DETERMINANTS OF PESTICIDE USE AND UPTAKE OF ALTERNATIVE PEST CONTROL METHODS AMONG SMALL SCALE TOMATO FARMERS IN NAKURU COUNTY, KENYA

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DECLARATION AND RECOMMENDATION

Declaration

This is to declare that this thesis is my original work and has not been presented for the award of any another degree elsewhere.

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Recommendation

This thesis has been submitted for examination with our recommendation as the University Supervisors.

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DEDICATION

I dedicate my work to my loving parents the late Gideon Kinuthia and Teresia Muremba for their unconditional support and prayers throughout my studies.

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ABSTRACT

Increasing demand for food and the diminishing agricultural land has resulted in farmers putting great efforts to increase crop yields by using more fertilizer and pesticides. Pesticide use in agricultural production has, however, produced undesirable effects on human health and the environment. Thus, the study aimed at contributing to sustainable agricultural intensification through safe pesticide use and uptake of alternative pest control methods among small-scale tomato farmers in Nakuru County, Kenya. Specific objectives of the research study were; to evaluate precautionary behaviours in pesticide use among small-scale tomato farmers and to determine socioeconomic and institutional factors that influence the level of pesticide usage among small-scale tomato farmers. The study also sought to establish the role of risk perception, institutional and socio-economic characteristics on the intensity of uptake of alternative pest control methods among small-scale tomato farmers. Multistage sampling procedure was used to select a sample of 384 respondents. A semi-structured questionnaire was used to collect data which was administered by trained enumerators. Data were analysed using descriptive statistics, trivariate ordered probit and multivariate Tobit models. Principal component analysis was used to categorize alternative pest control methods into four groups. Results indicated that safety behaviours in pesticide use were inadequate, particularly in the use mask (0.52%), gloves (18.49%) and hats (26.30%). None of the farmers was using goggles. High purchase cost (36.95%), discomfort (20.05%) and not necessary for each case (20.57%) were the leading factors attributed to lack of/limited use of protective gears. Majority of the small-scale farmers were overusing insecticides (97.66%) and fungicides (91.93%). A significant proportion of the tomato farmers were underusing herbicide (83.33%). Findings from the Trivariate ordered probit model estimation indicated that gender, farming experience, distance to the market and number of contacts with the extension service provider positively influenced the level of pesticide usage. Moreover, participation in training programs, group membership, and risk perception positively influenced the intensity of uptake of alternative methods; while farm size and participation in off-farm activities had a negative effect on the intensity of uptake of alternative methods. The study concluded that a significant proportion of small-scale farmers overuse pesticide while managing insect pests and diseases. Consequently, the study recommended the requisite for provision of safety training programs and adequate extension services to facilitate proper pesticide use and uptake of alternative methods for improved livelihoods and environmental conservation. To public policy, formulating and implementing targeted interventions aimed at promoting the use of alternative pest control methods that minimize negative health and environmental effects from overuse of pesticides.

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LIST OF ABBREVIATIONS AND ACRONYMS

CIDP	-	County Integrated Development Plan
CM	-	Control Measures
CMP	-	Crop Management Practices
DDT	-	Dichlorodiphenyltrichloroethane
GoK	-	Government of Kenya
Ha.	-	Hectare
HCH	-	Hexachlorocyclohexane
IPM	-	Integrated Pest Management
KES	-	Kenyan Shilling
Kg.	-	Kilogram
Km.	-	Kilometer
L.	-	Litre
MM	-	Mechanical Methods
MT	-	Metric Tonne
MoALF	-	Ministry of Agriculture, Livestock and Fisheries
PM	-	Preventive Measures
PPE	-	Personal Protective Equipment
SPSS	-	Statistical Package for Social Scientist
Ton.	-	Tonnes
WHO	-	World Health Organization
UNEP	-	United Nation Environmental Programme
USD	-	United States Dollar
VIF	-	Variance Inflation Factor

CHAPTER ONE
INTRODUCTION

1.1 Background information

Rising urban population in Kenya has increased demand for food specifically fresh agricultural produce. Consequently, small-scale farmers in peri-urban and rural areas are venturing into high-value horticultural production which can fetch higher prices in the urban market (Lagerkvist *et al*., 2012). Tomato is one of the high-value horticultural crop widely grown by small-scale farmers (Musah *et al*., 2016). It is a vital crop among small-scale farmers which generates income and creates employment particularly in rural areas (Ssejjemba, 2008; Sigei *et al*., 2014). Farmers grow tomato in an open field or in a greenhouse. Open –field tomato production under prevailing unfavourable climatic conditions has been challenging to small-scale farmers. Subsequently, greenhouse production is gaining popularity due to its potential to produce high yields and provide favourable conditions (Wachira, 2012; MoALF, 2015). The sub-sector contributes fourteen per cent to aggregate vegetable output and 6.72 per cent to total horticultural output in Kenya (Najjuma *et al*., 2016). In 2014, Nakuru County accounted for 17510.9 Tons of the total national tomato output with an increase in area under production from 495.2 Ha to 633 Ha. The County was ranked the sixth after Bungoma, Kirinyaga, Kajiado, Makueni and Kiambu County regarding tomato production (MoALF, 2015). In 2015, the total national tomato output increased from 383,868 MT to 400,204 MT.

With diminishing agricultural land due to population increase and urbanization, tomato remains an essential crop for small-scale farmers since it can be grown on a small piece of land. Tomato is a common dietary and nutritional component of many households in Kenya (Sigei *et al*., 2014). It is rich in Minerals such as phosphorus and calcium as well as vitamin A and C (Naika *et al*., 2005). Small-scale tomato farmers sell their fresh produce to local retailers, wholesale traders, processing companies, greengrocers, hotels and supermarkets to mention but a few. Furthermore, changes in consumer taste and preferences specifically on safe and healthy food has contributed to the growth and expansion of supermarket chains. Naivas, Tuskys, Nakumatt, Uchumi and Ukwala (currently Choppies) supermarkets have expanded their operations by engaging in contract farming with vegetable farmers. This has offered stable prices and a steady market for their farm produce (Ismail, 2013). Consumers can access high-quality fresh produce and other commodities under one roof.

Despite its contribution to economic development through poverty alleviation and income generation, tomato farmers face numerous challenges. For instance, high incidence of pests, harsh climatic conditions and fluctuation in agricultural commodity prices. In addition, poor infrastructure, the high cost of production and market constraints are some of the challenges facing small-scale tomato farmers (Waiganjo *et al*., 2013; Musebe *et al*., 2014; Sigei *et al*., 2014; Mueke, 2015). The common diseases of tomatoes include mildew, bacterial wilt, early and late blight, leaf spots, leaf curl, tomato mosaic virus and fusarium wilt. The major insect pests include cutworm, leaf miners, *Tuta absoluta*, root-knot nematodes, bollworms, spider mites, thrips, whiteflies and aphids (Desneux *et al.*, 2010; Musebe *et al*., 2014; Sigei *et al*., 2014; Mueke, 2015).

To meet the high local demand, small-scale farmers are intensifying their agricultural production by utilizing more pesticides (Lagerkvist *et al*., 2012) to mitigate major production constraints such as high insect pest and disease incidence. Consumers, on the other hand, are demanding fresh agricultural products that are of high quality and blemish free (Lagerkvist *et al*., 2013). Production of agricultural commodities that meet specific consumer requirements under prevailing climatic condition has been challenging. As a result, farmers are heavily relying on pesticides to combat pest problem, and reduce crop losses in quality and quantity (Macharia, *et al*., 2013; Macharia, 2015; Mwangi *et al*., 2015). The resultant misuse and excessive use of pesticides by small-scale tomato farmers have become detrimental to human health as well as the environment. Soil and air pollution, human health ailments and pest resistance to mention but a few are some of the adverse effects of indiscriminate use of pesticide (Macharia *et al*., 2009; Srinivasan, 2012; Macharia *et al*., 2013).

