figure 4.24). Once the caterpillar is exposed open, the farmer handpicks the caterpillar of fall armyworm and killing it.

Figure 4. 24: Image of FAW caterpillar on the maize whorl and cob at Bomet East, Bomet County

The result demonstrates that for smallholder farmers to be food secure, they must be resilient in adapting diverse measures towards the control of fall armyworm invasion. On the manual killing by gender (Figure 4.25), 2% male and 1% female farmers' use manual killing as a coping strategy to control fall armyworm invasion.

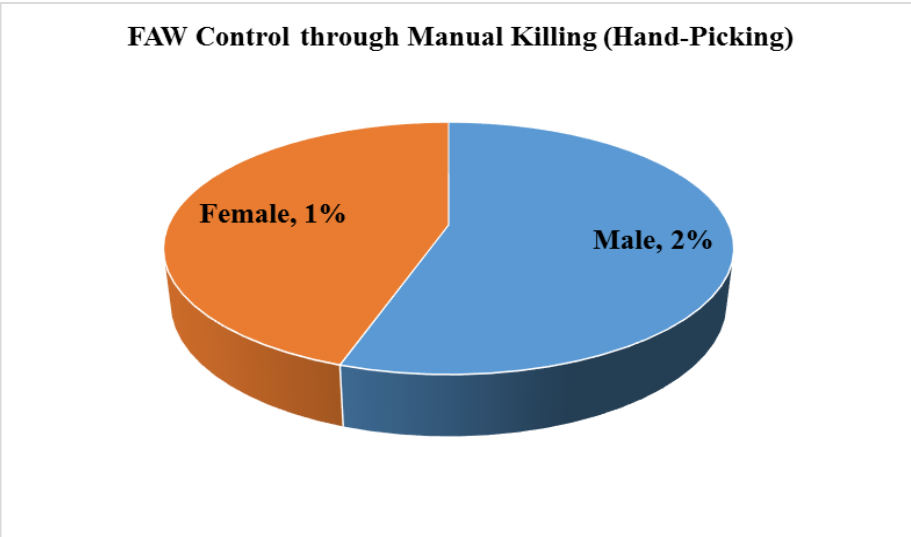


Figure 4. 25: FAW Coping Strategy through Manual Killing by Gender

The finding on FAW control through mechanical strategy as a choice of coping strategy by smallholder farmers (3%) (Figure 4.25), indicates a lower proportion percentage of 1% female farmers are involved on manually hand picking and killing the fall armyworm caterpillar as compared to 2% male farmers within different headed households. This percentage differentiation is a likely attribute to the education level differences, which requires technical knowledge, and understanding of the morphological behaviour of FAW (burrows deep into the maize whorl) and being a new invasive pest as compared to other crop pests requires thorough scouting and tearing of the maize cob to expose the caterpillar.

Studies have indicated that maize is the major food crop consumed in Kenya whereas the invasion of FAW is likely to reduce different headed household's food security. The result shows the tearing of maize cobs to kill the FAW caterpillar will reduce drastically maize yields either due to the destroyed maize cob or time used to scout and kill the FAW caterpillar meant for other productive activities during agricultural production thereby, making different headed households to being food insecure. This finding is in agreement with Chimweta *et al.* (2020) and Kansiime *et al.* (2019) whose studies stated that handpicking of crop pests by smallholder farmers in the

African region has been an old age tradition of crop protection. They noted that the strategy is laborious and time-consuming requiring the involvement of smallholder farmers to mechanically collect the caterpillars and destroy them through either smothering or burning and can only be feasible on a small acreage of field crops. This is an indication that manual killing through handpicking of the FAW caterpillar is not a viable strategy on a larger acreage of land due to the destruction of maize cobs, which will pre-dispose many households to being food insecure.

4.3.5 Shifting of priority crop production

The results in shifting of priority crop production by smallholder farmers (n=35, 9%) is an adaptation strategy whereas, different headed households change from planting their prioritised and preferred food crops (maize) to other local crops (sorghum, finger millet and sweet potatoes) due to the invasion of FAW in their crop fields. The result shows (n=16, 4%) male and (n=19, 5%) female farmers shifts their crop preferences to crops that are not affected by fall armyworm invasion (Figure 4.26).

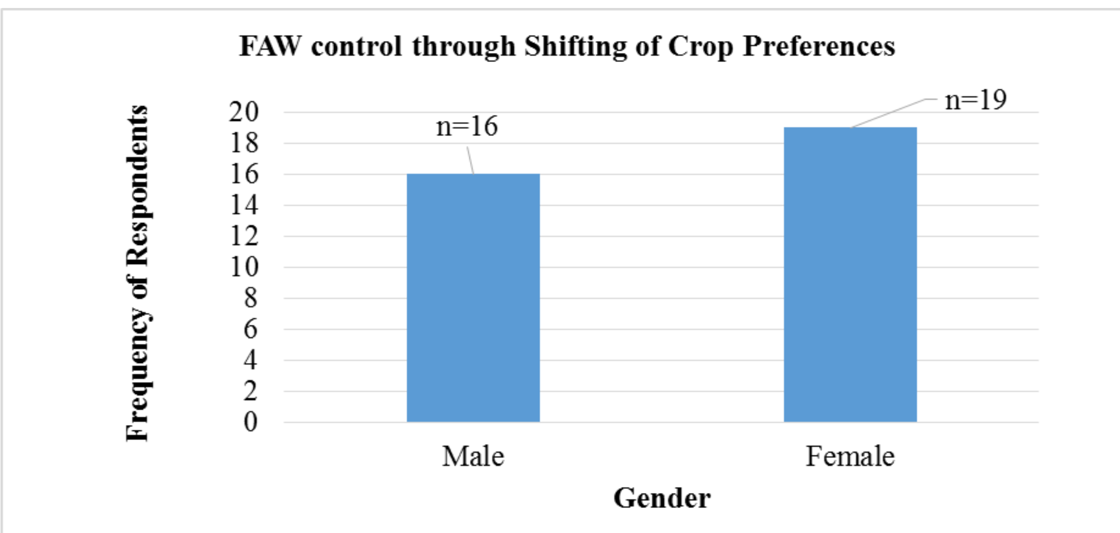


Figure 4. 26: Shifting crop preferences by gender

The result of shifting crop preferences by gender (Figure 4.26) shows that FAW invasion makes smallholder farmers to change their agricultural choices towards meeting the agricultural production requirements. The finding further shows 45.8% smallholder farmers have reasons for shifting their crop preferences due to production for home consumption (73%) and production for income generation (27%) (Figure 4.27).

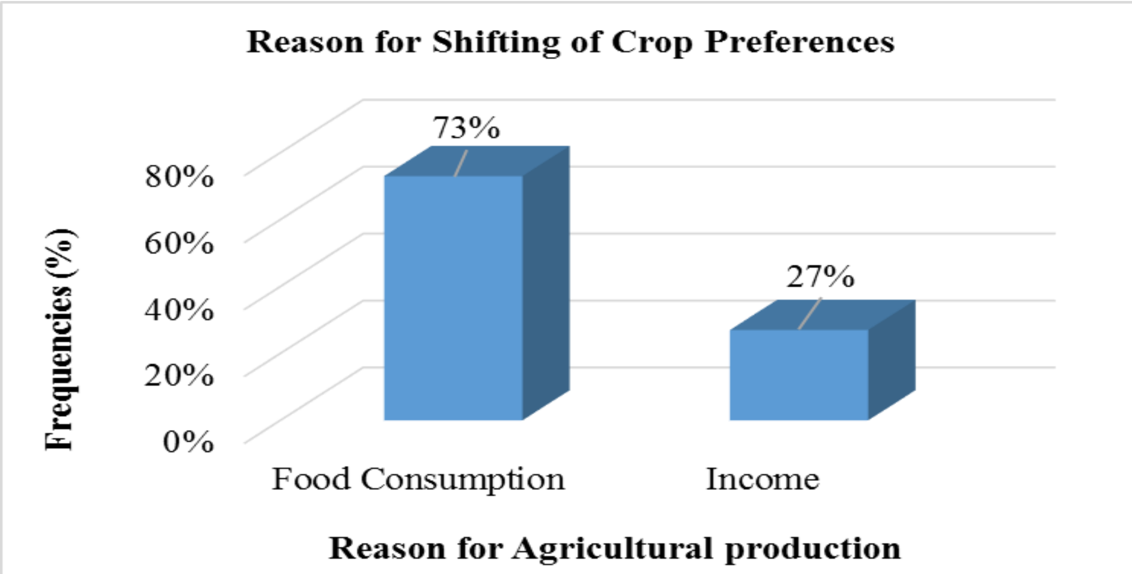


Figure 4. 27: Reason for Shifting of crop preference

The finding on reason for shifting of crop preference (Figure 4.27) shows that food consumption is the main reason smallholder farmers' shifts crop preference towards other crop type production. The finding indicates that the invasion of fall armyworm in smallholder farmers' crop fields has a likelihood of many households (73%) becoming food insecure whereas 27% are likely to compromise their source of livelihood from income due to fall armyworm invasion.

On the prioritized crops shifted during FAW invasion (Figure 4.28), 19% smallholder farmers' shifts to planting finger millet with 11% planting sorghum whereas 9% shifts to sweet potatoes and 5% opts for napier-grass (Figure 4.28). The finding shows that smallholder farmers' shifts from the most preferred crops to crops that are known as traditional crops indicates the resilience on food production within different headed households. Elsewhere, a study by Abeywardana *et al.* (2019) on indigenous agricultural systems shows that smallholder farmers have local crops produced by female farmers whereas during agricultural shocks, both male and female-headed households produce the production of these crops.

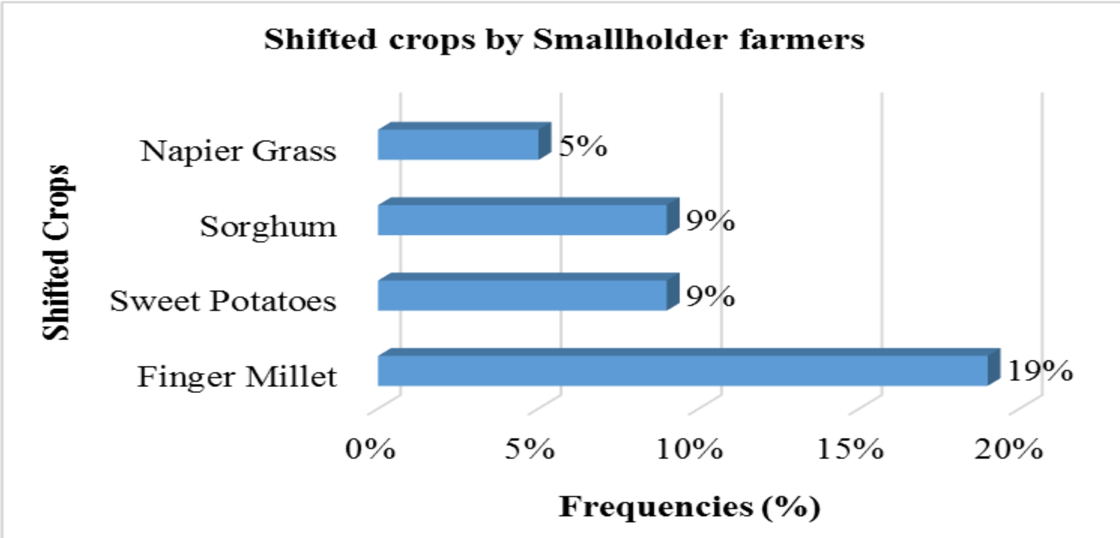


Figure 4. 28: Prioritized shifted crops during fall armyworm invasion

The result in Figure 4.26 shows that production of food crops and consequently the livelihood of the farmers threatened by the invasion and widespread infestations of the fall armyworm (*S. frugiperda*) which has led smallholder farmers to shifting their crop preferences to those not affected by fall armyworm invasion.

The finding on gender proportion indicates 9% male and 10% female shifts to finger-millet with 3% male and 6% female shifting to sorghum production whereas 5% male and 4% female planting sweet potatoes and 2% male and 3% female shifts to napier grass production (Figure 4.29). Another view, determining if there is a relationship between gender and shifted prioritized crops using a chi-square test analysis, the result shows a no statistically significant relationship between shifted prioritized crops and gender (χ^2=4.030, DF=3, p=0.402). This finding indicate that smallholder farmers have diverse adaptation strategies during any agricultural shocks regardless of the gender of the household head.

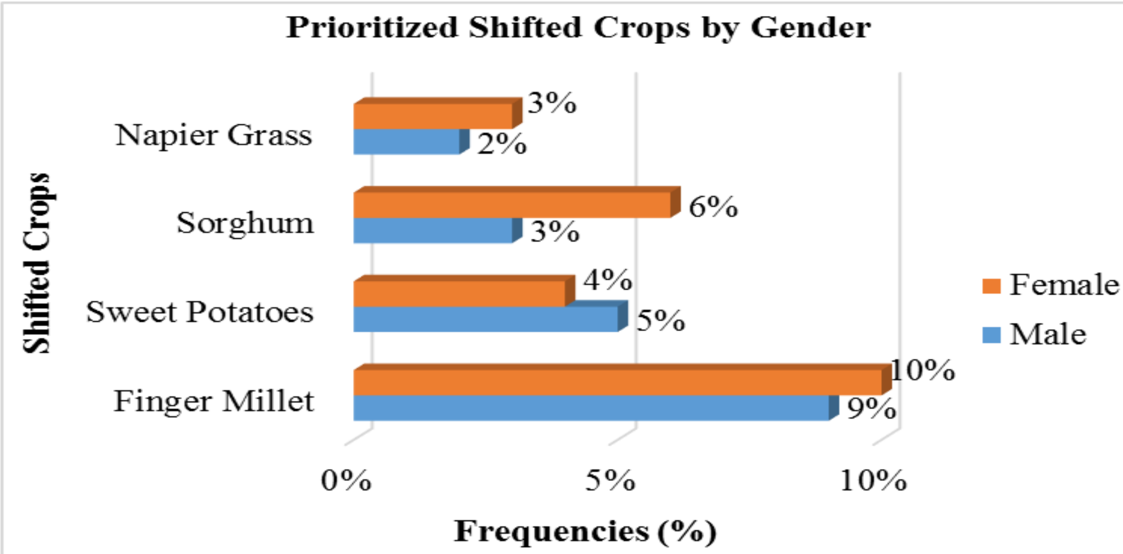


Figure 4. 29: Prioritized Shifted Crops by Gender

On prioritized shifting of crops by gender (Figure 4.29), the finding indicates that smallholder farmers develop and prioritize their crop pattern production during agricultural production shocks towards household food security during fall armyworm invasion. The result is in agreement with studies by Chimweta *et al.* (2020), Kasoma *et al.* (2021), Mallapur *et al.* (2018) and Tambo *et al.* (2020) states in their studies that smallholder farmers develop adaptation strategies that are suitable within their own social settings with the set prioritized objectives of being food security. The researcher however, found that the invasion of fall armyworm changed the gender roles within different headed households through shifting of their crop production patterns to new crops, which were not gender controlled.

4.3.6 Mixing hybrid seeds with local seeds for food crop production

The study result indicates 10% smallholder farmers adapts to planting hybrid maize seeds alongside the local maize seed varieties to mitigate FAW invasion with a gender proportion of 5% male and 5% female practicing the strategy as an adaptation strategy against fall armyworm invasion (Figure 4.31). The planting of hybrid alongside local maize varieties (Figure 4.30) is termed by male and female farmers as a sure way of ensuring household food security and environmental sustainability.

Figure 4. 30: Image of Hybrid and local maize varieties planted alongside each other at Konoin, Bomet County.

The finding shows 83% smallholder farmers' plant different maize hybrid seed varieties with 24% planting 513, 23% plants 520, 18% plants 614, 10% plants 6213 and 8% plants DK777 whereas the local maize varieties have 10% planting ndere and 7% opting for kipkaa (Figure 4.31).

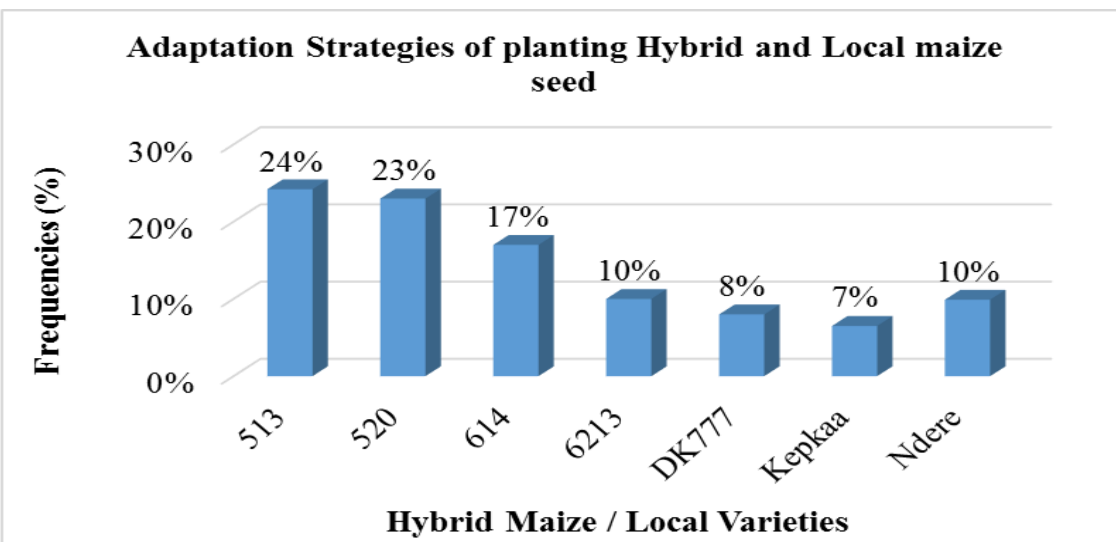


Figure 4. 31: Hybrid and Local maize Seed Varieties Planted

Result on FAW adaptations strategies through hybrid and local maize seed (Figure 4.28), indicates smallholder farmers' have different options of hybrid maize seed whereas they choose to plant the local varieties (ndere, 10% and Kepkaa, 7%) alongside hybrid maize seeds as a way of cushioning themselves from the invasion of fall armyworm towards household food security.

The result on the gender choices of maize seed they plant, 13% female and 12% male plant hybrid 513 with 13% female and 10% male planting 520 maize variety. The finding further shows 9% female and male and with 5%, female and male plant 614 and 6213 maize varieties whereas 6% female, 3% male, and DK777 maize seed variety. The finding on the local maize seed varieties shows 8% female and 2% male plant ndere with 5% female and 2% male planting kepkaa varieties (Fig. 4.29).

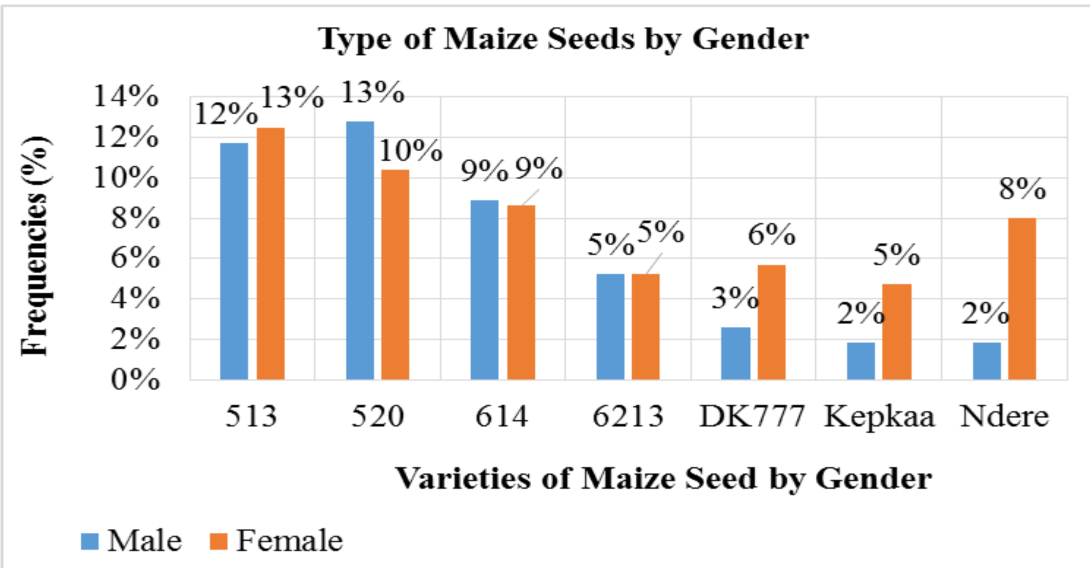


Figure 4. 32: Type of Maize Seed Planted by Gender

The result on the type of maize seed planted by gender (Figure 4.29) indicates the use of the local knowledge of planting local maize seeds alongside hybrid maize seeds as an adaptation strategy against fall armyworm invasion enhances household food security and a sustainable environment. The production of these local maize varieties are regarded by different gender as a social-cultural entity whereas the production is an indication of the smallholder farmers' eating habits (local maize seed are sweet when roasted) moreover, it is tolerant to fall armyworm invasion. This findings compliments studies by Chimweta *et al.* (2020) and Mallapur *et al.* (2018) who noted that different farm families are food insecure due to usage of uncertified planting seed thereby compromising their households' food security.

The result on the sources of hybrid maize seed and local maize seed varieties shows 30.5% sources their maize seed from local agro-vet dealers and 24.5% recycling their own maize seeds from the previous harvests. The result further indicates 18.2% buys from other farmers and 14.3% gets the seeds from companies free (for trials) whereas 12.5% sources from training institutions like KALRO and Universities (Figure 4.33).

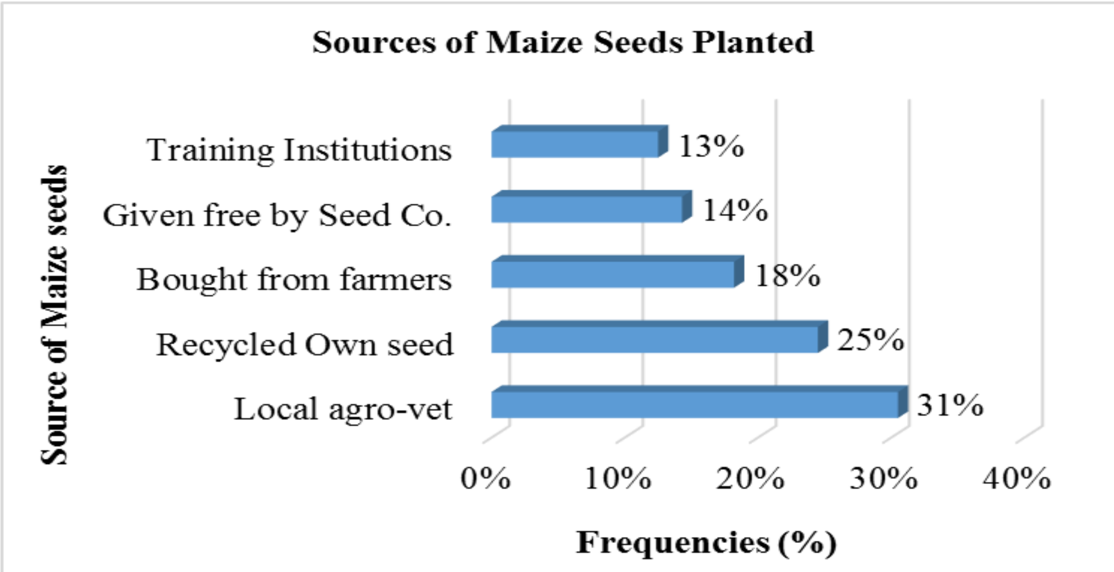


Figure 4. 33: Sources of Maize Seeds Planted by Smallholder Farmers

On sources of maize seeds plants by smallholder farmers (Figure 4.33), the accessibility of maize seed (hybrid seeds) sourced from local agro-vets with a large number of 25% recycling their own seed for planting. The results from the previous findings have shown that 73% households practice agriculture for home consumption whereas 27% practice for income generation. With this findings, there is a likelihood of many households' being food insecure due to fall armyworm invasion.

The findings on different households by gender on the sources of maize seed, 12% male and 19% male source their maize seed from local agro-vets with 14% male and 11% female opts for recycling their own seed (Figure 4.34). The result further shows that 8% male and 10% female buys from their neighbours (other farmers) whereas 7% male and female are given free by seed companies for farm trials and 4% male 8% female acquires their maize seed from training institutions (KALRO and Universities). The result in determining if there is a relationship between sources of maize seeds and gender using a chi-square test analysis, the result shows a no statistically significant relationship between sources of maize seed and gender (χ^2=8.052, DF=4 p=.09).

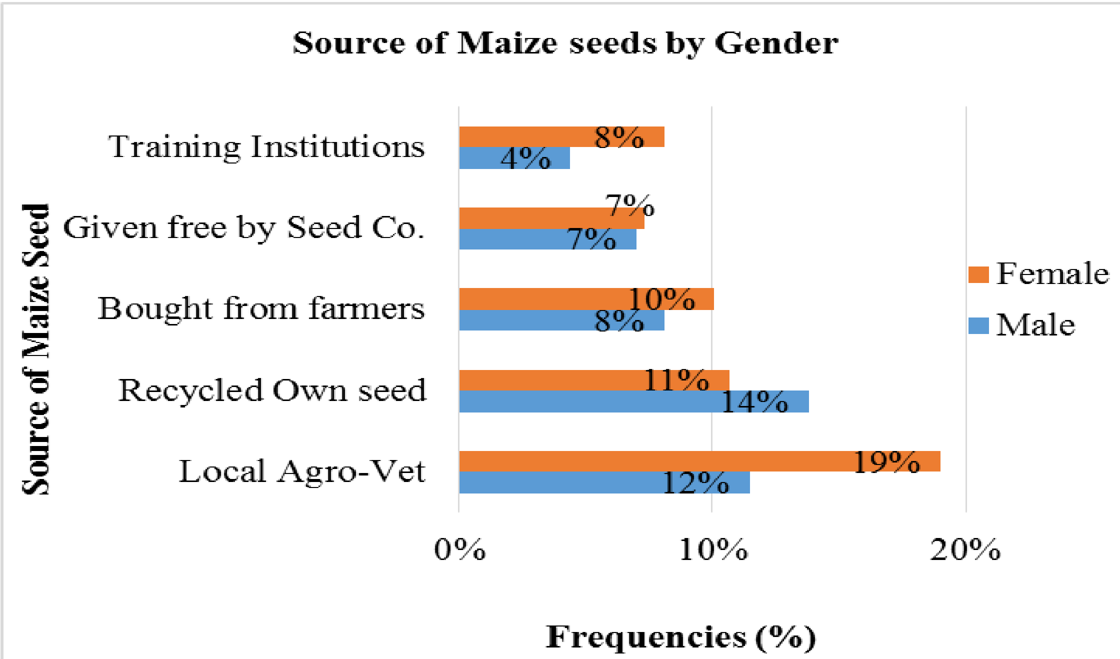


Figure 4. 34: Sources of Maize Seeds by Gender

Result on sources of maize seeds planted by gender (Figure 4.34), local agro-vet dealers being the main source of maize seeds to smallholder farmers with 14% male and 11% female farmers recycling their own seed from the previous harvests due to easy accessibility and cost effective. The recycling of maize seed gendered with male farmers recycling more seed as compared with female farmers an indication that male-headed households are likely to being food insecure as compared to female-headed households.

4.3.7 Crop rotations

The results from the study indicate 6% smallholder farmers practice crop rotation where they plant different crops on the same land in consistent pattern. The result shows the smallholder farmers plant different food crops at the same land in a planned sequence with the succeeding crops belonging to a different family of crops (Figure 4.35). The smallholder farmers (2% male and 4% female) indicates that crop rotation produces different type of crops (beans, fodder, cereals and vegetables) at one season enhancing consumptive varieties of foods and income generation within different headed households.

Figure 4. 35: A male farmers showing different crop production at his farm Sotik, Bomet County

The result in the illustration (Figure 4.35) shows a higher diversity of crop production with a likelihood of increasing in soil humus whereas, when comparing the type of crop practice, 20% male and 27% female practice mono cropping with 25% male and 29% male practice inter-cropping patterns of farming (Fig.4.36).

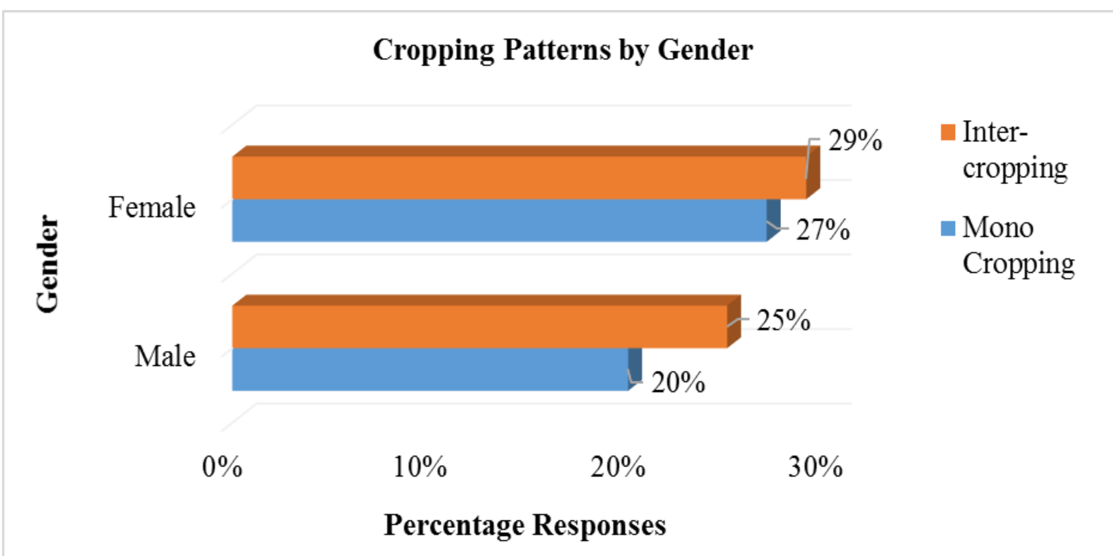


Figure 4. 36: Crop patterns within crop rotation by gender

The result in Figure 4.36 indicates intercropping of crop production as compared to mono cropping is the most preferred cropping pattern by both male and female smallholder farmers during crop rotation due to its diversity on crop production. The result on comparing if there is a relationship between cropping patterns and gender using a chi-test analysis, the results shows no significant relationship between the rotational cropping patterns and gender (χ^2=0.597, DF=2 p=.742). This finding infers that cropping patterns (mono cropping and inter-cropping) not controlled by gender rather they are determined by the farmers' specific objective of food production (Figure 4.37).

Figure 4. 37: Images of Mono- Cropping and Inter-Cropping Patterns at Bomet Central, Bomet County

The finding shows that crop rotation controls fall armyworm invasion due to the diversity of crops grown whereas, some are tolerant to FAW invasion thereby improving households' food security and environmental sustainability due to reductions of chemical use. This finding is in agreement with Francis and Clegg (2020) and Palm *et al.* (2014) whose studies stated that smallholder farmers traditionally used crop rotation as a measure towards maximizing crop yields towards household food security thereby practicing and managing the environment sustainably through a sequential cropping pattern within particular farmlands. This was an indication that crop rotation as an adaptation strategy against crop pests including FAW invasion indirectly enhances the integrated pest management (IPM) strategy thereby reducing the use of chemical and attaining sustainable environment and household food resilience.

4.3.8 Feeding livestock with infected plants

On feeding livestock with infected plants (Figure 4.33), 5% male and 1% female smallholder farmers feed the livestock with infected maize plants affected by FAW invasion as an adaptation strategy. The result shows the smallholder farmers' weed off the infected maize plants from the farmland thereby feeding the infected green maize stalk to animals. The finding further indicates that 34.9% male and 43.5% female farmers planting maize crop all year round with 9.9% male and 11.7% female planting maize in one season a year (Figure 4.33).