1.2 Statement of the problem

Tomato is a chief source of income and employment among small-scale farmers. The crop is however characterized by high pesticide use due to its vulnerability to insect pest and disease attack. This is confounded by consumer`s preference for blemish-free and high-quality tomatoes. To respond to the expanding market demand and consumer preferences, small-scale tomato farmers heavily rely on pesticides for crop protection so as to improve its yields and quality. Improper use of pesticides while controlling agricultural pests has undesirable effects on human health, environment, and even death due to direct exposure. In addition, inappropriate pesticide use may lead to an increase in the cost of production. In spite of efforts by government extension service providers to educate small-scale tomato farmers on pesticide use and alternative pest management techniques, there is little knowledge about determinants of the level of pesticide usage among small-scale tomato farmers. The role of risk perception, socio-economic and institutional factors in influencing the intensity of uptake of alternative pest control methods is still not clear in the empirical literature. Hence, it is on the foregoing that this study was geared towards filling these knowledge gaps among small-scale tomato farmers in Nakuru County.

1.3 Objectives

1.3.1 General objective

To contribute towards sustainable agricultural intensification through safe pesticide use and uptake of alternative pest control methods among small-scale tomato farmers in Nakuru County, Kenya.

1.3.2 Specific objectives

1) To evaluate precautionary behaviours in pesticide use among small-scale tomato farmers.
2) To determine socioeconomic and institutional factors that influence the level of pesticide usage among small-scale tomato farmers.
3) To establish the role of risk perception, socio-economic and institutional characteristics on the intensity of uptake of alternative pest control methods among small-scale tomato farmers.

1.4 Research questions

1) What are the precautionary behaviours in pesticide use among small-scale tomato farmers?
2) Which socioeconomic and institutional factors influence the level of pesticide usage among small-scale tomato farmers?
3) What is the role of risk perception, socio-economic and institutional characteristics on the intensity of uptake of alternative pest control methods among small-scale tomato farmers?

1.5 Justification of the study

Pesticide overuse during crop protection against pests has become a common feature in contemporary agriculture. This has created increasing concerns about pesticide-related adverse effects on human health and the environment (Hossard *et al*., 2017; Jallow *et al*., 2017). Some of the short-term and chronic illness due to pesticide exposure include skin irritation, excessive salivation, shortness of breath, sneezing, coughing, headache, vomiting, stomach pains, cancer and dermatitis to mention but a few (Karunamoorthi *et al*., 2012; Macharia *et al*., 2013; Macharia, 2015). As a result, understanding the farmer's extent of pesticide use is paramount in altering their behaviour towards decreasing pesticide use.

Tomato is an important commercial vegetable crop in Nakuru County which has potential to generate household income and creation of employment (Lagat *et al*., 2007; GoK, 2013; Munyua and Wagara, 2015). Nakuru County is one of the leading tomato producing areas in Kenya (Sigei *et al*., 2014; Mueke, 2015). Nakuru County has been reported as one of the regions with rising cases of pesticide misuse during crop protection leading to high levels of pesticide residues in agricultural produce. This threatens consumer food safety, human health as well as the environment (Lagat *et al*., 2007; Okworo, 2017). Proper utilization of pesticides in the area will lead to environmental conservation, improved food safety leading to improved human health and reduced cost of production. Consequently, tomato production will contribute towards poverty alleviation in the region where the human poverty index is 24.6% (GoK, 2013). This is a step towards achieving the first sustainable development goal of poverty eradication (Pisano *et al*., 2015) in the nation. Research findings will contribute towards the smooth implementation of Food, Drugs and Chemical Substances Act (2013), National Environment Policy 2013 as well as Crop Act 2013 which are aimed at promoting and enhancing food safety, environmental safety and increasing agricultural productivity through rational pesticide use.

Also, the literature on the level of pesticide usage, non-chemical pest control methods and pesticide risk perception among small scale farmers growing tomatoes in open field in this region is limited. Risk perception is significant in the choice of alternative pest control methods because of its influence on the farmer's decision-making process and behaviour. Consequently, information from the research study findings will enhance safe pesticide use. This could lead to reduced crop loss due to insect pest and diseases leading to increased yields, increased farm incomes, improved food nutrition and better living standard. Moreover, findings from this study will enable policymakers to formulate intervention strategies aimed at promoting an alternative to pesticide use leading to improved human health and conservation of the environment.

1.6 Scope and limitation of the study

The study was confined to Nakuru County. The study was limited to small-scale tomato farmers who grew tomatoes in open field. The selected main issues in this study included precautionary pesticide use behaviours, determinants of the level of pesticide usage as well as the role of risk perception, socio-economic and institutional characteristics on the intensity of uptake of non-chemical control methods among small-scale tomato farmers. The findings in this study though useful were limited in that farmers interviewed hardly kept records on pesticide use. Consequently, most of the answers to questions were based on the farmer's memory. However, thorough probing was undertaken to ensure respondents gave accurate data.

1.7 Operational definition of terms

Pesticide: As used in this study refers to synthetic compounds used by farmers in crop protection from pests. Some examples of pesticides include insecticides, fungicides, and herbicides**.**

Handling practices: It refers to the behaviours of the farmer while mixing, applying, storing and disposing of pesticide rinsate and empty containers.

Small-scale farmer: Refers to a farmer whose area under tomato production is five acres and less.

Household: Refers to an individual plus her/his dependants who have lived together for six months or more. The members are answerable to one person as the head and share a meal together.

Pest: As used in this study refers to an organism that is considered to be undesirable or destructive in crop production such as, insects, diseases, weeds, and rodents.

Precautionary behaviour: Refers to responses made by a small-scale tomato farmer to safeguard himself or herself against pesticide-related hazards.

Risk perception: In this study refers to small-scale tomato farmer`s attitude towards risk associated with pesticide use.

Sustainable agricultural intensification: It refers to a process where there is an increase in agricultural output (such as tomato yields) per unit of inputs (such as crop protection products) applied without adverse human health and environmental effects.

CHAPTER TWO
LITERATURE REVIEW

2.1 Tomato production in Kenya

Tomato (*Solanum lycopersicum L.*) is one of the chief vegetable crops in Kenya. It is rich in minerals and vitamins (C) which make it an imperative nutritional component among households in Kenya (Sigei *et al*., 2014). It is consumed either in raw form (salads) or processed form such as tomato paste or tomato sauce. Moreover, it contributes towards poverty alleviation through the creation of employment, income generation and earning foreign exchange (Sigei *et al*., 2014). Small-scale farmers play a significant role in tomato production in Kenya. A large proportion (95%) of gross tomato output comes from open-field production while the remaining part (5%) is produced under greenhouses (Seminis, 2007). According to FAO (2012), the aggregate quantity of tomato produced in Kenya was three hundred and ninety-seven thousand and seven tons. Besides, Kenya was ranked sixth in Africa which makes it be one of the prominent tomato producing country in the region. Some of the main tomato growing regions in Kenya are presented in Table 1.

Table 1: Tomato production in selected counties in Kenya

County	Area (Ha)	Amount (MT)	Value (KES) Millions	Share by amount
Bungoma	1,700	50,399	1,611	19.2%
Kirinyaga	1,648	48,560	1,156	18.5%
Kajiado	1,680	47,368	1,624	18.1%
Makueni	558	21,096	857	8.1%
Kiambu	964	18,029	812	6.9%
Nakuru	633	17,511	347	6.7%
Kisumu	1,477	16,720	328	6.4%
Kisii	937	16,664	351	6.4%
Trans Nzoia	628	14,848	416	5.7%
Bomet	644	10,750	319	4.1%
All Counties Total	10,869	261,945	7,821	100.0%

Source: MoALF, (2015)

From Table 1, Bungoma County (19.2%) is the leading producer of tomato followed by Kirinyaga (18.5%), Kajiado (18.1%) and Makueni (8.1%). They account for the largest share of tomato production in the country. According to Musyoki *et al*. (2005), determinate variety requires open-field production. Examples of such high-yielding variety include Monyalla, Onyx, Tanzanite, and Eden. Cal. J (Kamongo) is also grown due to its long shelf life and high market value in spite of its vulnerability to diseases. Anna F1, Marglobe, Nemonneta, Kenom, and Monset are indeterminate varieties which require greenhouse production (Odema, 2009).