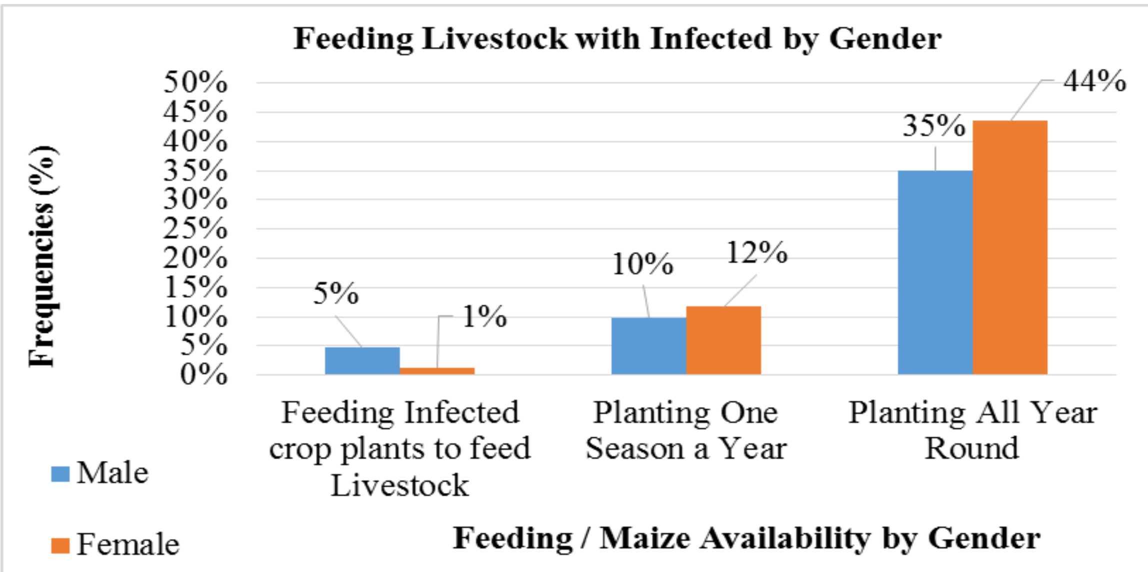


Figure 4. 38: Feeding Livestock with Infected Plants by Gender

The result in Figure 4.33 shows 79% of the smallholder farmers' plant crops in their farmland throughout the year in anticipation of getting maximum yields whereas, planting of crops all year round enhances the survival of fall armyworm invasion due to the availability of feeding vegetation. The finding further indicates that there is limited knowledge and understanding of pest management including FAW invasion whereas, smallholder farmers (6%) opts to feed their livestock with infected maize plants is an adaptation strategy of controlling FAW invasion in their crop fields. Studies by FAO (2018) and Mengistu *et al.* (2019) show that the movement of infected materials with fall armyworm pests is one mode of transferring the pest from one area to another. The result on the gender perspective indicated more males as compared to female smallholder farmers fed their livestock with FAW infected maize plants. This is an indication of resource control and the cultural association of livestock as a male identity within different headed households (Figure 4.39).

Figure 4. 39: Different stages of maize crop and infected maize plants as animal feed at Konoin, Bomet County

The result on comparing if there is a relationship between feeding livestock with infected maize plants and gender using a chi-test analysis, the results show no significant relationship between feeding livestock with infected maize plants and gender (χ^2=1.684, DF=2, *p*=.142). This findings show that the feeding of livestock with infected maize plants as an adaptation strategy by differential households is not effective towards control of FAW invasion rather it is a substitute of feed for animals thereby becoming an environmental pollutant due to transferring of FAW pests from one point of farm to the other.

4.4 Gender Roles in FAW Management

The study result shows that all the respondents have experienced fall armyworm invasion in their farm fields during agricultural production. The study findings has shown that agricultural production is the major source of livelihoods of the study smallholder farmers with 57% engaging on crop farming and 43% engaging in livestock production. The finding shows 14% male and 29% female are involved in livestock production whereas, 26% male and 31% female are involved in crop farming (Figure. 4.40).

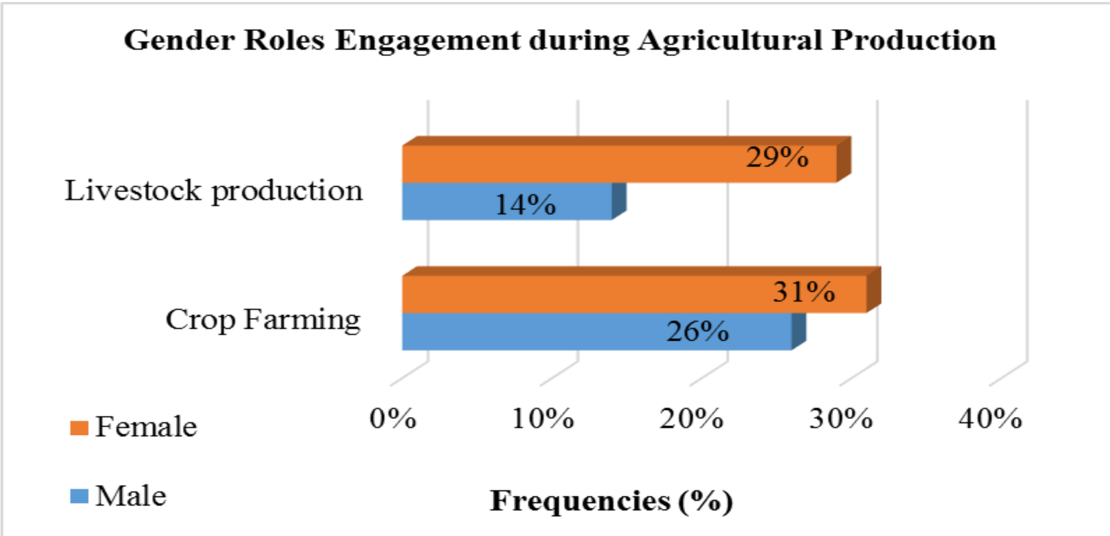


Figure 4. 40: Gender Roles Engagement during Agricultural Production

The result on gender roles' engagement during agricultural production (Figure 4.40), illustrates that different headed households' major source of livelihoods is from agricultural production with different gender roles and prioritization of activities apportioned during food production. This finding supports studies by Doss *et al.* (2015) and Huyer (2016) states that in the African households' farming setup, they engage gender roles based on the need and prioritization during agricultural production.

4.4.1 Gendered Roles on prioritized crops during FAW management

The gender roles findings indicated the social roles and activities engaged during agricultural production on controlling FAW invasion. The study finding shows smallholder farmers (n=384) engage themselves during FAW management whereas the roles are prioritized and dependent on the type of food crops being produced. The results further shows 36.7% engage in controlling FAW invasion during maize crop production with 29.2% controlling FAW during sorghum production whereas, 13.8% smallholder farmers engage in controlling FAW during finger millet production with 11.7% engaging in potatoes and sweet potatoes FAW control and 8.6% control FAW invasion during napier-grass production (Figure 4.41).

The study result on gender roles shows 16.4% male and 20.3% female farmers engage in controlling FAW invasion during maize production whereas, 13.5% male and 15.6% female control FAW during sorghum production. The decision to control FAW invasion during finger millet production has 2% male and 3% female farmers with 7% male and 6.8% female farmers whereas, 3.4% male and 5.2% female engages themselves in controlling FAW invasion during napier-grass production (Figure 4.41).

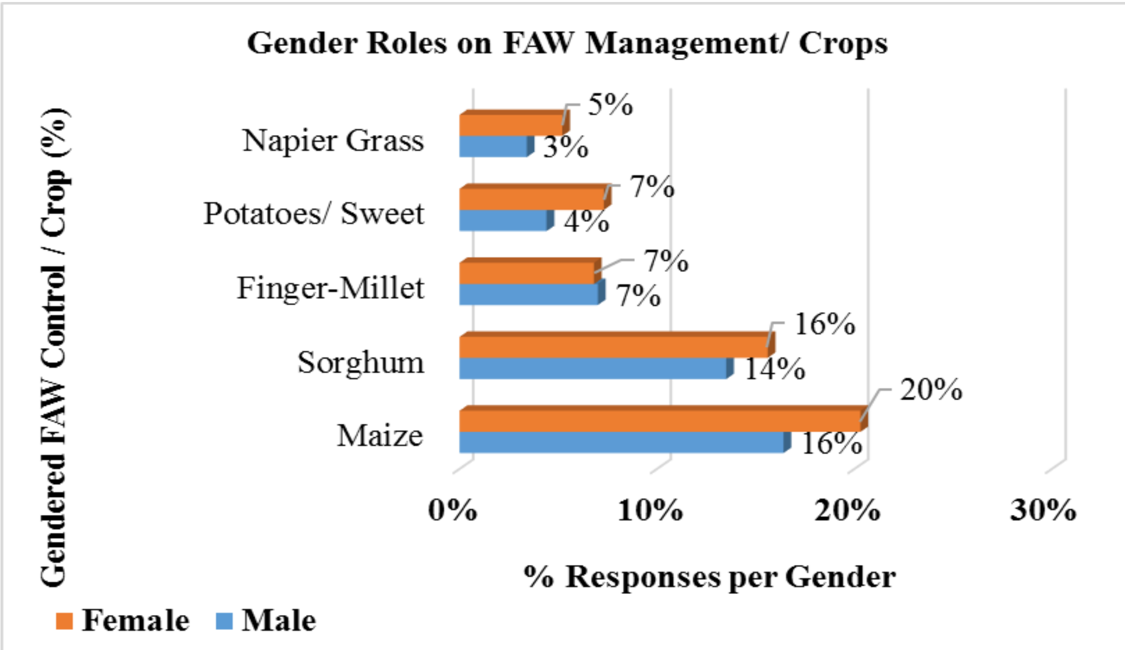


Figure 4. 41: Decisions on Gender Roles during FAW Management

The results on gender roles during fall armyworm management (Figure 4.41), there are gender roles differentials between male and female headed households during FAW management whereas, finger millet which is termed as an indigenous food crop, the FAW management roles 7% each is equally distributed between male and female farmer respectively. This finding supports a study done on a global outlook by Botreau and Cohen (2020) who stated that the indigenous food crops' reverence has no specific gender roles required for its production.

4.4.2 Gendered labour perspective during FAW management

The study result on the labour use by gender towards the control of fall armyworm is to understand how different gender provides labour on the prioritised crops during agricultural production. The result on gender roles apportionment towards labour engagement during agricultural production (Figure 4.42), 21% smallholder farmers use family labour in controlling FAW invasion during maize production whereas, 16% use family labour to control FAW invasion during sorghum production. The results shows hired labour is highest used during maize production (7%) whereas, control of FAW invasion during sorghum production uses 6%. The result on own labour between male and female household heads shows 31% male used own male labour in controlling FAW invasion during sorghum production as compared to female own labour of 4% only. The result further shows 0% of both male and female labour used during FAW control on both sweet potatoes and napier-grass production (Fig. 4.42).

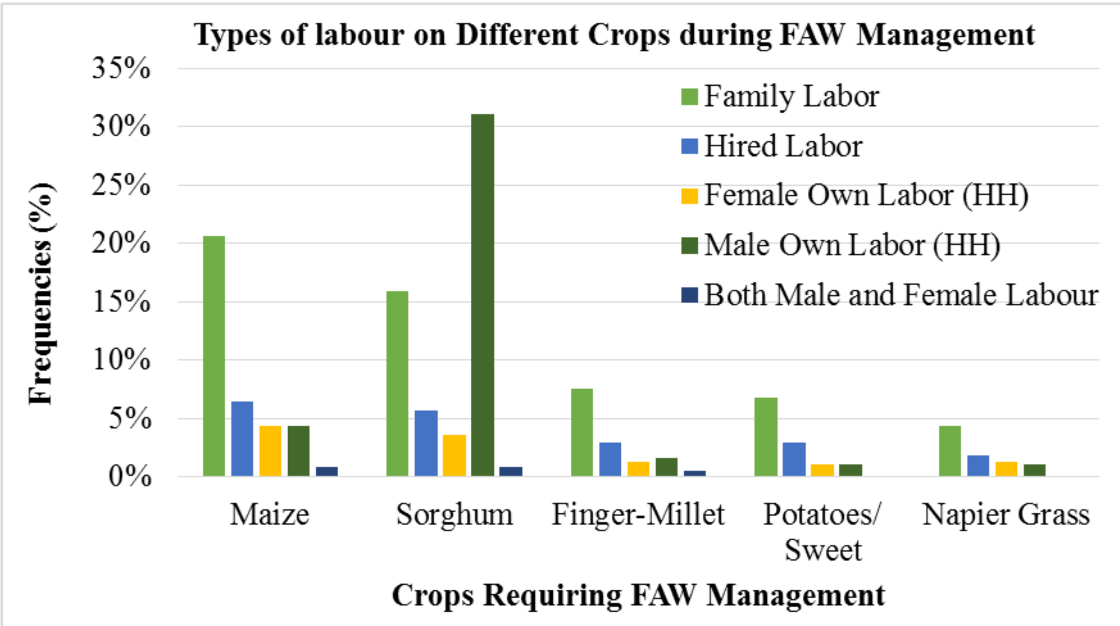


Figure 4. 42: Labour use on Different Food Crops during FAW Management

The result Figure 4.36 on labour apportionment during FAW control indicates variations of labour apportionment within different headed households with maize and sorghum production having a higher labour apportionment whereas, male farmers (31%) contribute highest to sorghum pest management as compared to female farmers (4%). This labour disparities could be attributed either to male farmers using sorghum as animal feed since the study has shown that a higher percentage of male farmers (5%) feed livestock with infected maize plants as compared to female farmers (1%) or because sorghum is a hardy crop that can be used both as a household food and animal feed. This finding supports a study done by Doss *et al.* (2018) on women in agriculture and Quisumbing and Doss (2021) on gender in agriculture and food systems stated African farming communities apportions labour based on the crop demand and its uses. The promotion of equitable gender in agriculture by Rubin and Manfre (2014) indicates differences in labour division between female and male-headed households during agricultural production.

The result on the gender engagement during FAW invasion control and the source of labour used by different headed households (Figure 4.43), 22% male and 28% female farmers engages family labour during agricultural production. The finding further shows that there is hiring of extra labour during the high peak season of agricultural production with 10% male and 9% female headed households hiring labour as substitution for the control of FAW invasion whereas, 8% male and 23% female use own labour without any support to manage FAW invasion during agricultural production (Figure 4.43).

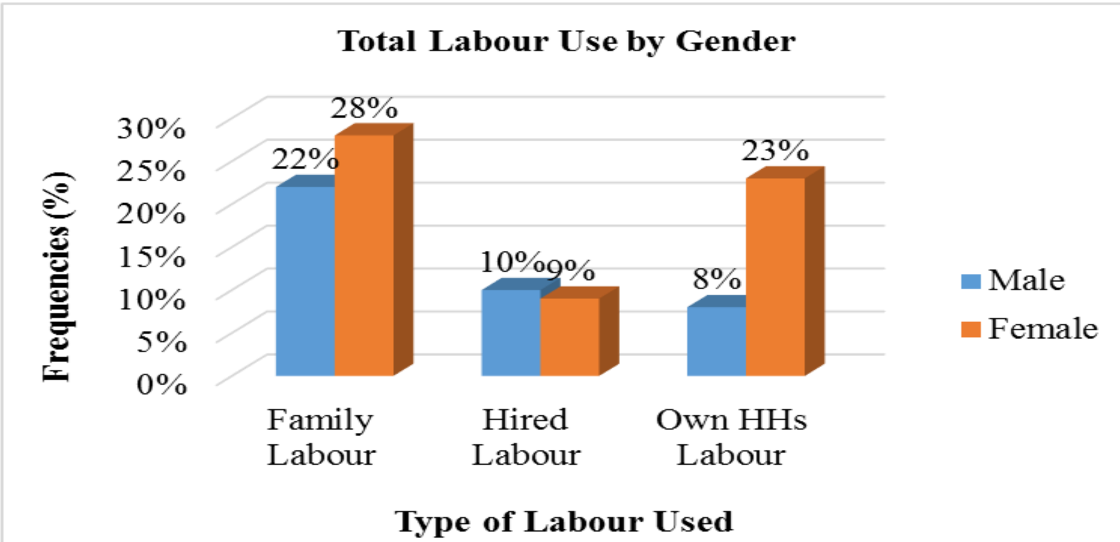


Figure 4. 43: Source of Labour use by Gender during FAW Management

The result shows (Figure 4.43) agricultural production has gender-specific roles and responsibilities. This finding is in agreement with a study done by Palacios-Lopez *et al.* (2017) who stated that labour gendered within different headed households and allocated according to type of activity required during crop and livestock production in developing countries.