Despite its crucial role in the development of the national economy, farmers are faced with insect pest and disease outbreak which is a major production constraint. They lead to crop loss hence have an adverse effect on tomato production. Some of the common tomato diseases comprise of mildew, blight, leaf spots and wilt. Examples of tomato pests include cutworm, leaf miners, nematodes, bollworms, *Tuta absoluta*, spider mites, thrips, whiteflies and aphids (Desneux *et al*., 2010; Mueke, 2014; Sigei *et al*., 2014). Consequently, various pest management methods can be used to minimize crop loss and improve yields. Some of the crop protection methods consist of mechanical control, planned crop rotation, biological control, cultural control and pesticide use. However, small-scale farmers heavily rely on pesticides to combat pest problem which has the potential to destroy non-target organisms, negatively affect human health and the environment (Waiganjo *et al*., 2006; Macharia, 2009).

2.2 Health and environmental effect of pesticide use in agriculture.

Modern agriculture is characterized by widespread utilization of pesticides in an attempt to prevent crop losses from insect pests and diseases. Despite the potential economic benefits (increased yields and crop protection) associated with pesticide use, related hazards are still a concern (Lagat *et al*., 2007; Quinteiro *et al*., 2013; Alam and Wolff, 2016; Hossard *et al*., 2017). For instance, in less developed countries, farmers and farm workers are constantly exposed to pesticides which have resulted to short-term (acute) and long-term (chronic) ailments (Tandi *et al*., 2014; Macharia, 2015). According to Dasgupta and Meisner (2005), pesticide poisoning rate ranges from two to three person per minute based on UNEP and WHO estimates most of which are experienced in less developed countries.

Prior studies have reported unsafe pesticide handling behaviours in some countries including Kenya (Hashemi *et al*., 2012; Macharia *et al*., 2013; Khan and Damalas, 2015). These consist of overdose, improper storage, hazardous disposal and failure to wear protective gears (Dasgupta *et al*., 2007; Karunamoorthi *et al*., 2012; Macharia *et al*., 2013; Jin *et al*., 2014). Furthermore, failure to observe proper hygiene during application and preparation of pesticides in the kitchen were common unsafe practices observed among farmworkers in Palestine (Zyoud *et al*., 2010). Improper storage of pesticides and inappropriate disposal of pesticide rinsates and empty containers has been reported in previous studies (Macharia *et al*., 2013; Yang *et al*., 2014). Other examples of improper pesticide handling practices include applying excess dosages and using pesticides that have been prohibited or are outdated (Mohanty *et al*., 2013; Raman *et al*., 2013; Fan *et al*., 2015; Gerber *et al*., 2016).

Some of the routes of exposure during pesticide use are dermal contact, inhalation, ingestion and eye contact to mention but a few (Damalas *et al*., 2006). This has resulted in ill health and adverse environmental effects in less developed countries (Damalas and Khan, 2016). According to a study carried out in China (Wang *et al*., 2017), a significant number of respondents indicated that their health had been affected by pesticide use. For instance, forty-three per cent of women and forty-seven per cent of men agreed that pesticide use had an adverse effect on the environment. Examples of acute ailments which have been associated with pesticide exposure include a headache, nausea, vomiting, sneezing, eye, respiratory problems, stomach pains and skin irritation (Antle and Pingali, 1994; Macharia *et al*., 2013). Chronic illnesses include endocrine disruption, neurobehavioural disorders, dermatitis, congenital disabilities, asthma, and cancers (Macharia, 2015). In extreme cases, death due to direct exposure has also been reported (Dasgupta and Meisner, 2005; Selvarajah and Thiruchelvam, 2007). For instance, a substantial proportion of Ethiopian farmers reported a headache, nausea, vomiting, sneezing, and salivation as short-term illness due to pesticide exposure (Karunamoorthi *et al*., 2012).

Mismanagement of chemical pesticides not only negatively affect human health but also the environment. For instance, the disposal of empty pesticide containers in the farm fields or cleaning equipment used to apply pesticides in the ponds or stream causes soil and water pollution. Moreover, Loss of non-target organisms, loss of livestock and the beneficial organism, as well as air pollution, have also been associated with inappropriate pesticide use (Macharia *et al*.,2013; Diomedi and Nauges, 2016). In Pakistan (Khan, 2009), above seventy-seven per cent of the farmers experienced at least one health ailments due to pesticide exposure. The most self-reported acute illnesses were skin irritation, fever convulsion and dizziness, difficulty in breathing, vomiting, headaches and eye irritation. However, some farmers not once experienced any symptoms during pesticide application or were unaware of the pesticide health hazards (Khan, 2009). These findings correspond with Zyoud *et al*. (2010) observations on self-reported pesticide ailments in Palestine. From the study in Palestine, a strong inverse relationship between scores on the protective measure and pesticide-related acute diseases was reported.

On average, health expenditure estimates due to pesticide-related sicknesses in Vietnam and Philippines was USD 56.66 and USD 32.83 per annum correspondingly (Selvarajah and Thiruchelvam, 2007). In Kenya, indirect health costs were estimated to be USD 3.5 per farmer per annum (Macharia, 2015). In addition to these monetary expenses, farmers suffer from emotional stress and discomfort due to the ailment. Travel expenses, loss of yield, the cost of hiring labour, loss of leisure time and dietary costs due to illness are incurred by the farmer. The cost of illness due to pesticide application in Sri Lanka incurred by affected farmers was Rs.2325 per annum (Selvarajah and Thiruchelvam, 2007). However, some farmers drank thick squeezed coconut milk instead of going to the hospital after experiencing the symptoms.

Inappropriate handling practices of a pesticide such as burning empty containers in open air contribute to air pollution. Disposing of empty pesticide containers in the field or burying them is also hazardous to the environment (Mengistie *et al*., 2015). Mostly chemical properties of the pesticides are unknown to the majority of the users especially farmers (Zyoud *et al*., 2010). By disposing of rinsates in the soil, it endangers beneficial arthropods in the soil if it is toxic. Ajayi (2000) indicated that farmers were aware of the adverse effect of pesticide on the environment. They stated that pesticides destroyed plants and polluted the environment. However, this did not prevent its use among farmers in the region. In India, pesticides which have been banned (DDT and HCH) are still in use which endangers human health and environmental components (Abhilash and Singh, 2009; Chandra *et al*., 2015). Use of banned pesticides and intentional poisoning of wild animals was established in Spain which threatened the biodiversity (Ruiz-suárez *et al*., 2015).

Furthermore, residues of persistent organic pesticide were found in the soil, air, and water in some areas. This has contributed to environmental pollution in the region. The presence of above-normal maximum residue levels in the ecology has been attributed to the application of excessive dosage of pesticides (Chandra *et al*., 2015). Hossard *et al*. (2017) established that pesticide consumption in France did not decrease despite the implementation of the environmental policy aimed at reducing pesticide use. Moreover, the contamination of water bodies due to pesticide use did not reduce either. Improper implementation of these strategies designed to reduce pesticide use in agricultural production might have contributed to it (Hossard *et al*., 2017). Though cases of pesticide-related ailments due to misuse of pesticides are not as rampant in Africa as in Asia, there is fear that they might rise with increasing intensification of agricultural production which accelerates the use of pesticides.