The result shows the exploitation of family labour was higher in crop and livestock feed production as compared to the use of hired labour and household head's own labour. Different headed household engages different labour by gender depending on the agricultural activity needed which is an essential input during management of agricultural shocks including fall armyworm invasion. This finding agrees with Due (2019), and Rubin and Manfre (2014) who states that labour in an African household is one of the most demanded and important requirement with the smallholder farmers being dependent on manual labour sourced mainly from family and hired labour.

4.4.3 Gendered social change during FAW Management

The result shows 28.6% of the households intimates to spending extra financial (money) towards management of fall armyworm (Figure 4.44). The results further shows 16.7% of the smallholder farmers adapts to using local knowledge of the known pest management strategies to control fall armyworm invasion in their crop fields whereas, 16.1% households hire extra labour due to the labour involved in the control of fall armyworm invasion.

The study finding indicates 14.1% of the household respondents shift of their preferred crop production to new resilient crops that are not susceptible to FAW invasion whereas, 10.4% households sources for information about FAW management through joining new farmer groups and frequently attending communal social gatherings. The study result further shows 9.9% households' leases in extra land and practice crop rotation as a management strategy against fall armyworm invasion with 4.2% household heads changing their access and control of resources (land) to making them accessible and available to other family members due to fall armyworm invasion (Figure 4.44).

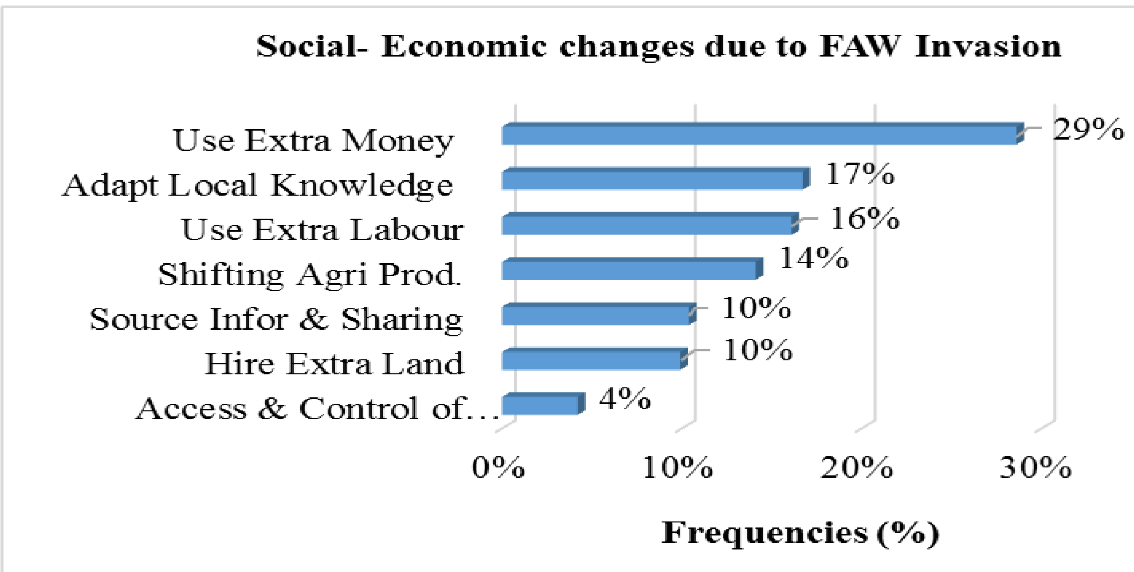


Figure 4. 44: Social- Economic changes due to FAW Invasion

The result in Figure 4.44 shows a change in social-economic status within different headed households due to fall armyworm invasion. This finding agrees with Abubakari *et al.* (2018) and Mukherjee (2019) who states that different households' farming communities faced with social-economic changes during agricultural shocks due to the transfers of resources from the intended use to another new use creating an imbalance in households' food securities and risks to the environment. The socio-economic inequalities in this study arises from agricultural shocks including the management of the new invasive pest (FAW) due to the transfers of resources from the intended use to another new use creating an imbalance in households' food securities and environmental risks.

The result further showed 12% male and 16% female use extra finances (money) to control fall armyworm invasion with 9.3% male and 7.4% female household heads seeking to learn local knowledge strategies of the known pest management. During crop production gender roles influences social-economic changes during management of fall armyworm invasion (Figure 4.39).

The results further shows 7.6% male and 8.6% female household heads hires extra labour during fall armyworm invasion (Figure. 4.39). About 6.3% male and 7.8% female farmers shifts their usual pattern of agricultural production to new patterns of agricultural due to FAW invasion whereas, 4.9% male and 5.5% female headed households joins farmer groups and attends communal social gatherings towards getting information about FAW management. Another view, expressed by 4.9% male and 5% female headed household, held that leasing in extra land helps in practicing crop rotation as a fall armyworm invasion management strategy with 1.6% male and 2.6% female headed household allowing the access and control of resources to other household family members due to fall armyworm invasion during agricultural production.

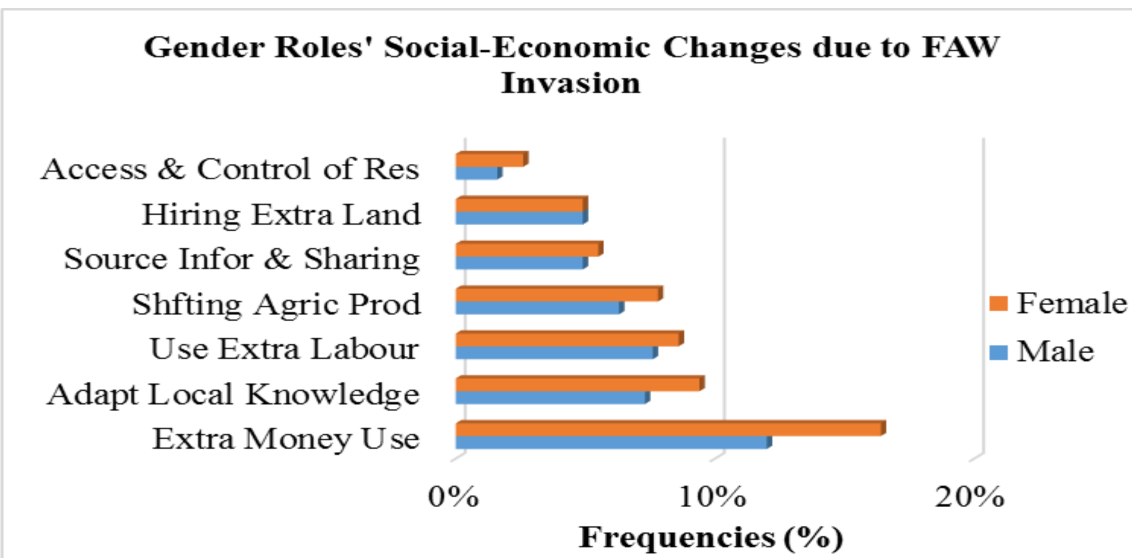


Figure 4. 45: Gender Roles' Social-Economic Changes due to FAW Invasion

The result shows that there are differential social-economic changes within different headed households due to fall armyworm invasion. The result on the gender differences on social economic changes does not imply that female headed households are more affected by fall armyworm than the male headed households' rather the difference might be due to not being the main handlers of the technologies (pesticides) used in controlling fall armyworm.

4.5 FAW Management Practices that are likely to lead to Environmental Contamination

The results on determining potential environmental impacts due to the use of strategies during management of FAW are results from enumerated respondents' and nine Focus Group Discussions as "perceived" or "physically seen" (Table 4.1). The potential environmental impacts arose from perceptions as well as results obtained from composition of pesticides that were in use towards control of fall armyworm invasion. The result shows fall armyworm invasion has effects on smallholder farmers' resource use with 42.7% calling it economically expensive due to extra money and labour requirement during FAW invasion. The finding indicates 29.4% households experience poor food yields due to FAW invasion with 27.9% households' experiencing ill health due to FAW invasion (Table 4.1).

Table 4. 1: Perceived Environmental Issues after FAW invasion by Gender

Perceived and Physical Issues	Frequency (n / %)	Male	Female
Poor Yields due to FAW invasion	113(29.4%)	48(12.5%)	65(16.9%)
Perceived ill-health Experiences	107(27.9%)	51(13.3%)	56(14.6%)
Economically Expensive	164(42.7%)	73(19%)	91(23.7%)
Total (n)	**384**	**172(44.8%)**	**212(55.2%)**

The result in Table 4.1 shows there are differences on the potential environmental impacts between male (44.8%) and female (55.2%) headed households due to fall armyworm invasion.

4.5.1 Types and Categories of pesticides used

Smallholder farmers in the world use synthetic pesticides to control agricultural pests classified by the World Health Organization (WHO) as moderately, highly and extremely hazardous. In 1985, the Food and Agriculture Organization of the United Nations released the international code of conduct on use and published (Lewis *et al.*, 2016). The published consumer improvement on the International Code of distribution of pesticides revised and advertised the 2002 stating the sub-standard pesticides and highly hazardous formulations used with little precaution and no capacity building to the handler of the pesticides.

In Kenya, pesticides use enacted in 1921 have remained one of the most important FAW management strategy that smallholder farmers use with different toxicity effects to the handlers and consumers of the pesticides (Bertrand 2019; Larramendy & Soloneski 2019). The outbreak of fall armyworm in the African region including Kenya has seen a rise in the application of pesticides use during agricultural production.

The current option for the control of FAW invasion during agricultural production is the use of chemical pesticides that have been known to smallholder framers during other crop pest and diseases control with a likelihood of environmental contamination and human health poisoning. These chemicals known to be contaminants of the environment due to their ability of being transported long distance from the place of use released by wind or water affecting ecosystem and human health (Olisah *et. al.,* 2019). The finding shows smallholder farmers (n=172 male and n=212 female) use different organochlorines pesticides (OCPs) that are easily available in Kenya's local agro-dealer shops with different active ingredients for the control of FAW invasion during agricultural production (Figure 4.46). The finding from literature reviews has shown that smallholder farmers in Africa including Kenya produce over 75% of the food consumed (FAO, 2021) whereas, they use pesticides with a highly hazardous formulations without enough capacity building on pesticide handling, disposals of used containers and wearing of protective equipment (PPEs) (Sarkar *et al.,* 2021).

On the trade names of pesticides used for FAW control by smallholder farmers (Figure 4.40), smallholder farmers are highly dependent on pesticide use for the control of FAW invasion and other agricultural pests with numerous studies in Africa including Kenya indicating misuse and improper handling of pesticides during agricultural production (WHO, 2016). This is an indication that despite pesticides offering smallholder farmers' with an increase in livestock and crop production, a likelihood of environmental pollution and ill health to human handlers due to pesticides use.

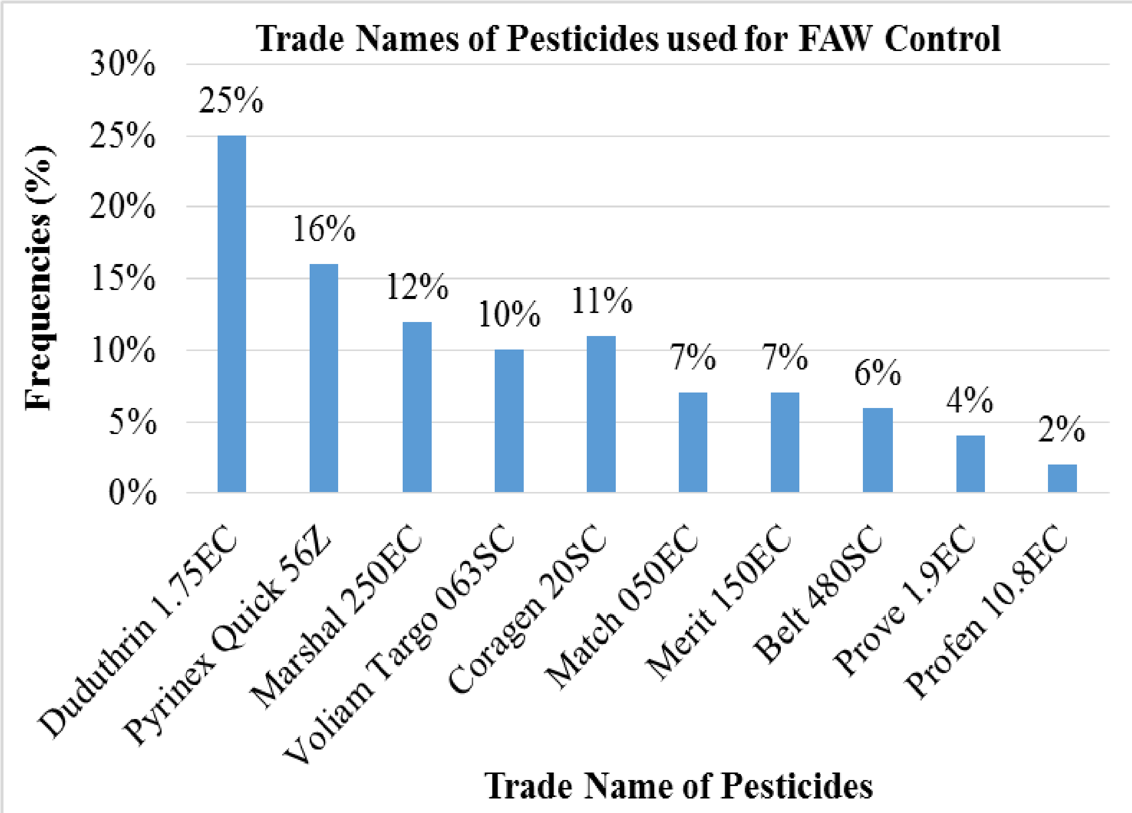


Figure 4. 46: Trade Names of Pesticides used for FAW Invasion Control by Smallholder farmers

The availability and accessibility of pesticides within the local agro-vet dealer shops encourages the rampart usage of pesticides. Smallholder farmers make decisions to use pesticides during FAW invasion in achieving better agricultural yields irrespective of the environmental consequences and perceived illhealth issues.

Figure 4. 47: A farmer displaying a FAW defoliated maize plant and Pesticide samples at Sotik, Bomet County

Results from the study shows a variation of pesticide handling by gender (73% male and 27% female) during FAW invasion control with the likelihood of male handlers being exposed more to illhealth as compared to female handlers due to the frequency of contact of the pesticides (Figure 4.48).

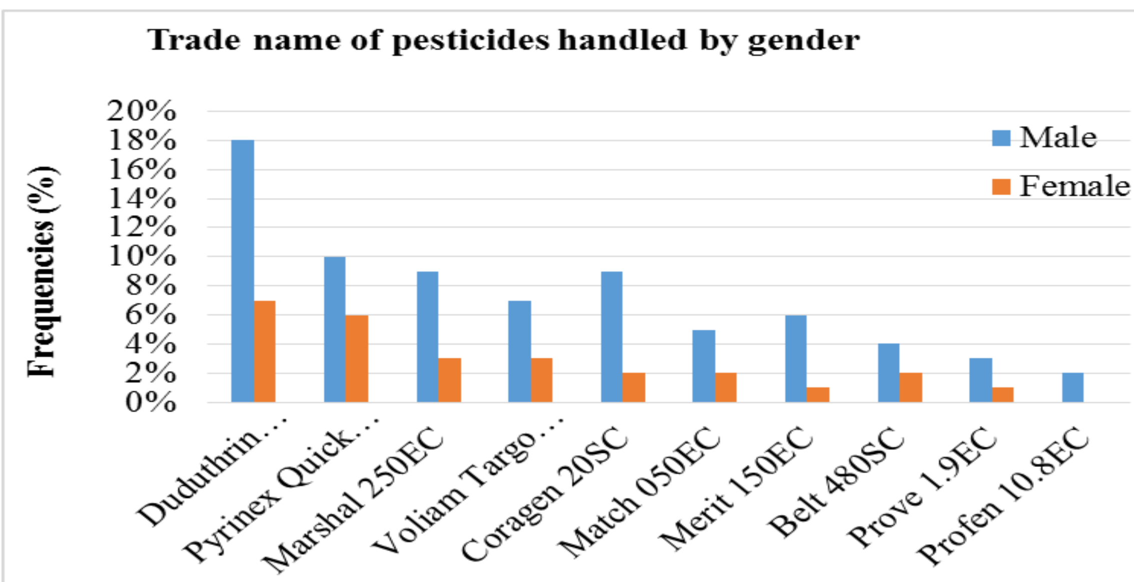


Figure 4. 48: Handling of Pesticides by Gender

The result in Figure 4.48 shows pesticide use is one of the most important FAW control management strategy whereas there are possibilities of erroneous management strategies such as application time of pesticide spraying, lack of using PPEs, and lack of knowledge on spraying regimes thereby leading to exposure of pesticides due to poor practices of pesticide handling. This findings support study by Bertrand (2019) and Sarkar *et al.* (2021) whose studies notes that exposure to pesticides frequently occurs during the handling, time of aplication, loading into knapsack sprayer and pesticide disposal of used containers.

4.5.2 Potential hazards of Chemical Pesticides used

There is a widespread use of chemical pesticides, used as crop pest control during the production of food crops, thereby leading to the pollution of environment. Studies by Elibariki and Maguta (2017) have shown that smallholder farmers in the developing world, including Kenya continue using banned pesticides several years ago during their agricultural production with no realization on the chemical composition of the pesticides that smallholder farmers are using. From literature reviews, the major pesticides used by smallholder are OCPs, which are divided into three major classes namely DDT, hexachloride (BHC) and cycldiene whereas, the OCPs have been banned in developing countries including Kenya because of its environmental persistent and non-target toxicity (Fiedler *et al.,* 2019). The major health problems arising from usage of OCPs are both chronic and acute health affects human health (FAO, 2021; WHO, 2020).

The invasion of fall armyworm in smallholder farmers crop fields has seen excess usage of pesticides (insecticides) with poor handling strategies due to lack of capacity building on both male and female farmers whereas, the behaviour of fall armyworm hiding itself inside the maize whorl requires technical skills enhancing repeated pesticides exposures during applications (Day *et al.,* 2017; FAO, 2018).

The study result showed smallholder farmers used pesticides during agricultural production with different behavioural actions during spraying. About 21.4% respondents reported drinking water when spraying pesticides with 16.4% eating a snack during spraying. The result further shows 33.2% pesticide handlers did not take a shower immediately after spraying whereas, 20% mixed their chemical directly inside knapsacks and 9% did not watch the direction of wind when spraying (Figure 4.49).

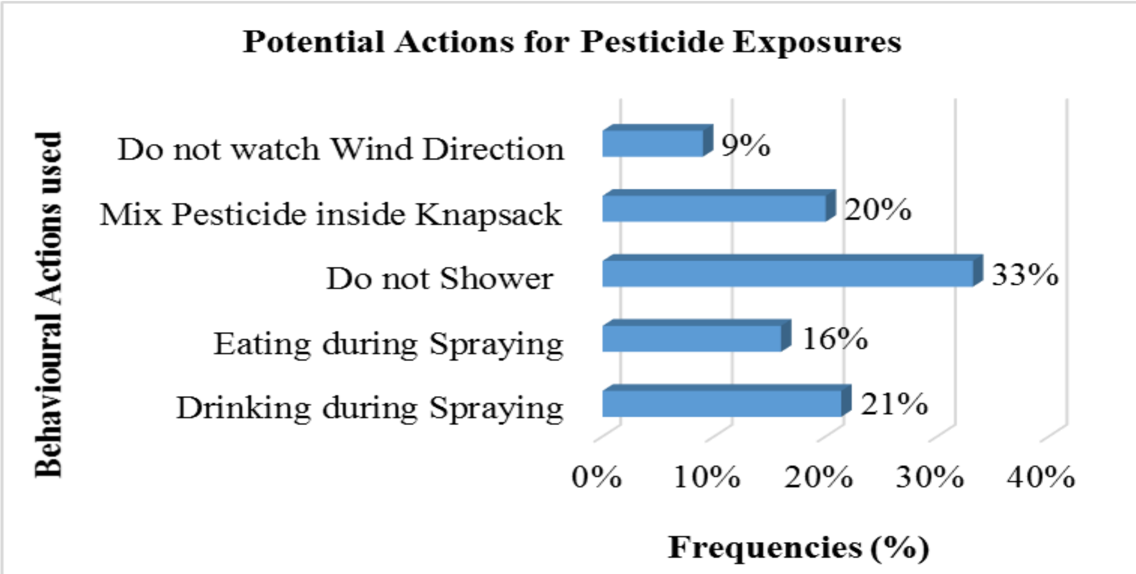


Figure 4. 49: Potential Hazards of Organochlorines Pesticides used

On the potential hazards of organochlorines used (Figure 4.49), smallholder farmers potential hazard impacts is compounded by the behavioural actions used during spraying thereby, enhancing occupational exposures. Furthermore, findings is in agreement with a study done by Tsimbiri *et al.* (2015) on health impact of pesticides on residents and horticultural workers in the Lake Naivasha Region, Kenya, showed subsequent impacts of pesticides on human health through occupational exposure is through pesticide misuse and mishandling during agricultural production.

The result show the gender handling in pesticide use varies greatly within different headed households depending on household needs, decision making patterns and labour availability during fall armyworm management whereas, the decisions regarding pesticide handling were made by household heads, irrespectively of the gender. About 15% male and 6% female farmers reported drinking water when spraying pesticides with 7% male and 9% female ate a snack during spraying. The result further shows 5% male and 28% female pesticide handlers did not take a shower immediately after spraying whereas, 13% male and 7% female mixed their chemical directly inside knapsacks using a hand and 4% male and 5% female did not watch the direction of wind when spraying (Figure 4.50).

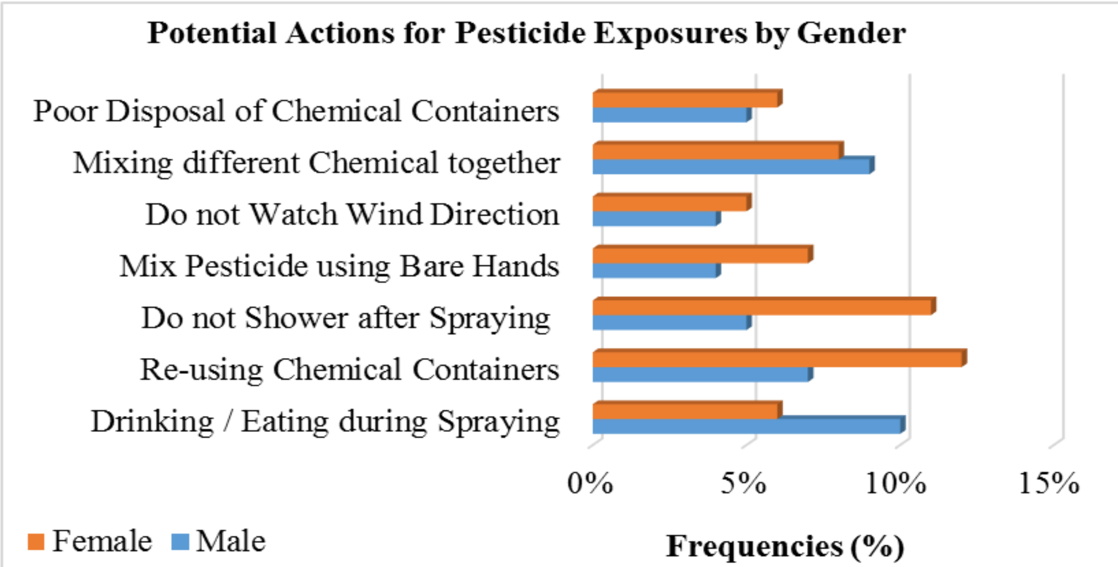


Figure 4. 50: Potential Hazards of Organochlorines Pesticides used by gender

On the potential hazards of OCPs used by gender (Figure 4.50), pesticides enter into the human body through ingestion and inhaling whereas, not watching wind direction is likely to contaminate the food and the environment (soils and water ways). This is in agreement with Bembah *et al.* (2012 and Kolani *et al.* (2016) noting that Africa and other parts of the world are polluted including soils and waterways.

4.5.3 Sources of pesticide for FAW management

The result indicates that during fall armyworm invasion in the country, efforts on control strategies is the use of synthetic pesticides the application with different sources. The results shows 41.4% smallholder farmers sources pesticides from local agro-chemical dealers with 21.3% receiving free pesticides from the county government whereas, 17.2% sources pesticides from MOALF (Table 4.2). The result further shows 10.2% sources pesticides from other farmers/ neighbours with 9.9% receiving from research institutions. The result on the gender proportion on pesticides sourcing indicates 20.6% male and 20.8% female farmers acquiring their pesticides from local agro-chemical dealers whereas, 8.3% male and 13% female farmers' sources from county government. The result further shows 6.5% male and 10.7% female farmers sources their pesticides from MOALF with 5% male and 5.2% female farmers sourcing from other farmers/ neighbours with 4.4% male and 5.5% female farmers sourcing from research institutions (Table 4.2). These findings showed gender differences during pesticides sourcing with a higher proportion of female farmers sourcing pesticides more as compared to male farmers.

Table 4. 2: Source of pesticides with respect to gender

	Gender of farmer		
Source of pesticide	**Male**	**Female**	**Total (n)**
Agro-input Dealers	79(20.6%)	80(20.8%)	159(41.4%)
County Government	32(8.3%)	50(13%)	82(21.4%)
MOALF	25(6.5%)	41(10.7%)	66(17.2%)
Other Farmers	19(5%)	20(5.2%)	39(10.2%)
Research Institutions	17(4.4%)	21(5.5%)	38(9.9%)
Total(n)	**172(44.8%)**	**212(55.2%)**	**384**

The result in Table 4.2 indicates there are gender differential between male and female smallholder farmers during decision making on pesticide acquisition. The sourcing of pesticides determination by the household head irrespective of the gender. This finding supports a study by Botreau and Cohen (2020) on gender inequality and food insecurity by noting there are differences between rural male and female during pest and disease control in agricultural production due to households' social gender differences.

4.5.4 Self - Reported Healthy outcomes

The results on self-reported outcomes show 33.3% experiences sneezing and coughing, 25% gets eye sores or teary eyes, 17% gets skin itching, 11% gets mild headaches, 7% receives stomach bloating with 7% experiencing heavy chest and constrained breathing (Figure 4.44).

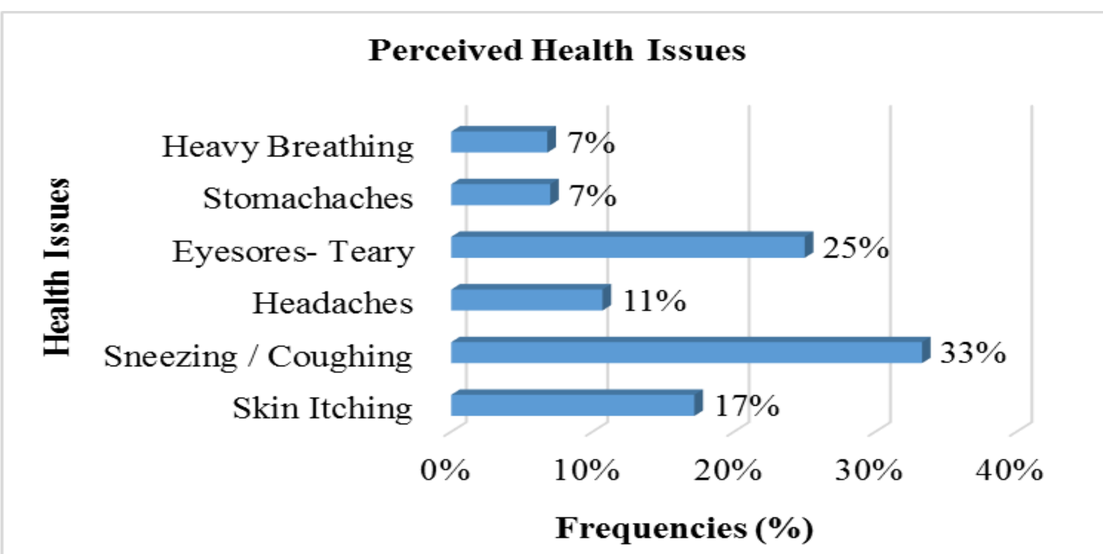


Figure 4. 51: Differential perceived health problems associated with pesticides use

The implication of result (Figure 4.44) is that smallholder farmers' pesticides' exposure is likely through inhalation, ingestion and skin absorption. There is a likelihood of exposure during pesticide preparation and mixing for spraying and spraying time.

Table 4. 3: **Self- reported ill-health experiences due to Pesticide use by Gender**

Perceived Health Problems	**Totals**	**Gender**	
	(n)	**Male**	**Female**
Sneezing / Coughing	128(33.3%)	65(16.9%)	63(16.4%)
Eyesores- Teary	96(25%)	39(10.2%)	57(14.8%)
Skin Itching	66 (17.2%)	26(6.8%)	40(10.4%)
Headaches	41(10.7%)	20(5.2%)	21(5.5%)
Stomach gas flatulence	27(7.1%)	11(2.9%)	16(4.2%)
Heavy Chest/Breathing	26(6.8%)	11(2.9%)	15(3.9%)
Totals (n)	**384**	**172 (44.8%)**	**212 (55.2%)**

On self- reported ill health experiences due to pesticides use by gender (Table 4.3), sneezing and coughing affected both male (16.9%) and female (16.4%) farmers highly an indication that inhalation exposure is the potential hazard of pesticides to smallholder farmers. This is in agreement with a study by Damalas and Eleftherohorinos (2011) and Lekei *et al*. (2014) who stated that pesticides extensively used for pest control in agriculture whereas, the usage and unsafe handling practices is likely to expose the farmer to ill-health effects.

4.5.5 Application Time of Pesticides Spraying

The study findings shows 39.3% farmers applies their pesticides during the early morning hours with 4.4% farmers applies pesticides at nightfall whereas 26% applies in the evening just before sunset with 30.2% farmers applying at mid-day time (Table 4.4). However, the gender indicator shows 22.1% male and 17.2% female farmers applies pesticides in the morning with 12.2% male and 18% female smallholder farmers applying pesticides during the mid-day hours. The result further indicates 8.3% male and 17.7% female apply their pesticides during the evening just before sunset with 2.1% male and 2.2% female farmers applying their pesticides at nightfall (Table 4.4).

Table 4. 4: Pesticide application time by gender

	Gender of farmer		
Time applied	**Male**	**Female**	**Total (n)**
Early morning	85(22.1%)	66(17.2%)	151(39.3%)
Mid-day	47(12.2%)	69(18%)	116(30.2%)
Evening	32(8.3%)	68(17.7%)	100(26%)
Night past 7.00pm	8(2.1%)	9(2.3%)	17(4.4%)
Total(n)	**172(44.8%)**	**212(55.2%)**	**384**

The result in Table 4.4 indicates that 65.3% smallholder farmers apply pesticides at the correct timing (39.3%, early morning and 26%, evening) with 30.4% male and 34.9% female applying pesticides at the correct time (morning and evening). The appropriate timing of pesticide application ensures not only maximum control of the pest but also least damage on the environment due to less frequency of sprays of pesticides whereas, the wrong timing of pesticides spray is a trajectory towards ineffectiveness use of pesticides during the control of fall armyworm invasion. Another view, female farmers are likely to likely to contribute to more environmental contamination by pesticides use as compared to male farmers requiring the gender perspective in regulatory frameworks for pesticides management and capacity building on safe handling of pesticides being gender specific.

From previous studies by Day *et al.* (2017) and FAO (2018), have shown that fall armyworm hibernates deep in the whorl of maize plants and covers itself with its waste and only comes out during the early hours of the morning and evening when the temperatures are ideal for feeding. This clearly indicates that there are implications of ineffective spraying due to wrong timings enhances repeated pesticide spraying to kill the FAW caterpillar. Moreover, the study result did not give a clear picture on the gender whose practices are more effective than the other during fall armyworm management or the use of more pesticides rather, both male and female farmers use pesticides towards households' food security. The frequency of pesticides spraying is likely to pollute the environment through spray drift of the pesticides to the unintended targets like the water sources and close human neighbours.

4.5.6 Personal protection equipment (PPEs) during pesticide application

The study results shows smallholder farmers use different types of PPEs, against exposure to pesticides. The finding indicates 47.9% wears gumboots when applying pesticides with 19% putting on old clothing which includes tattered trousers and shirts whereas, 21.6% wears top coats when carrying knapsack -pumps with 11.5% wearing overalls (Table 4.5). The result on the gender preferential on PPEs use during pesticide application shows 23.2% male and 24.7% female smallholder farmers wears gumboots with 8.1% males and 13.5% female farmers wearing top coats. The results further shows 5% male and 6.5% female wears overall with 8.6% male and 10.4% female wearing old clothing (Table 4.5).