2.3 Determinants of safe pesticide use

Farmers desire to increase yields, improve product quality and manage pests drives them to use chemical pesticides. However, indiscriminate use of pesticide has become a significant public health and environmental concern specifically in less developed countries. Precautionary practices in pesticide use could minimize the adverse effects of pesticide use. Some examples of the safety practices include applying a recommended dose, wearing personal protective equipment, appropriate disposal, safe storage, observing proper personal sanitation during and after pesticide application among others (Selvarajah and Thiruchelvam, 2007; Zyoud *et al*., 2010; Schreinemachers *et al*., 2016). Factors such as age, gender, education, farm income, farm size, training and farming experience have been found to have an effect on farmers` behaviours in pesticide use (Macharia *et al*., 2013; Damalas and Khan, 2016; Wang *et al*., 2017). Previous studies (Jin *et al*., 2014; Khan *et al*., 2015; Damalas and Abdollahzadeh, 2016) have revealed that inappropriate use of pesticides has been attributed to lack of training and education in pest management and inadequate provision of extension services. Education level was found to influence the usage of pesticide labels in Pakistan. According to Damalas and Khan (2016), a solid fraction of cotton farmers in Pakistan reported that they did not read the labels.

Age, income, education level, training, and farming experience have been reported as determinants of usage of pesticide product labels by farmers. Better educated farmers tend to use pesticides judiciously and are careful to follow the recommended guidelines to the latter, unlike less educated or illiterate farmers. This might be attributed to awareness of the ill effects associated with misusing pesticides since they have access to that information. Knowledge level of pesticide use and safety was low among the majority of the farmers. For instance, farmers who failed to read labels had lower income, a low level of education and training and higher age than their counterparts. On the contrary, there was no significant relationship between farm size and reading pesticide labels (Damalas and Khan, 2016). Jin *et al*. (2017) found out that farmers with more experience in farming had a higher likelihood of pesticide overuse because of difficulty in reading and understanding pesticide label instructions. In contrast, Kabir and Rainis (2012) revealed that farmers with more experience were disinclined to use more pesticide during vegetable farming. In China, farmer`s Socioeconomic characteristics were found to have a substantial influence on their precautionary behaviours (Wang *et al*., 2017). Farmer's pesticide risk perception, the primary source of information on pesticide and other socio-economic characteristic have been found to play a role in influencing farmer's behaviour in pesticides use (Jin *et al*., 2014; Damalas and Abdollahzadeh, 2016). For example, young farmers tend to perceive pesticide overuse as risky as compared to elderly farmers (Damalas and Hashemi, 2010).

Source of information on pest management and pesticide use related hazards have been highlighted as a determinant of safe pesticide use (Ngowi *et al*., 2016). For instance, cotton farmers relied on friends, neighbours, pesticide vendors and pesticide companies for information. On the other hand, few farmers relied on extension officers for information. A recent study in Thailand indicated that lower pesticide use was associated with improved knowledge on pesticide use, route of exposure and adverse health effect (Praneetvatakul *et al*., 2015). Inefficacy of extension officers in providing accurate and reliable information on pest control and safe pesticide use has been attributed to high incidences of pesticide overuse in some of the developing countries (Jin *et al*., 2017). Moreover, information sources (social learning, extension officer, and pesticide sellers) played a role in the adoption of health protection practices in Bangladesh (Alam and Wolff, 2016).

Income has been found to influence precautionary behaviour in pesticide use in previous studies. Damalas *et al*. (2006) revealed that a significant proportion of tobacco farmers in Greece did not use any personal protective clothing during pesticide application. Face masks, gloves and coveralls were reportedly used by only a few farmers in the region. Contrary, respirators were not used by farmers. The majority of the farmers reported that they replaced their work clothing after wearing out or upon contamination. This implies that replacement is not done regularly as required. Factors such as financial constraint, being uncomfortable, not essential, unavailability when needed and time-consuming to wear were associated with failure to use protective clothing during pesticide handling. Preceding studies in Africa have reported improper use of PPE (Kenya (Macharia *et al*., 2013), Cameroon (Tandi *et al*., 2014), Ethiopia (Mengistie *et al*., 2015). In most instances, farmers hardly used protective gears during pesticide application despite their knowledge of the related health hazards and availability. Gloves were rarely used by vegetable farmers in Kenya during spraying (Macharia *et al*., 2013; Macharia, 2015).

The previous study has reported hazardous disposal of pesticide containers and rinsates (Macharia *et al*., 2013). For instance, in Kenya, farmers disposed of empty containers within the farm by burying them, throwing in the disposal pit or latrine, dumping in the field or recycling (Macharia *et al*., 2013). Also, some of the vegetable farmers were using water from the streams or ponds to clean equipment used to apply pesticides. Consequently, releasing rinsates into the water bodies hence polluting the environment. Similarly, in Papua New Guinea, farm households were disposing empty pesticide containers into the bush (44%) and buried them (9%). A significant proportion of coffee growers (6%) washed and re-used pesticides for household purposes. This could have been attributed to lack of knowledge of ill effects of improper disposal of pesticide containers on the environment.

Lack of knowledge and training in pest management and information source was attributed to poor pesticide handling practices in Kenya and Ethiopia. For example, a significant number of Ethiopian farmers were reusing empty pesticide containers for various household purposes (Karunamoorthi *et al*., 2012). Lack of training in pesticide use and failure to keep records on vegetable production were associated with mishandling of pesticides among farmers in Kenya. Prior experience of adverse pesticide use effect and pesticide risk perception had no direct influence on farmer's pesticide handling practices. Furthermore, reliance on pesticide vendors as the primary source of information accelerated pesticide mishandling practices among farmers (Macharia *et al*., 2013). Farm size, GLOBALGAP certification and farmer as the first applicator were inversely related to pesticide handling though insignificant. Geographical location and pesticide toxicity substantially influenced vegetable farmer's pesticide handling practices (Macharia *et al*., 2013).

Institutional factors and farmer`s risk perception have been reported as determinants of safe pesticide handling practices. Weak implementation of rules and regulation relating to pesticide use and the strict market requirement for agricultural products that are appealing and flawless has also led to pesticide misuse (Lagerkvist *et al*., 2012). Excessive use of pesticide by farmers in developing countries have been documented by various studies (Selvarajah and Thiruchelvam, 2007; Macharia *et al*., 2013; Schreinemachers *et al*., 2016). In Vavuniya district, frequent application and pesticide overuse were common among farmers in the area. These improper practices were associated with farmers attitude, inadequate legal framework and pesticide use promotion campaigns which led to increased pesticide use (Selvarajah and

Thiruchelvam, 2007). A significant majority of farmworkers in Bangladesh were overusing pesticides (Dasgupta *et al*., 2007). Excessive use was positively associated with low-risk perception. Prior experience in pesticide-related ill health effect, education and training increased respondents adoption of protective measures and risk perception (Remoundou *et al*., 2013; Schreinemachers *et al*., 2016).

On the contrary, knowledge of pesticide-related hazards was positively associated with the uptake of precautionary measures in pesticide use (Zyoud *et al*., 2010). Strong *et al*. (2009) revealed that existing belief played a role in the adoption of precautionary measures. Community and worksite characteristics and family dynamics were found to have an influence on safety precautions. Education and training in pesticide management were reported to be the most important drivers of farmer's pesticide handling practices in Papua New Guinea. For instance, being educated and receiving training in pest management increased the chances of adopting precautionary practices by ten and twenty-two per cent respectively (Diomedi and Nauges, 2016). In Pakistan, cotton farmers were excessively applying pesticides, and utilizing them in combinations in order to exercise control over pest (Khan, 2009).