Table 4. 5: Personal Protection Equipment used by farmers with respect to gender

PPE used	**Gender of farmer**		**Total (n)**
	Male	**Female**	
Top Coats	31(8.1%)	52(13.5%)	83(21.6%)
Gumboots	89(23.2%)	95(24.7%)	184(47.9%)
Overalls	19(5%)	25(6.5%)	44(11.5%)
Old clothing	33(8.6%)	40(10.4%)	73(19%)
Total(n)	**172(44.9%)**	**212(55.1%)**	**384**

On PPEs used by farmers with respect to gender (Table 4.5), show a gender variation of PPEs wearing during pesticide spraying with a low percentage of male farmers wearing their respective PPEs as compared to female farmers. Low wearing on PPE during pesticides application in this study was defined as wearing only either one or two of the following- a head cap, nose mask, eye goggle, hand rubber glove, overall, and gumboots during pesticides application (Figure 4.52). The result on farmers' not wearing their PPEs during pesticides spraying enhances the chances of the farmers' exposure to pesticides through body contact. However, the findings show the PPEs use is not a gender preferential choice rather is due to the availability and accessibility of the PPEs within different headed households.

Results from different studies by Abro *et al.* (2021), Otim *et al.* (2021) and World Health Organization (2020) shows pesticide use poses health hazards to the handler and the environment requiring the handler to wear personal protective equipment (PPEs) for protection from pesticide exposures and pollution of the environment. This is an indication showing that there are limited understanding amongst smallholder farmers ‘on the health implications and environmental effects that arises from not wearing PPEs during pesticide spraying to control FAW invasion.

This findings shows the PPEs that smallholder farmers use towards protection against pesticide exposure do not protect them rather expose them to harm (Figure 4.53). The findings indicates a knowledge gap on how smallholder farmers perceive PPEs either they do not have enough resources (money) to buy PPEs or it is a show of ignorance or not aware of the personal or environmental potential negative impacts that are associated with using poor personal protective equipment that are not designed for pesticides handling during FAW control.

Figure 4. 53: Personal Protective Equipments worn for Demonstration (circled) at Bomet Central, Bomet County

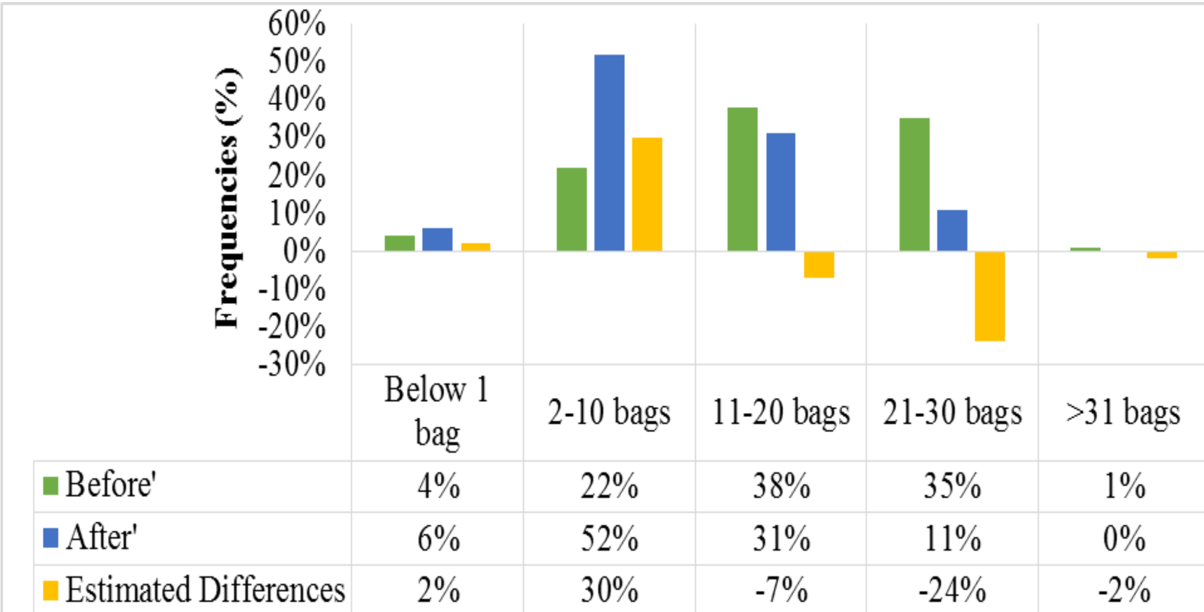
Figure 4. 53: A farmer spraying with minimum Protective Equipments at Konoin, Bomet County

4.6 Differences in Maize Production between Female and Male Headed Households due to Fall Armyworm Invasion.

The researcher used maize production as an indicator for determining the differences in food production between male and female households through respondents' recall on the estimations of maize harvests received 'before' and 'after' FAW occurrences in their crop fields. The estimated average maize yield production 'before' was 12.8 bags of 90kg per acre per households whereas estimated maize yielded an average of 5.1 bags of 90kg per acre per household 'after' FAW invasion.

The study finding has shown that maize production is the main staple food crop within different headed households with 59% respondents ranking maize production as their main preferred food crop as compared to other crops like finger millet (18%), sorghum (9%), sweet-potatoes (9%) and napier-grass (5%) with distributions of uses and purposes varying within different gendered households. This finding concurs with Bista *et al*. 2020), Padhee and Prasanna (2019), and Wang and Romeis (2021) who states maize crop is the major staple food crop in sub-Saharan Africa (SSA) and the most preferred crop by fall armyworm and the occurrence of FAW on smallholder farmers' food fields will lead to food insecurity and unhealthy environment.

The results on determining the differences in food production between female and male headed households due to fall armyworm invasion is determined by the yields realized from "before" and "after" FAW invasion of maize production within different clusters (Figure 4.54).



	Below 1 bag	2-10 bags	11-20 bags	21-30 bags	>31 bags
Before'	4%	22%	38%	35%	1%
After'	6%	52%	31%	11%	0%
Estimated Differences	2%	30%	-7%	-24%	-2%

Figure 4. 54: Estimates of maize yield differences- 'before' and 'after' FAW invasion

The result on estimated of maize yield differences before and after fall armyworm invasion (Figure 4.54), shows 33% smallholder farmers were affected by the invasion of fall armyworm with negative yields whereas, 32% of the respondents having a declines of yields to below 10 bags of 90kg per bag.

4.6.1 Trend of fall armyworm occurrences in Bomet County

Bomet County has three major distinct growing agro-ecological zones (LH2, LH3 and UM4) with highly fragmented farms where smallholder farmers (n=384) grow crops at different planting dates all year round. There are no differences in agro ecological zones (LH2, LH3 and UM4) on observations of FAW invasion within the five sub-counties enumerated from both differentiated household heads and farmers group discussions. The results shows 8% respondents have a progressive sighting of first appearance of fall armyworm invasion being in December 2016. The result further indicate 85% smallholder farmers reported an increase of FAW invasion on maize and other crops including sorghum, millet, napier-grass, sweet potatoes and kales in the successive year of 2017 (Figure 4.55).

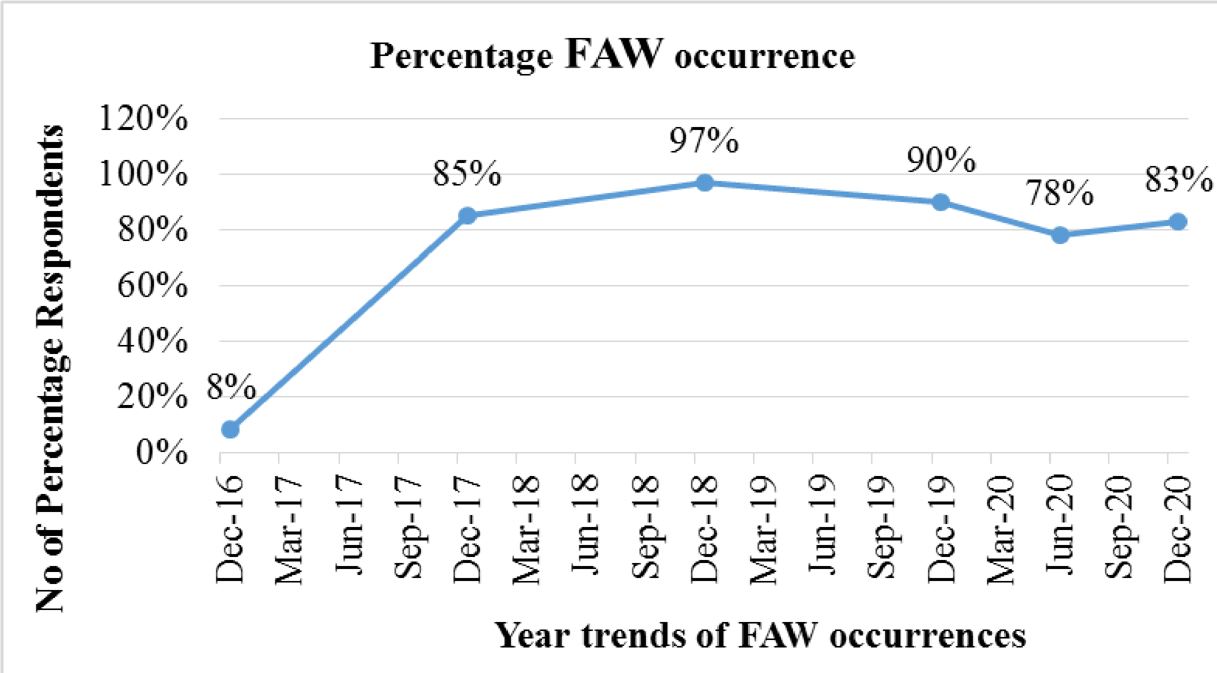


Figure 4. 55: Trend of FAW occurrences in Bomet County during data collection (2020), Bomet County

The result Figure 4.55 on trend of fall armyworm occurrences indicates 97% respondents' highest spread of infestations was from December 2018 to December 2019. Studies by Kom *et al.* (2020), Paumgarten *et al.* (2020) and Prasanna *et al.* (2018) indicates FAW is an invasive pest with the ability of laying up to 1000 eggs given condusive vegetation or favourable grounds. The pest has a diversified plant feeding range of over 100 plant species likely to cause losses on all cultivated crops if left unmanaged. This a likelihood of compromising households' food security within different headed households and environmental contamination during use of management strategies for FAW invasion.

4.6.2 Estimated household crop yields harvested 'before' fall armyworm invasion by gender

The results on estimated crop yields harvested before FAW invasion shows a representation of 38% of both male and female farmers harvests between 11 bags to 20 bags of 90kg per acre followed with 35.1% harvests between 21 bags to 30 bags of 90kg per acre (Table 4- 6). The female farmers who harvest between less 1 bag to 20 bags of 90kg per acre are 36.3% with male farmers being 28.2% whereas 17% of male farmers' harvests above 21 bags of 90 kg /acre of maize with 19% female farmers harvesting above 21bags of 90kg per acre (Table 4.6).

Table 4. 6: Crop yields harvested before FAW invasion

	Clusters of maize estimation yields 'before' FAW invasion per acre							
Gender	**<1 bag**	**2-10 bags**	**11-20 bags**	**21-30 bags**	**>31 bags**	**Total (n)**	χ^2	***P***
Male	5 (1.3%)	36 (9.4%)	67 (17.5%)	62 (16.1%)	2 (0.5%)	**172 (44.8%)**	**55.675**	**.000**
Female	11 (2.9%)	49 (12.8%)	79 (20.6%)	73 (19%)	0	**212**		
Total (n) (%)	**16 (4.2%)**	**85 (22.1%)**	**146 (38.1%)**	**135 (35.1%)**	**2 (.5%)**	**384**		

The analysis of association between maize yields harvested 'before' fall armyworm invasion and gender using chi- test analysis reveals that there is a significant association between gender of household head and maize crop yields harvests 'before' fall armyworm invasion, (χ^2 =55.675, DF=4, *p*=0.000). This means that maize yields within different headed households' controlled by the gender of the household head thereby, an implication on households' food security status.

The result further shows that yields received 'before' fall armyworm invasion, maize production within different headed households is highest (73.2%) at cluster 11 bags to 30 bags of maize per 90 kg per acre with low production (26%) between cluster below 10 bags to 1 bag and above 31 bag of maize per 90kg per acre (Figure 4.56). The gender results indicates 0% female harvested above 31 bags of maize per 90kg per acre with 1% male harvesting above 31 bags and below 1 bag of maize per 90kg per acre. This is a clear indication on different determining factors that affected maize yield production within different headed households before the invasion of fall armyworm.

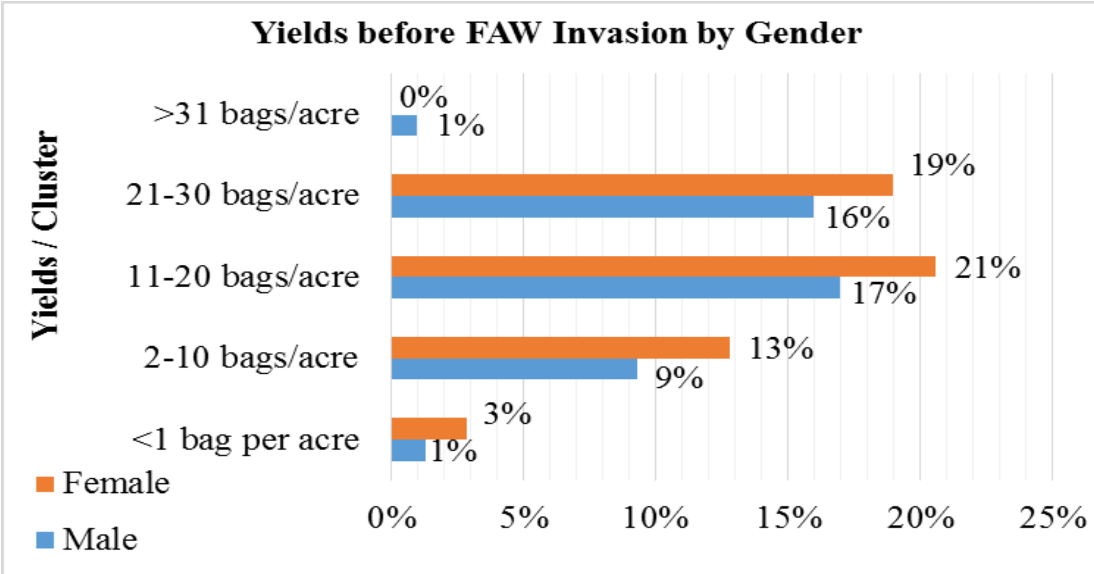


Figure 4. 56: Maize yields harvested 'before' FAW invasion by Gender

The results in Figure 4.56 shows there is a production difference of maize yields before FAW invasion between male and female-headed households. This findings supports studies by Ansah *et al*. (2019), and Jensen and Orfila (2021) whose findings indicates households' have differential food crop production clusters with female farmers being the main food producers that is consumed within different households.

4.6.3 Estimated crop yields harvested 'after' fall armyworm invasion by gender

The study results shows a yield crop difference 'after' FAW invasion with 51.8% smallholder farmers harvesting between 2 to 10 bags of 90kg per bag per acre whereas 31% harvests between 11 to 20 bags of 90kg per bag per acre and 6% harvests below 1 bag of 90kg per bag per acre (Table 4.7).

A gender comparison shows a higher proportion of 20.8% male and 31% female smallholder farmers produces between 2 to 10 bags of 90kg per acre whereas 14.1% males and 16.9% female smallholder farmers produces harvests between 11 to 21 bags of 90kg per acre after FAW invasion (Table 4.7). The finding further shows there is no harvests realized of above 31 bags of 90kg per acre of maize 'after' FAW invasion with an increase of 3.1% male and a decrease of .1% female harvesting below 1bag of 90kg per acre of maize 'after' FAW invasion.

Table 4. 7: Estimated crop yields harvested 'after' FAW invasion

	Clusters of maize estimation yields 'after' FAW Invasion per acre						
Gender	**<1 bag**	**2-10 bags**	**11-20 bags**	**21-30 bags**	**Total(n)**	χ^2	***P***
Male	12(3.1%)	80(20.8%)	54(14.1%)	26(6.8%)	**172(44.8%)**	**43.115**	**.000**
Female	11(2.9%)	119(31%)	65(16.9%)	17(4.4%)	**212(55.2%)**		
Total (n)	**23(6%)**	**199(51.8%)**	**119(31%)**	**43(11.2%)**	**384**		

The results in Table 4.7 when comparing estimates of maize crop production within different headed households by gender shows a yield difference of more male headed households producing less than 1 bag of 90kg per bag per acre of maize as compared to female headed households an indication of the effects of FAW invasion on food yields.