Risk perception, age, and gender have been reported as determinants of safe pesticide use. Preceding studies have found out that farmers who perceive pesticide as harmful or have previously experienced pesticide-related illness tend to apply precautionary measures (for example wearing PPE) while using pesticides, unlike farmers whose pesticide risk perception is low (Ríos-gonzález *et al*., 2013; Damalas and Abdollahzadeh, 2016). Consequently, creating awareness of the dangers of misusing pesticides is essential. This can be achieved through training and education programs on pest management. Unsafe storage of pesticides in the bedroom, kitchen or in the farm store together with farm produce was reported in developing countries (Ibitayo, 2006; Macharia *et al*., 2013). Zyoud *et al*. (2010), reported that in Palestine, farmworkers were preparing pesticides in the kitchen, eating and drinking while spraying and inappropriately disposing of pesticide containers.

Damalas and Hashemi (2010) evaluated the use of personal protective gears and risk perception of pesticide use among cotton growers in northern Greece. The findings suggested that younger farmers had a heightened perception of pesticide use hazards as compared to old farmers. Moreover, younger farmers were more positive toward the uptake of Integrated Pest Management practices, even though adoption scores were low. Female workers perceived pesticide use to be risky to their health and thus employed precautionary behaviours (Cabrera and Leckie, 2009). Similarly, more men avoided spraying during the dry season and against the wind in China. However, more women wore long-sleeved shirts or jackets during pesticide application than men (Wang *et al*., 2017). Male Chinese farmers had a greater awareness of pesticide-related risks and had a better knowledge of pesticide use than their counterparts. However, only a few male farmers were applying safety measures during pesticide application (Wang *et al*., 2017).

2.4 Determinants of adoption of alternative pest control methods

Use of chemical pesticides in crop protection has raised concern over unintended adverse health and environmental effect worldwide. Consequently, studies on adoption of eco-friendly pest management practices in agriculture have been carried out in developing countries (Khan and Damalas, 2015; Sharif *et al*., 2017). Examples of alternative pest management techniques include the use of planned crop rotation, bio-pesticides, mechanical control, use of hybrid varieties and biological control methods (Srinivasan, 2012; Chabi-olaye *et al*., 2013; Rahman, 2013; Mwangi *et al*., 2015; Jallow *et al.*, 2017; Sharif *et al*., 2017). Farmers risk perception and information source have been reported to play a role in the adoption of an alternative to pesticide. Farmers in developing countries continue to use pesticides due to its efficacy and unavailability of an alternative to pesticides (Abdollahzadeh *et al*., 2015; Zyoud *et al*., 2010; Khan and Damalas, 2015). The majority of farmers are driven by economic motive (reduce yield loss due to pest attack and increasing farm output) while applying pesticides (Rahman, 2015, 2016). For instance, older chilli farmers in Indonesia were less tolerant of the risk associated with pest and diseases hence used pesticides frequently to combat the problem (Mariyono and Battharai, 2009).

Training, age, risk perception, geographical location, and income have been reported to play a role in the adoption of an alternative to pesticides. Khan (2009) used a probit model to estimate the probability of a cotton farmer to adopt eco-friendly pest control practices in Pakistan. The farmer`s likelihood of utilizing environmentally friendly pest control method was assumed to be a function of farmer and farm characteristics, plus health experience. Results from the probit regression analysis failed to support the assumption that farmers with prior ill health experience were likely to adopt an alternative to pesticide than their counterparts. Age, training, risk perception and income were found to have a positive relationship with the adoption of alternative pest management (Khan, 2009). Furthermore, the geographical location had an influence on the chances of using other crop protection methods besides chemical pesticides.

Institutional factors such as government policies, extension programs, taxes, and development of farmer organizations may influence the use of pesticides in turn affecting the adoption of other pest management methods. In West Africa, policies which promote the use of pesticides in cotton production might have encouraged farmers to utilize more pesticides as compared to alternative methods. For instance, subsidy and credit financing of pesticides and spraying equipment might have motivated farmers to heavily rely on pesticides as compared to other crop protection methods (Ajayi, 2000). Additionally, exemption of pesticides from various taxes and weak implementation of the pesticide use regulatory framework at farm and retail section has also been contributing factors (Mengestie *et al*., 2015; Amoabeng *et al*., 2017). For instance, exemption of pesticides from taxes lowered the price making them more affordable and cheaper than non-chemical methods (Ajayi, 2000). Failure of the government agency to promote non-chemical crop protection method and to provide relevant information to farmers has also been highlighted as contributing factor to over-reliance on synthetic pesticides (Rahman, 2013; Mengestie *et al*., 2015; Jin *et al*., 2017).

Farmer`s decision to adopt agricultural technology is influenced by the farmer`s attitude towards that technology which is in turn influenced by knowledge about the technology. Risk perception might affect farmer's practices in pesticide use. For instance, farmers whose risk perception is heightened tend to use pesticide judiciously as compared to farmers who view pesticides as unhazardous. Studies on perception, knowledge, and practices have indicated that there are cases of pesticide misuse and overuse. This can be attributed to lack of knowledge on associated health and environmental risks and wrong perception about pesticide use (Riwthong *et al*., 2016). This sheds light on the possible response of farmers to other crop protection technologies.

Source of information have been found to influence farmers knowledge as well as the adoption of agricultural technology. For instance, media, social learning among farmers and government extension agents have been found to play a vital role in disseminating information on crop protection methods. However, Ajayi (2000) discovered that farmers were unaware of IPM in Cote d'Ivoire. This could be due to limited information sources since common sources were government agencies, other farmers, and media. Limited use of IPM technology in Bangladesh was evident as an alternative to chemical pesticide. This could be attributed to inadequate dissemination of information to the target audience (Rahman, 2013).

Socioeconomic factors such as education and training have been found to influence the adoption of alternative crop protection method. Khan and Damalas (2015) evaluated factors hindering adoption of non-chemical pest management practices among cotton farmers in Pakistan. Results from the binary probit regression analysis indicated that education and participation in training programs were the major predictors. This could be attributed to inadequate access to information on new agricultural technology. Economic factors such as the cost of the crop protection method and expected yields have been highlighted as drivers for adoption. Surprisingly, the perceived human and environmental effect of crop protection method was given less weight by farmers in Cote d`Ivoire (Ajayi, 2000).

In a recent study (Sharif *et al*., 2017), perceived self-efficacy, perceived usefulness, compatibility, and ease of use were found to influence acceptance and use of biological control among rice farmers in Iran. Provision of favourable conditions such as extension services, precise manual guides, and training was identified as drivers for uptake of biological control methods (Sharif *et al*., 2017). Elsewhere, the perception of pesticide efficacy was found to play a crucial role in influencing farmer's behaviour in pesticide use and adoption of alternative methods such as Integrated Pest Management techniques (Hashemi and Damalas, 2011).

2.5 Theoretical and Conceptual framework

2.5.1 Theoretical framework

The study assumes that there is potential for households to increase yields, improve human health and conserve the environment through the adoption of alternative pest control methods and appropriate use of the pesticide**.** The study draws upon the theory of random utility as described by Green (2003). The chief assumption is that a farmer`s decision whether to adopt or not to adopt alternative crop protection methods and extent of pesticide usage will be based on utility maximization. The expression $U = D_i\left(Z_{ji}, F_{ji}\right)$ is a non-observable utility function which ranks the preference of i_{th} farmer for j_{th} adoption decision (where $j = 1$, if farmer adopts eco-friendly behaviours and $j = 0$, does not adopt them). Consequently, the utility derived from the adoption of ecologically sound practices (adoption of an alternative to pesticide) will depend on a vector of socioeconomic characteristics, a vector of institutional factors and risk perception.

$$U_{ji} = Di\alpha_i\left(Z_{ji}, F_{ji}\right) + \varepsilon_{ji}, where\left(j = 1, 0\right) and \ \left(i = 1, 2.....n\right) \dots\dots\dots\dots\dots\dots(1)$$

Since the utilities are random, the i_{th} farmer will choose alternative $j = 1$ conditional upon $U_{1i} > U_{0i}$ or if $y^* = U_{1i} - U_{0i} > 0$. The likelihood that $Y_i = 1$(probability that a farmer adopts ecologically sound behaviours) can be written as a function of explanatory variables;

$$P_i = P_r\left(Y_i = 1\right) = P_r\left(U_{1i} > U_{0i}\right)$$

$$= P_r\left\lfloor D_i\alpha\left(Z_{ji}, F_{ji}\right) + \varepsilon_{1i} > D_i\alpha\left(Z_{ji}, F_{ji}\right) + \varepsilon_{0i}\right\rfloor$$

$$= P_r\left\lfloor D_i\alpha_1\left(Z_{ji}, F_{ji}\right) + \varepsilon_{1i}\right\rfloor > \left\lfloor D_i\alpha_0\left(Z_{ji}, F_{ji}\right) + \varepsilon_{0i}\right\rfloor$$

$$= P_r\left\lfloor \varepsilon_{1i} - \varepsilon_{0i} > D_i\left(Z_{ji}, F_{ji}\right)\left(\alpha_0 - \alpha_1\right)\right\rfloor$$

$$= P_r\left\lfloor \varepsilon_i > D_i\left(Z_{ji}, F_{ji}\right)\right\rfloor = D\left(X_i^1\beta\right) \dots\dots\dots\dots\dots\dots(2)$$

Where,

P_i = is the probability of i_{th} individual adopting alternative pest control method.

$\varepsilon_i = \varepsilon_{1i} - \varepsilon_{0i}$, is a random disturbance term.

D is a cumulative distribution function for the random disturbance term evaluated at $X_i^1\beta$. The distribution of the random error term defines the distribution of D. For instance, if the random disturbance term is normally distributed, then D is a cumulative normal distribution (Phiri, 2007). Consequently, based on the assumed distribution of the random disturbance term, numerous qualitative choice models can be estimated (Green, 2003).

2.5.2 Conceptual framework

As illustrated in figure 1, farmers encounter various factors which influence their decision-making process aimed at maximizing their utility. Socioeconomic attributes such as level of education, age, gender, household size, farming experience, farm size and risk perception affect farmer`s decision. Institutional factors such as access to credit, extension services, training program, social network and access to information also affect productivity and choice of pest management methods on the farm. Risk perception, institutional and socioeconomic factors have a great influence on farmer`s decision on the level of pesticide usage. Furthermore, institutional and socioeconomic attributes, as well as risk perception, affect farmer`s decision on the intensity of adoption of alternative pest management methods. Figure 1 indicates a representation of factors that can influence farmer`s decision on the intensity of adoption of alternative pest control methods as well as the level of pesticide usage.

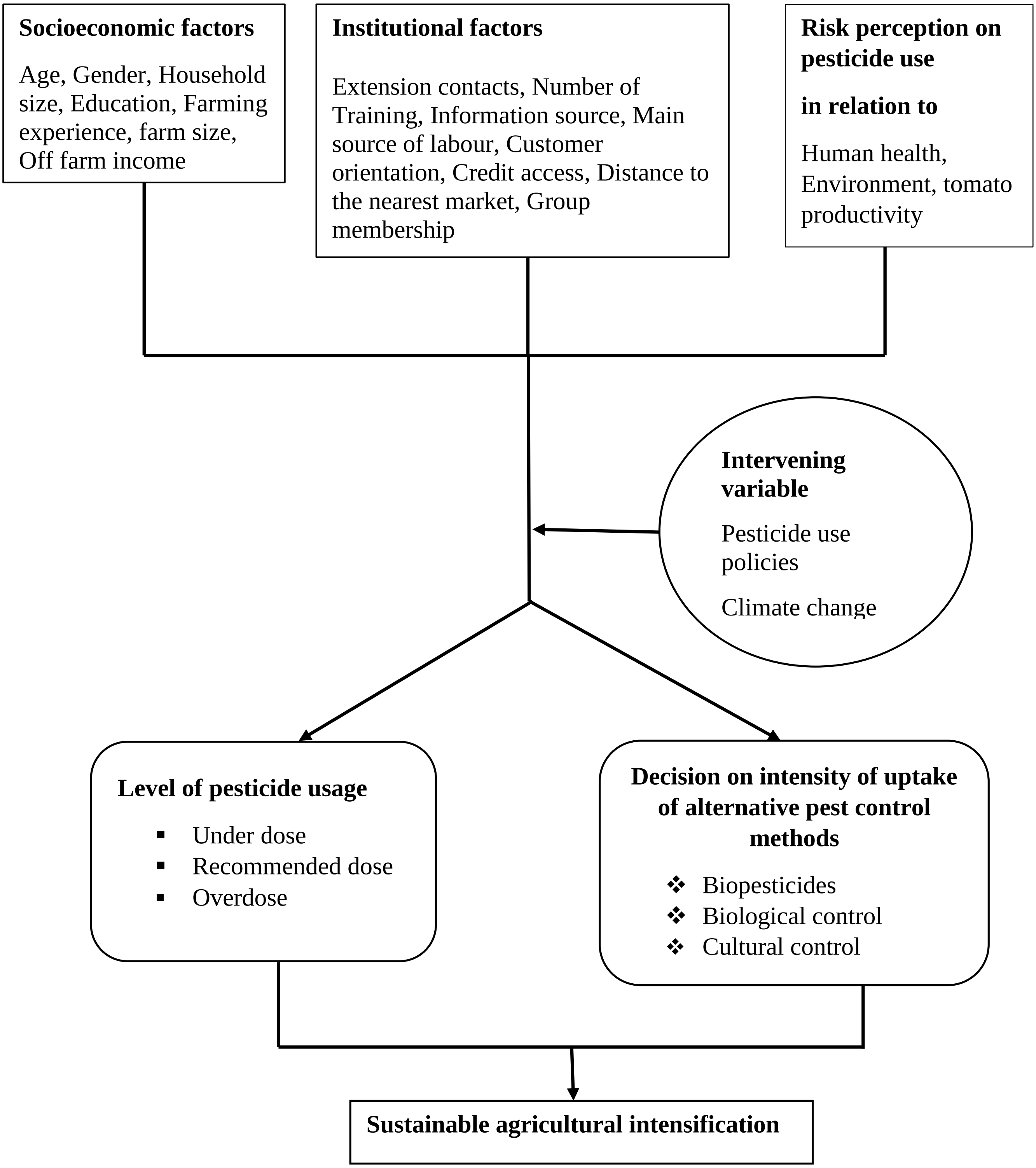

Figure 1: Conceptual framework on determinants of the level of pesticide usage and uptake of alternative pest control methods.

CHAPTER THREE

METHODOLOGY

3.1 Study area

The study took place in Nakuru County. It is among the leading tomato producing areas in Kenya with close proximity to Nairobi area which is among the largest urban tomato market. Nakuru County is located within the Great Rift Valley. It is located at latitude 0˚13 and 1˚10` South and longitudes 35˚28` and 35˚36` East. It borders other Counties like Baringo and Laikipia to the North, Kajiado and Kiambu to the South, Kericho and Bomet County to the West, Nyandarua to the east and Narok to the south-west. The County covers an area of 7495.1 Km^2. In 2012, Nakuru County had an estimated population of 1,756,950 comprising of 881,674 male and 875,276 female. With a population growth rate of 3.05%, the population is expected to increase to 2,046,395 in the year 2107. This will lead to increased food demand. The area receives bimodal rainfall. The long rains occur during the months of March to May. The short rains occur during the months of October to November (GoK, 2013). The temperature ranges from an average of 12˚C to 29.3˚C. The county is divided into eleven sub-counties namely Subukia, Kuresoi North, Nakuru town west, Gilgil, Rongai, and Nakuru town east, Kuresoi South, Njoro, Naivasha, Molo and Bahati. Agriculture is the major economic activity in the region. Tomato, maize, beans, kales, wheat, carrots, peas, onions, french beans, strawberries, and other fruits are some of the main crops grown in the area. Some of the livestock bred kept in the area include; cattle, poultry, goats, sheep, rabbits as well as bees (GoK, 2013). Figure 2 represents a map of the study area.