The analysis of association between maize yields harvested 'after' fall armyworm invasion and gender using chi- test analysis reveals that there is a statistically significant association between gender and maize crop yields harvests 'after' fall armyworm invasion, (χ^2 =43.115, DF=3, p=.000). This indicates gender of the household head determines maize yields enhancing food security (Figure 4.57).

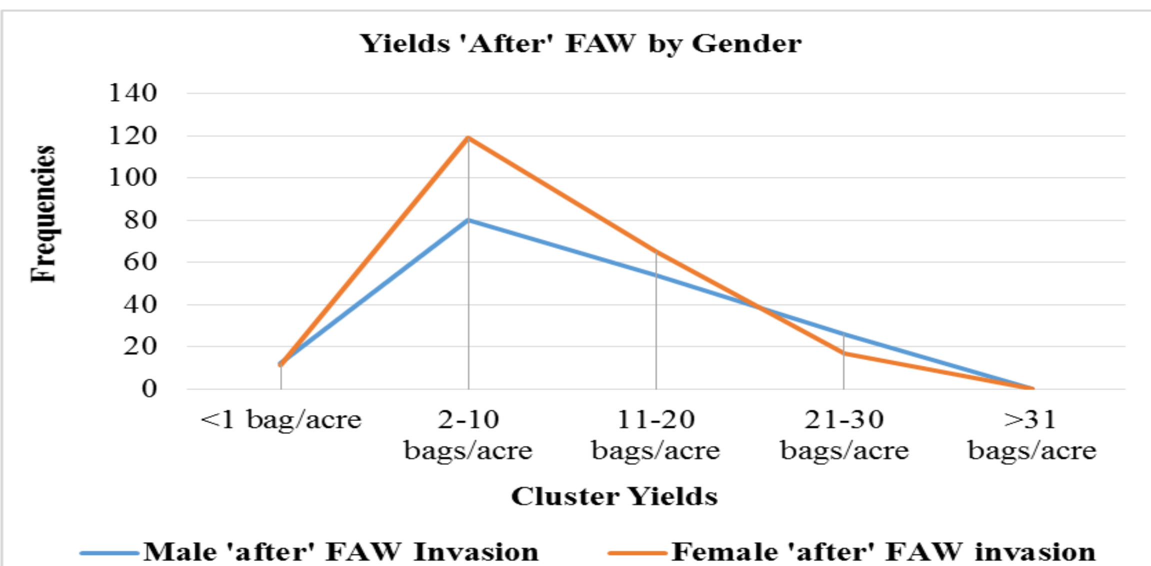


Figure 4. 57: Comparison of estimated crop yields "after" FAW invasion by gender

The result demonstrates that gender is a controlling factor towards FAW management but rather other socio-characteristics playing significant roles during crop production. The high peaks of crop yields between 2 to 10 bags of 90kg per acre from 11 to 20 bags of 90kg per acre is an indicator of crop yield decline due to FAW invasion between in differential households of male and female farmers (Figure 4.58).

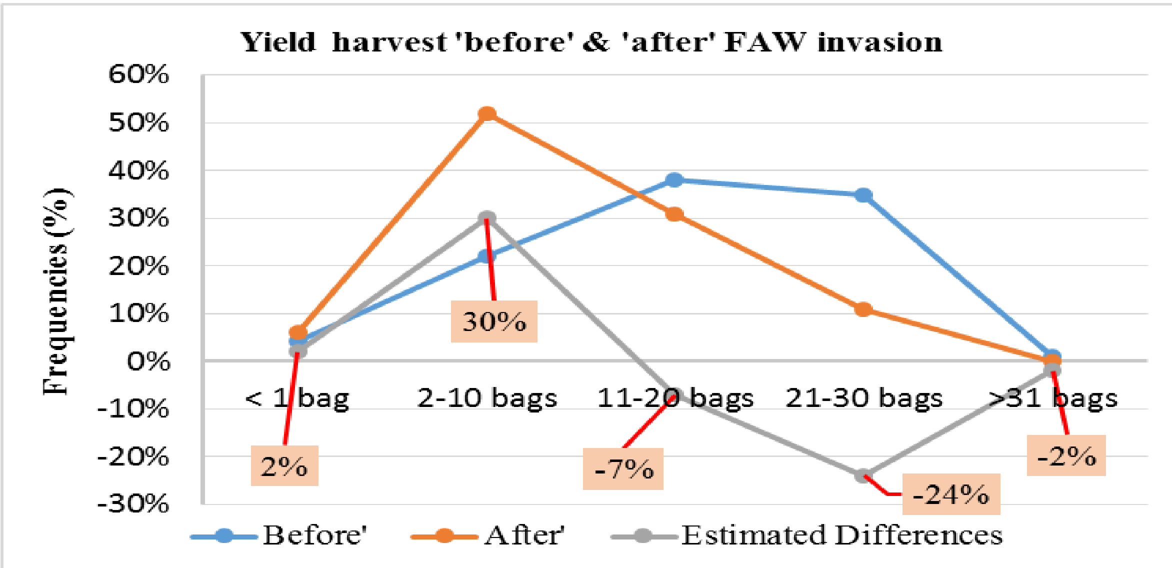


Figure 4. 58: Total maize yield differences estimates

The results on responses given on maize yield difference estimates between 'before' and 'after' FAW invasion (Figure 4.58), shows different headed households are affected by the invasion of fall armyworm in their crop fields with a likelihood of having insufficient household food production. Studies by Abrahams *et al*. (2017), Baudron *et al*. (2019) and Rwomushana *et al*. (2018) have noted that FAW can cause maize crop damage up to 100% reduction of crop yields if not well controlled.

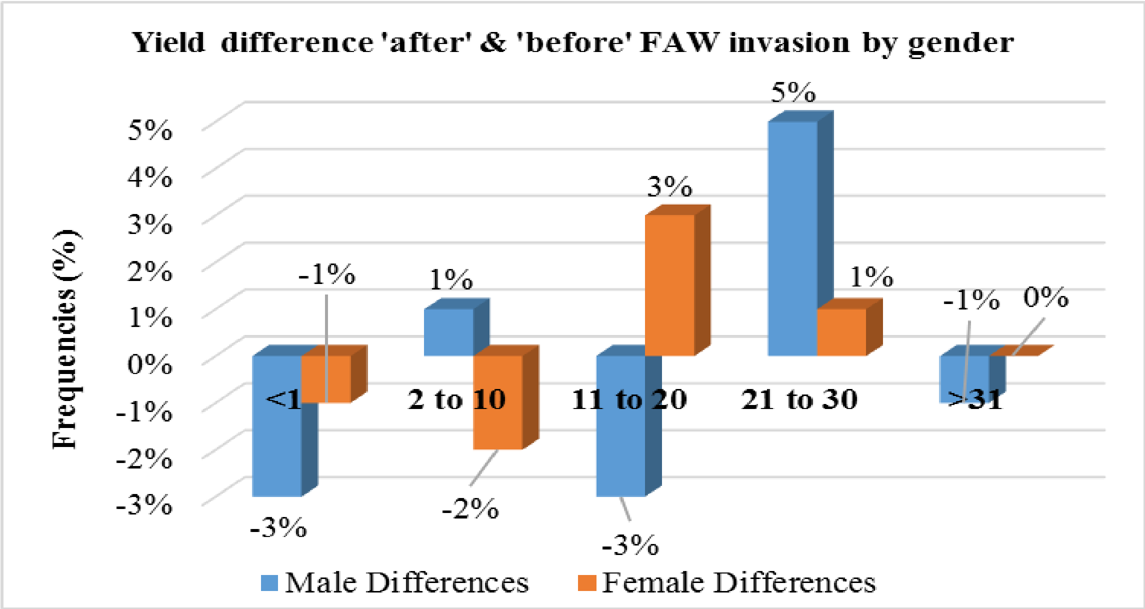


Figure 4. 59: Yields difference between 'before' and 'after' FAW invasion by gender

The result (Figure 4.59) shows the decline differences in food production due to fall armyworm invasion as estimated by different respondents. For female-headed households those most affected were those who harvested between 2 to 10 bags of 90kg per acre and for the male-headed households those who were most affected were those who harvested less than 1 bag of 90kg per acre and between 11 to 20 bags of 90kg per acre. The least affected were female farmers between cluster 11 to 20 bags of 90kg per acre and male farmers between cluster 21 to 30 bags of 90kg per acre. Studies by Bista *et al.* (2020), Padhee and Prasanna (2019), and Wang and Romeis (2021) have noted that maize crop is the major staple food crop in many households in sub-Saharan Africa (SSA) and the most preferred crop by fall armyworm thereby the occurrences of FAW invasion will make many different smallholder farmers' households to being food insecure.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

i. From these study findings, the mitigation strategies for controlling FAW practiced by both male and female smallholder farmers included chemical use (pesticide spraying and local mixtures), spiritual interventions (prayers), consulting with traditional seers, manual killing, shifting of priority crop production, mixing hybrid maize seeds alongside local maize seed varieties and feeding livestock with infected plants. The researcher concludes that the mitigation measures in controlling fall armyworm invasion during agricultural production's activities are not gender based requiring the need to train both male and female smallholder farmers to be involvement on environmental policy decisions and make choices that are less risk during fall armyworm management.

ii. On gender roles, both male and female smallholder farmers were involved in pesticide spraying, spiritual interventions (prayers), consulting with traditional seers, manual killing, shifting of priority crop production, mixing hybrid maize seeds alongside local maize seed varieties, feeding livestock with infected plants, crop rotation, and inter-cropping and mono-cropping. The researcher concludes that during FAW invasion, there is no role done by either male or female smallholder farmers only rather, working towards attainment of different headed households' food security and environmental sustainability.

iii. The researcher found that the FAW management were likely to lead to environmental contamination with relation to chemical (synthetic pesticides) use. Smallholder farmers used organochlorines that take long period to biodegrade in the environment. Practices that were likely to lead to environmental contamination include mixing of different chemicals together, poor disposal of pesticide containers, spraying at the wrong time of day and spraying against the wind. Those that were likely to enhance occupational exposures to the farmers' included mixing pesticides using bare hands, eating and drinking during spraying without washing hands. The practices that were likely to expose the farmers' families to the chemicals included not showering after spraying and re-using of chemical containers. The author concludes that an effective network of extension and advisory that provide technical advice on the safe use of pesticides can be of great value in preventing health effects and environmental risks among the smallholder farmers during fall armyworm management.

iv. The researcher found that both the male and female-headed households' food yields decreased after FAW invasion whereas, the yields were lower in female-headed households compared to male-headed households. The researcher concludes that there was little awareness by smallholder farmers on the effects of FAW invasion on food yields requiring capacity building for both male and female smallholder farmers.

5.2 Recommendations

From the analysis of data gathered from all the 384 respondents in Bomet County, the researcher recommends that:

i. There is need for researchers and extension officers to create awareness for farmers on better FAW mitigation strategies during management practices such as transporting infected plants to feed their animals.

ii. There should be training for both men and women farmers on fall armyworm practices. The training should take into consideration the different gender roles.

iii. The sensistization on smallholder farmers' should to use chemicals that are more biodegradable and less polluting to the environment. Raising awareness creation on practices that are less likely to enhance occupational exposures to family members.

iv. Smallholder farmers' should be encouraged to change their food preferences to alternative food crops that are resilient to fall armyworm.

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APPENDICES

APPENDIX I: Questionnaire Household Survey

Hello, my names are Nyakwara A. Zilpher, a PhD student at Egerton University, Njoro, currently, undertaking a research on: Gender perspective in mitigating fall armyworm (*Spodoptera frugiperda*) towards environmental and food production resilience in Bomet County, Kenya. This project is facilitated by Kenya Climate Smart Agricultural Project (KCSAP- World Bank) and Kenya Agricultural and Livestock Research Organization (KALRO). The selection of households is random and your households is one of respondents in this exercise recommended to answer some questions formulated in a form of a questionnaire.

Your participation in this study will be voluntary and you have the right to refuse to participate or answer any questions that you feel uncomfortable. The handling of provided information will be confidential, and not linked to you or your farm.

Name of Respondent: …………………………………………………………..

Sub- County: ………………………………………………………………………

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1. Gender (Interviewee) i) Male (…..) ii) Female (…..)

2. Age of Respondent (farmer) (years)…
   i. 18- 25 (…..)
   ii. 26- 35(…..)
   iii. 36-45(…..)
   iv. 46-55 (…..)
   v. Above 56 (…..)

3. Farmer's level of education….
   i. Informal (did not attend any formal education), (…..)
   ii. Primary, (…..)
   iii. Secondary, (…..)
   iv. Tertiary, (…..)

4. What is the size of your household composition? (......................) *write in numbers including respondent*

5. Household head marital status…

   i. Married (…..)
   ii. Single (…..)
   iii. Widowed (…..)
   iv. Divorced (…..)

6. What is your land size (in total)…………………………..

7. How much land acreage is allocated to each enterprise in your farm

   i. Crops ….
   ii. Livestock…
   iii. Wood lot…………….

8. Main occupation of household head: ...
   i. Crop / livestock Farmer …
   ii. Formally Employed (Government Offices)…
   iii. Self-Employed (Business -Shop/ Vegetable vendor)…
   iv. Other…………(Please Specify)

9. What is your primary source of income?

   i. Crop Farming (…..)
   ii. Livestock Farming, (…..)
   iii. Own Business, (…..)
   iv. Employed Elsewhere- Office/ Labourer, (………………....)- *Please Specify*

10. How many people live in the household (those who eat and sleep) within the following age groups in years?

Age	<5	6-12	13-18	19-25	26-35	36-45	46-55	>55	**Total**
Number	….	….	….	….	….	….	….	….	…..

11. What is your Source of labour during farming?

   i. Family Labour (…..)
   ii. Hired Labour (…..)
   iii. Female Own Labour (household) (…..)
   iv. Male Own labour (household (…..)

v. Did not work at all (Health Issues) (…)

12. . What are your years of experience in farming? *Please tick one only*

i. 1 to 10 years (…..)
ii. 11 to 20 years (…..)
iii. 21 to 30 years (…..)
iv. 31 to 40 years (…..)
v. 41 to 50 years (…)

13. What are the main purpose / Reason for agricultural production? *Please explain either crops, livestock or both.*

i. Home Consumption (…..)
ii. Sale (…..)
iii. Animal Feed (…..)

14. What are the main five crops grown in your farm in order of priority? *Please give numbers from 1 to 5.*

i. Maize (…..)
ii. Finger Millet (…..)
iii. Sweet Potatoes (…..)
iv. Sorghum (…..)
v. Napier grass (…)

15. Where do you often source maize seed?

i. Local Agro-vet (…..)
ii. Own (Recycled) (…..)
iii. Bought from other farmers (…..)
iv. Given free by other farmers (…..)
v. Other (……) - *Either given free samples during agricultural trainings*

16. What maize variety have you planted on your farm?

i. 513 (…..)
ii. 520 (…..)
iii. 614 (…..)
iv. 6213 (…..)
v. DK777 (…)
vi. Kipkaa (…)
vii. Ndere (…)

17. What is the total acreage land owned (both inherited and bought) *(Let the respondents give a clear estimation)*

i. Below 2 Acres (…..)

ii. Between 2-5 acres (…..)
iii. Between 5-15 acres (…..)
iv. Between 15-25 acres (…..)
v. Above 25 Acres (…)

18. How much land is under agricultural activities in your farm? *Please tick the appropriate acreage of both crops and livestock.*

i. Below 2 Acres (…..)
i. Between 2-5 acres (…..)
ii. Between 5-15 acres (…..)
iii. Between 15-25 acres (…..)
iv. Above 25 Acres (…)

19. What mode of crop production do you mostly grow your crops? (*Please explain and tick appropriately*)

i. Rain-fed (…..)
ii. Irrigation (…..)