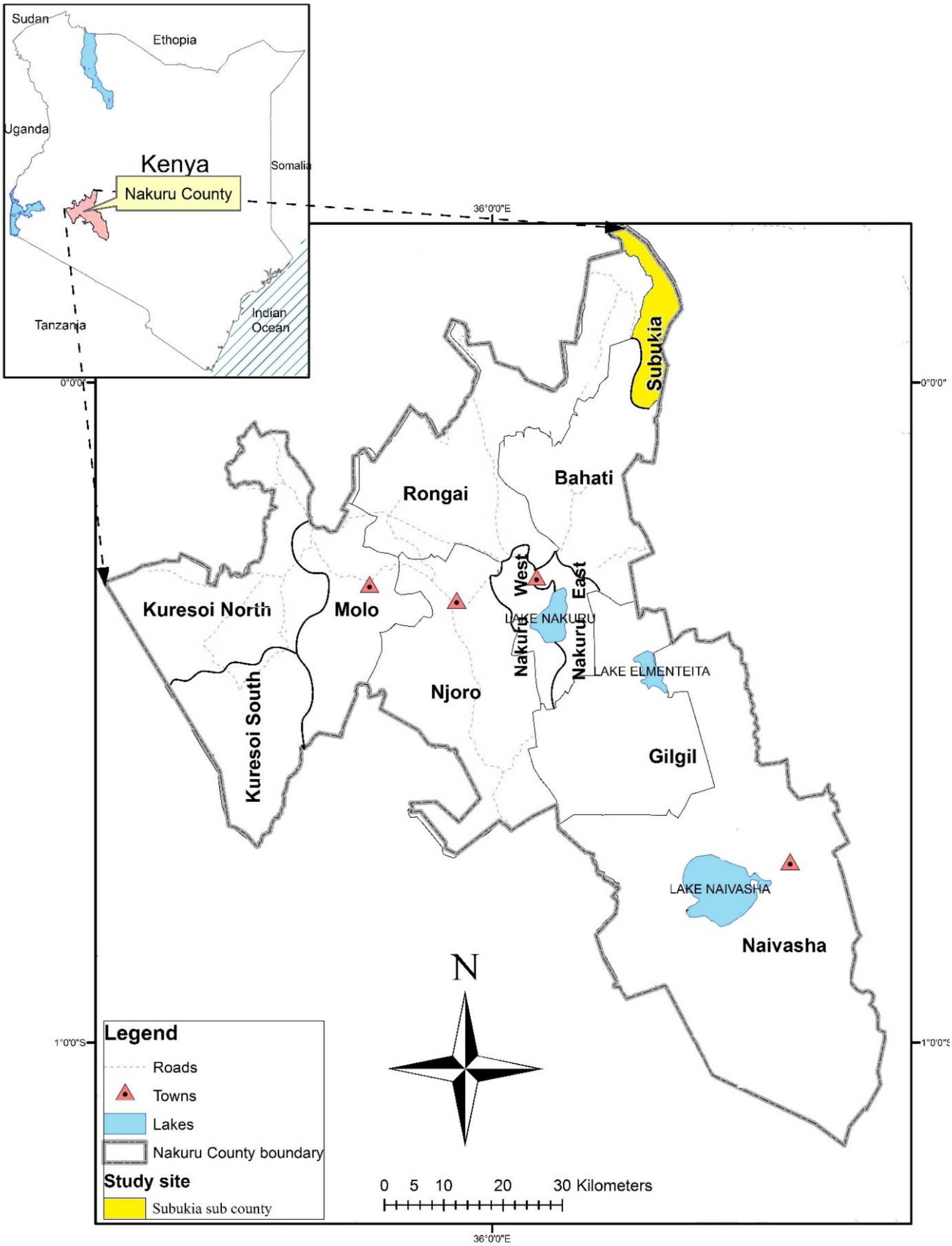

Figure 2: Map of Nakuru County

Source: World Resource Centre, 2017.

3.2 Sampling procedure

The study adopted a multi-stage sampling procedure to select the respondents. First, Nakuru County was purposively selected. Second, Subukia sub-county was selected since it is one of the major tomato producing area in the county. Subsequently, the random selection of two wards (Subukia and Weseges) in Subukia Sub-county was carried out. Finally, simple random sampling method was used to select the final sample from the chosen wards. A list of farmers generated with the help of agricultural extension officer in the area was acting as a sampling frame from which respondents were drawn.

3.3 Sample size determination

The required sample size was determined using a formula for sample size determination as described by Kothari (2004) as;

$$n = \frac{pqZ^2}{E^2} \quad \text{.......................} \quad (3)$$

Where; n= Sample size; Z= confidence level (α= 0.05); p= proportion of the population containing the main characteristics of interest; q=1-p and E= allowable error. Since the proportion containing the major characteristics of interest was unknown, p= 0.5, q=0.5, Z=1.96 and E= 0.05. This gave rise to a sample of approximately 384 respondents.

3.4 Data collection and Analysis

The study used both primary data and secondary data. A semi-structured questionnaire (Appendix I) which was administered to the respondents by well-trained enumerators through face to face interview was used to collect data. A pre-test of the questionnaire was conducted before embarking on the actual survey to test its validity and suitability for the research study. Secondary data was obtained from journals on pesticide use and government publications to mention but a few. Secondary data was used to group chemical pesticides according to WHO toxicity classification and to classify based on the type of pesticide (that is an insecticide, fungicide and herbicide). Data were coded and entered into SPSS (version 20) and STATA (version 14) software for data analysis.

3.4.1 Analytical framework

Objective one: To evaluate precautionary behaviour in pesticide use among small-scale tomato farmers in Nakuru County.

Descriptive statistics were used to determine small-scale farmers` precautionary behaviour in pesticide use. Precautionary (safety) behaviours or practices while mixing, spraying, storing and disposing of empty pesticide containers and rinsate were examined. The results were presented in tables.

Objective two: To determine socioeconomic and institutional factors that influence the level of pesticide usage among small-scale tomato farmers in Nakuru County.

The level of pesticide usage (Y_I) was measured in Litre or Kilogram per acre applied where, 1 = underdose, 2= recommended dose and 3= overdose. Pesticide overdose refers to the amount of pesticide (undiluted) applied in excess of recommended dosage as indicated on the pesticide product label. Pesticide under dose refers to the amount of pesticide applied which is less than the recommended dosage as specified on the pesticide product label. Farmers reported application rate was divided by the treated area (expressed in hectare) to arrive at the quantity of pesticide applied for each application. This was expressed in Litre per Hectare (L/Ha) or Kilogram per Hectare (Kg /Ha). Subsequently, the total quantity of pesticide applied per Hectare per season was derived by summing up all quantities calculated for all applications per season. Finally, Trivariate Ordered Probit model was used to estimate determinants of the level of pesticide usage. An Ordered Probit model is suitable in circumstances with several and ranked discrete dependent variable. In addition, where the response variable takes more than two values which are naturally ordered (Damalas and Khan, 2017). In this case, a Trivariate version of an Ordered Probit model was used so as to capture the interdependence between the decisions on the level of pesticide usage for the various types of pesticide. As a result, three equations representing each type of pesticide (insecticide, fungicide, and herbicide) were simultaneously estimated. The system of equations for the Trivariate Ordered Probit model can be written as follows (Scott and Kanaroglou, 2002):

$$Y_{1i}^* = \beta_1 X_{1i} + \varepsilon_{1i}, \; Y_{1i} = l \;\; if \;\; \alpha_{1,l} < Y_{1i}^* \le \alpha_{1,l+1},$$
$$Y_{2i}^* = \beta_2 X_{2i} + \varepsilon_{2i}, \; Y_{2i} = f \; if \; \alpha_{2,f} < Y_{2i}^* \le \alpha_{2,f+1},$$
$$Y_{3i}^* = \beta_3 X_{3i} + \varepsilon_{3i}, \; Y_{3i} = h \;\; if \;\; \alpha_{3,h} < Y_{3i}^* \le \alpha_{3,h+1}, \quad \ldots\ldots(4)$$

Where

$l = 1,2,..,L$ represents the level of insecticide usage.