20. How do you grow your maize crops each season? (*Tick appropriately*)

i. Intercropping (…..)
ii. Mono cropping (…..)
iii. Other (…) (*Please explain*)……………………………………………………

21. How much yields of maize do you harvest during good season?

i. Below 1 bag / Acre (…..)
ii. Between 5 to 10 Bags / Acre (…..)
iii. Between 10- 20 Bags / Acre (…..)
iv. Between 20-30 Bags / Acre (…..)
v. Above 30 Bags / Acre (…)

22. How much yields of maize did you obtain after FAW invasion in your maize fields?

i. Below 1 bag / Acre (…..)
ii. Between 5 to 10 Bags / Acre (…..)
iii. Between 10- 20 Bags / Acre (…..)
iv. Between 20-30 Bags / Acre (…..)
v. Above 30 Bags / Acre (…)

23. What are the possible causes of crop yield decline in your farm? (*Please recall the previous 5 years*)

i. Decrease in Rainfall (…..)

ii. Increase of pest and Disease incidences e.g. Fall Armyworm/ MLND (…..)
iii. Low Soil Fertility (…..)
iv. Drought (…..)
v. Poor Seed Quality (…)
vi. Crop Disease e.g. MLND (…)
vii. High Increase in Input Costs (…)
viii. Lack of agricultural training (…)
ix. Small land sizes (………….)
x. Poor Extension accessibility (………….)
xi. Land Use Change (……………)

24. Has your farm been invaded by the pests called fall armyworms or any other disease e.g. MLND?

i) Yes (…..)Year of first sighting of FAW in your farm…………

ii) No (…..)

25. If yes, on what crops did you see them? (*Please recall the year and list two main crops*)

i. Year………………Crop…...
ii. Year………………Crop………………………….…

26. Do you have any knowledge about fall armyworm?

i. Yes (…..)
ii. No (…..) *(If NO, please skip to question 28)*

27. If yes, how often do you scout for fall armyworm in your farm?

i. Daily (…..)
ii. Weekly (…..)
iii. Monthly (…..)
iv. Never (…..)

28. Have you received any information about fall armyworm?

i. Yes (…..)
ii. No (…..) *(If NO, please skip to question 31)*

29. If yes, what was the source of information?

i. Extension Staff (…..)
ii. Agro-Input Dealer (…..)
iii. From Other Farmers (…..)

iv. Radio (…..)
v. T.V. (…)
vi. Newspaper (…)
vii. Other Research Institutions (…)

30. What was the type of Information materials did you receive about fall armyworm?

i. Poster (…..)
ii. Leaflet / Brochure (…..)
iii. Newspaper (…..)
iv. Meeting / Baraza (…..)

31. Can you positively differentiate fall armyworm from other crop pest?
i. Yes (…..)
iii. No (…..) *(If NO, please skip to question 32)*
ii. Not Sure (…..) (*Please explain*)…………………………………………………

32. What crop stage did you notice fall armyworm on your crops?
i. 3 weeks after germination (…..)
ii. Knee high (…..)
iii. Tussling (…..)
iv. Cob Stage (…..)
v. All the above stages (…)
vi. Other- Not seen any (…)

33. How many fall armyworm caterpillars did you notice on one maize crop?
i. No Caterpillars (…..)
ii. Few Caterpillars (…..)
iii. Many Caterpillars- (above 5) (…..)

34. Have you seen other crops affected by fall armyworm?
iii. Yes (…..)
iv. No (…..) *(If NO, please skip to question 36)*

35. If yes, name crops that were being affected by fall armyworm (*Please tick appropriately*)
i. Sorghum (…..)
ii. Finger Millet (…..)
iii. Potatoes (…..)
iv. Napier Grass (…..)
v. Kales (…)
vi. Tomatoes (…)
vii. Cabbages (…)

viii. Onion (…)
ix. Sunflower (…)
x. Fruits trees (Avocadoes/ fig trees) (………………)

36. What coping strategy did you use to control fall armyworm / pests from attacking your farm crops? *(Kindly let the farmers list and explain the coping strategies)*
……………………………………………………………………………………………

37. If pesticides, what was the source of pesticides used to control fall armyworm?
i. Ministry of Agriculture and Livestock / Fisheries (MOALF) (…..)
ii. Free from County Government (…..)
iii. Agro-Input Dealers (…..)
iv. Other- Research Institutions / Universities (…)
v. Neighbour Farmer (…)

38. What are the top three names of the common pesticides you use to control FAW invasion? *(Kindly let the farmers list all the top three names of the used pesticides)*
(i)…………………………… (ii)……………………………… (iii)…..…………………

39. What application methods do you employ? *(Kindly guide the farmers if the method is through knapsack/ motorized/ dusting/ smothering etc.)*……………………………….

40. At what time of the day are pesticides applied?
i. Early Mornings (…..)
ii. Mid-Day (…..)
iii. Evening (…..)
iv. At Night after 7.00 p.m. (…)

41. What protective equipment or attires do you use while applying pesticides?
i. Coats (…..)
ii. Gumboots (…..)
iii. Gloves (…..)
iv. Helmets (…..)
v. Overalls (…)
vi. Old clothing- tattered shoes, torn shirt and trousers (…)
vii. Eye Glasses- Shades (…)

42. What are the problems, difficulties and challenges experienced during pesticide application? *(Be specific from the applicators point of view).*
i. Heavy Breathing (…..)
ii. Skin Itching (…..)

iii. Sneezing and Coughing (…..)
iv. Headaches (…..)
v. Eye Sores- Teary (…)
vi. Stomach Gas- Flatulence (…)

43. Do you do any of these things during or after pesticide spraying? *(let the farmer guide you and tick appropriately*)

i. Eating during spraying (…)
ii. Drinking during spraying (…)
iii. Do not Shower after spraying / mixing pesticides (…)
iv. Do not Watch wind Direction during spraying (…)
v. Mix pesticide using bare hands (…)
vi. Mixing different chemicals together (…)
vii. Disposal of chemical containers near fences (…)
viii. Re-using chemical containers (…)

44. Where do you store the used containers / chemical within your house? *(Please explain from your own storage perspective)*

i. ....
ii. ....
iii. ………………………………………………
iv. ………………………………………………

45. Where do you dispose the containers that contain pesticides after they become empty?

....
……………………………………………………………………………………………

46. Has there ever been an accident caused by chemical use? *(Specify the accident type).*

....
……………………………………………………………………………………………

47. How did you deal with the accident?

....
……………………………………………………………………………………………

48. What control measures have you put in place to protect yourself from chemical accidentals and your surrounding from the pesticide contamination? (*Guide the respondents to be specific*)

....

....

49. What adaptation strategies are using as fall armyworm continues to stay in your crop- field? *(Kindly let the farmers list and explain the adaptation strategies)*

………………………………………………………………………………………………

50. What are some of the potential environmental effects that you have seen in your area since the arrival of fall armyworm?: (*No order of priority*)

i……………………………………………

ii……………………………………………

iii...

iv...

v………………………………………………

vi………………………………………………

51. What has changed in your households and the community since the arrival of fall armyworm in your farm-fields? *(Let the farmers list the changes in order of priority and explain about the changes)*

i……………………………………………………………….……………………………

ii…………………………………………………..………………………………

iii...

iv..

v……………………………………………………….…………………………

52. Any comments or questions you could wish to have clarification: (*Let the farmers ask or comment*)………………………………………………………………………………

....

APPENDIX II: Checklist for Farmer Groups Discussions

My names are Nyakwara A. Zilpher. I am a PhD student at Egerton University, Njoro, currently, undertaking a research on: "Gender perspective in mitigating fall armyworm (*Spodoptera frugiperda*) towards environmental and food production resilience in Bomet County, Kenya". Your participation in this study will be voluntary and you have the right to refuse to participate or answer any questions that you feel uncomfortable. If you change your mind about participating during the course of the interview, you have the right to withdraw at any time. The handling of the provided information will be confidential, and never to be linked to any individual or your farmer group. I hope you will allow me to look at your certificate of registration.

Signature: …………………………… **Date**…………………………………………

These questions will serve as a guideline in case the discussions are stuck. The moderator and co-moderator will lead the discussion towards meeting the research objectives. The responses noted in the notebooks of the researcher and enumerators.

Study topic: Gender perspective in mitigating fall armyworm *(Spodoptera frugiperda*) towards environmental and food production resiliency in Bomet County, Kenya

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1. What is the name of your group?
2. What year did you form your group?
3. How many members… (i) Males (ii) Female (iii) Youths (iv) Abled Differently
4. Why and how did you decide to form your group?
5. What are the main objectives of your group?
6. What are your main different gender roles / activities within your group?
7. How did you choose your members?
8. How would you describe your farming methods? (small or large scale)
9. What are the most important crop for your group and family?
10. Why? *Explain for each crop they mention.*
11. Do all your group members know about fall armyworm (FAW)?
12. What kind of chemicals do you use to control FAW?

13. How do you apply chemicals these chemical within your farms?
14. Who is responsible for the application of the chemicals being used and why?
15. What kind of management practices is best?
16. Are the whole household members affected or is it just individuals?
17. Where do you source your pesticides?
18. How many times do you apply pesticides within one season?
19. What are the specific timings for applications and are there signs on leaves or other signs that you have to pay attention?
20. How do you apply pesticides? (*I.e. what kind of precautions do they use)?*
21. Are you concerned about the effects of pesticides on your health, soil, water, food chain?
22. Where do you store the containers of already used chemicals?
23. What protective clothing do you use during chemical spray?
24. Has there ever been an accident caused by chemical use? *(Specify the accident type).*
25. How did you deal with the issue?

APPENDIX III: Checklist for Key Informants

My names are Nyakwara A. Zilpher. I am a PhD student at Egerton University, Njoro, currently, undertaking a research on: "Gender perspective in mitigating fall armyworm (*Spodoptera frugiperda*) towards environmental and food production resilience in Bomet County, Kenya". Your participation in this study will be voluntary and you have the right to refuse to participate or answer any questions that you feel uncomfortable. If you change your mind about participating during the course of the interview, you have the right to withdraw at any time. The handling of provided information will be confidential, and not linked to any individual or your farmer group. I hope you will allow me to look at your certificate of registration.

Signature: …………………………… **Date**…………………………………………

These questions will serve as verifications from the responses gathered from different households and farmer focus groups. The responses noted in the notebooks of the researcher and enumerators.

Study topic: Gender perspective in mitigating fall armyworm *(Spodoptera frugiperda*) towards environmental and food production resiliency in Bomet County, Kenya

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1. What are the type of farming methods farmers practice here in Bomet County?
2. What are the major five important food crops grown in the county?
3. What are the major climatic changes that have occurred in Bomet County?
4. Has these climatic conditions affected the production of food crops in Bomet County?
5. When was the first time that FAW reported in Bomet County?
6. Which sub-county was affected more by FAW invasion
7. How did you advice for the control of FAW invasion?
8. Did the invasion of FAW affect different headed households differently?
9. Any impacts (<u>environmental/ food security</u>) due to the invasion of FAW in the county?
10. Which is the way forward for smallholder farmers on food crop production?

APPENDIX IV: Research Publications

International Journal of Science and Research (IJSR)
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Gender Roles Influencing Fall Armyworm Management Towards Environmental and Food Production Resilience in Bomet County, Kenya

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Abstract: ***The emergence and rapid spread of the fall armyworm (FAW) Spodoptera frugiperda in Africa having spread from its Native American since 2016 seriously threatens the food crop production of millions of smallholder farmers. In December 2016, the Kenyan government started experiencing the invasion of FAW threatening the food crop production in the country. Smallholder farmers have different household setups with gender differentials towards managements of any new invasive crop pests including FAW. A household baseline survey and focus group discussions were done using a structured questionnaire and checklist with the aim of identifying gender roles in the management of the fall armyworm invasion in Bomet County. The study result showed that both male and female farmers were involved in decision making during pesticide spraying, local sorcery (seers), shifting of priority crop production, mixing hybrid maize seeds alongside local maize seed varieties, feeding livestock with infected plants, crop rotation, and inter - cropping and mono - cropping. Spiritual interventions and manual killing was done by female farmers only whereas, there was no role that was done by male farmers only. There should be awareness creations on farmers so that they don't spread fall armyworm through their management practices such as transporting infected plants to feed their animals. There should be training for both men and women farmers on fall armyworm management practices whereas, the training should take into consideration the different gender roles.***

Keywords: Gender; Fall Armyworm; Households, Food Production; Environmental Management

1. Introduction

There has been changes in the social system between many smallholder farmers' and their households' daily farming welfare. These changes have been occasioned from the impacts of the fall armyworm (FAW) (*Spodoptera frugiperda*). The FAW is an invasive pest from Latin America which appeared in Africa in 2016 and spread widely threatening the food and income security of millions of smallholder farmers (Day *et al.*, 2017; Kebede 2018; De Groote, 2020). FAW is known to feed on over 350 plant species with a preference for maize, a staple food for over 300 million Africans including Kenya's smallholder farm families (Midega *et al.*, 2018; FAO, 2018; MOA, 2018; Montezano *et al.*, 2018). Different study findings have shown that if FAW is left uncontrolled, it can cause up to 100% maize yield loss (Burtet *et al.*, 2017; Day *et al.*, 2017; Deole and Paul, 2018; De Groote, 2020).

There is an abundance of new pesticide users in agricultural production where invasive pests including FAW have recently invaded. The overuse of these pesticides is known to cause negative consequences to the environment (e. g. soil, food contamination, water and air) and ultimately human health (Chimweta, *et al.*, 2020). As the indiscriminate use of pesticide in farmlands increased over the past few years since the arrival of FAW, the likelihood of smallholder farmers' exposure to these chemicals increased considerably (Goergen *et al.*, 2016; Burtet *et al.*, 2017). On the other hand, the invasive pests significantly disrupted the environment's resilience to agricultural production activities. Once a new invasive pest arrives on farmer crop, the change and shift is almost dramatic (Bottrell and Schoenly, 2018). Environmental systems have always been vulnerable to hazards like new invasive pests, which upset the smooth functioning of many interconnected components thereby interfering with the resilience of the environment (Castells – Quintana *et al.*, 2018). This study, used the resilience theory which is an integrative theory of social change that examines processes and drivers of change in complex adaptive environmental systems.

The outbreak of FAW was first reported in Kenya in 2016 (Davis, 2018). The pest spread rapidly to all major maize producing areas in the country including Bomet County causing heavy losses affecting food security and trade. Agriculture is the main economic activity in Bomet County with over 80 percent of the total population engaging in crop and livestock production (FAO, 2017). The main farming systems practiced in Bomet County are small - scale mixed crop - livestock systems and medium to large - scale mono - cropping systems (Cramer, 2021). Food crops in Bomet have been threatened by the outbreak of invasive pests especially FAW and maize lethal necrosis disease (MLND) (Niassy *et al.*, 2020; De Groote *et al.*, 2021). These challenges relate largely to poor crop husbandry, use of uncertified seeds, poor land management, and lack of information (Ansah *et al.*, 2021; Asare - Nuamah, 2021). Bomet County is unique since it has all year round crop production potential. This conditions greatly favours FAW, and hence the importance of knowing the management strategies. This study probed on identifying smallholder farmers' different gender rolesin the

EFFECTS OF FALL ARMYWORM INVASION ON FOOD PRODUCTION BETWEEN DIFFERENTIATED HEADED HOUSEHOLDS IN BOMET COUNTY, KENYA

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Abstract

The emergence and rapid spread of the fall armyworm (FAW) Spodoptera frugiperda in Africa having spread from its Native American since 2016 seriously threatens the food crop production of millions of smallholder farmers. In December 2016, the Kenyan government started experiencing the invasion of FAW threatening the food crop production in the country. Smallholder farmers have different household setups with gender differentials towards managements of any new invasive crop pests including FAW. From literature reviews, fall armyworm invasion can affect food production to zero production if not properly managed but there are gaps on effects of fall armyworm within different headed households by gender prompting the study on effects of fall armyworm invasion on food production between differentiated headed households in Bomet County, Kenya. Data was collected using multiple approaches including interviews on households and key informants, focus group discussions and observations. A household baseline survey and focus group discussions were done using a structured questionnaire and checklist where a total of 384 respondents were enumerated. The study result showed that the management of fall armyworm are gender specific with different gender roles and activities being used. Therefore, gender specific programs and different headed households should be approached differently during agricultural production using an effective network of extension and advisory which provides technical advice on management of new invasive pests towards food production and environmental resilience

Keywords. Fall Armyworm; Food Production; Households; Gender; Environmental Management

APPENDIX V: NACOSTI Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 245944

Date of Issue: 25/June/2021

RESEARCH LICENSE

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