$f = 1,2,..,F$ denotes the level of fungicide usage.

$h = 1,2, ... H$ signifies the level of herbicide usage.

$i = 1,2,3, ..., n$ sample size.

$Y_{ij}^* =$ a latent variable which captures the decision on the level of pesticide usage for each type of pesticide.

β= a vector of regression coefficients to be estimated not consisting of the intercept.

X_{ij}= a set of socioeconomic and institutional explanatory variables.

ε_{ij} = random error term.

Similarly, the corresponding standard normal trivariate distribution function can be rewritten as follows;

$$\Phi_3 = \Phi_3(\varepsilon_{1i}, \varepsilon_{2i}, \varepsilon_{3i}, \rho_{\varepsilon1\varepsilon2}, \rho_{\varepsilon1\varepsilon3}, \rho_{\varepsilon2\varepsilon3}) \ldots\ldots(5)$$

The ρs denotes the correlation between the disturbance terms (ε).

Alternatively, the systems of equations can be summarized as follows;

$\mathrm{Y}_{ji}^* = \mathrm{X}_{ji}^{`}\beta + \varepsilon_{ji}$, where i = 1, 2,…, n……………………………………………………… (6)

Where

J =1, 2, …….,K are types of pesticide used by a farmer.

Since Y_{ij}^* is unobservable, the association between the latent variable and observed (Y_{ij}) depended variable can be illustrated as follows (Daykin and Moffat, 2002);

$$\mathrm{Y} = 1 \, if \, -\infty < \mathrm{Y}^* < \alpha_1$$
$$\mathrm{Y} = 2 \, if \, \alpha_1 < \mathrm{Y}^* < \alpha_2$$
$$\mathrm{Y} = 3 \, if \, \alpha_2 < \mathrm{Y}^* < \alpha_3$$

.

.

$$\mathrm{Y} = j \, if \, \alpha_{j-1} < \mathrm{Y}^* < \infty \quad \ldots\ldots(7)$$

Where $\propto_j, j = 1,2,..,j-1$ are cutoffs, also referred to as threshold parameters (Daykin and Moffat, 2002). The nonexistence of an intercept in the model specified above is as a result of j-1 threshold parameters "all being free".

To generate the log-likelihood function, let $\Pr_i(Y)$ be the probability that i^{th} farmer`s response is Y. Thus the likelihood will be;

$$Pr_i\,(Y) = \Pr(\propto_{y-1} < Y^* < \propto_Y) = \Phi(\propto_y - X_i^{`}B) - \Phi(\propto_{y-1} - X_i^{`}\beta), y = 1,2 \ldots j. \ldots\ldots(8)$$

Where Φ(.) denotes the standard normal cumulative distribution function. Consequently, the log-likelihood function can be derived as follows given a sample ($Y_i, X_i, i = 1,2, \ldots., n$);

$LogL = \sum_i ln\,[Pr_i(Y_i)] = \sum_i \ln[\Phi(\alpha_{yi} - X_i^{`}\beta) - \Phi\big(\alpha_{yi-1} - X_i^{`}\beta\big)$ ………………………(9).

The maximum likelihood estimates of both threshold (α) and β parameters are obtained by maximizing the function with regard to β parameters along with cut points by an iterative process.

Description of the variables used in the model and their expected signs are presented in Table 2. The variables were derived from review of previous studies (Hashemi *et al*., 2012; Murendo *et al*., 2015; Alam and Wolff, 2016 ; Amoabeng *et al*., 2017; Jallow *et al*., 2017; Jin *et al*., 2017 ; Schreinemachers *et al*., 2017; Wang *et al*., 2017).

Table 2: Description of variables in the Trivariate Ordered Probit Model

Variables	Description	Expected signs
Dependent		
Level of pesticide usage.	Quantity of pesticide used (underdose, recommended dose, and overdose)	
Explanatory		
GendHH	Gender of the household head where 1=male and 0=female	+/-
AgeHH	Age of the household head in years	+/-
EducHH	Number of years of schooling of household head	-
Farmexp	Farming experience in years	-
Household size	Number of people living in the household for the last six months.	+/-
Off-farminc.	Participation in the offfarm activity where 1= yes, 0=No.	+/-
Farmsz	Total farm size in acres	-
RiskpercHuman.	Risk perception towards pesticide use on human health where 1=strongly disagree, 2=disagree, 3=uncertain, 4=agree, 5= strongly agree.	+/-
RiskpercEnviron.	Risk perception towards pesticide use on the environment where 1=strongly disagree, 2=disagree, 3=uncertain, 4=agree, 5= strongly agree.	+/-
ProductivityPerc	Attitude towards pesticide use on crop productivity where 1=strongly disagree, 2= disagree, 3=uncertain, 4=agree, 5= strongly agree.	+/-
Grupmembership	Number of groups that the farmer belongs to.	+
Creditacc	Access to credit 1= yes,0= otherwise	+/-
Traingpest	Number of trainings on pest management	-
Distancemkt	Distance to the nearest input market measured in walking minutes.	+
Laboursource	Main source of labour where 1=family labour, 2=hired labour	+/-
CustomerOrient.	Perception towards customer`s demand during tomato production and maketing where 1=strongly disagree, 2= disagree, 3=uncertain, 4=agree, 5= strongly agree.	+/-
Extencon.	Number of contacts with extension service provider.	-
Inforsource	Dummies of the main primary information source for pesticides use and agriculture in general (fellow farmers, pesticide retailer, pesticide company and media).	-/+

Objective three: To establish the role of risk perception, socio-economic and institutional characteristics on the intensity of uptake of alternative pest control methods among small-scale tomato farmers in Nakuru County.

Farmers use a variety of alternative methods in crop protection. Examples of alternative (non-chemical) pest control methods include; cultural methods, biological control and use of biopesticides. Cultural methods involve pest management by manipulation of the environment or implementation of preventative practices. It includes; planting disease-resistant varieties, planned crop rotation, weeding, pruning and mulching to mention but a few. Biological methods refer to the use of other organisms to manage pests (insect, weeds and diseases). It involves predation, parasitism, herbivory and other natural mechanisms. Biopesticides are crop protection products which are obtained from natural materials such as animals, plants, and bacteria. Thus farmers are faced with various pest control methods which may be adopted simultaneously and or sequentially as supplements, complements or substitutes. This implies that the number of strategies adopted may not be independent but interdependent. Therefore, farmers will choose a set of strategies that maximize expected utility. Accordingly, the decision on the extent of adoption is multivariate and applying univariate approach might exclude relevant information contained in interdependent and concurrent adoption decisions (Ali *et al*., 2012).

Firstly, the study employed Principal Component Analysis to categorize different pest control strategies into groups. It is a statistical technique for discovering unidentified trends and simplifying the description of a bundle of interrelated variables by decreasing dimensionality of data. It performs a covariance analysis between factors and identifies a pattern of association between variables which in this case are pest control strategies (Aching, 2010). Principal component model can be illustrated as follows;

$$Y_i = \sum_{i=1}^{I} \beta_i X_i + \varepsilon_i \quad \text{...} (7)$$

Where;

Y_i = Matrix of standardized observed variables

X_i = Matrix of scores of components

β_i = Matrix of Eigenvectors or loadings (weights)

ε_i = stochastic error term.

Chemical pesticide was used as a reference category. Subsequently, Multivariate Tobit model was used to analyze the role of risk perception, socio-economic and institutional characteristics on the intensity of uptake of non-chemical control methods. The model concurrently estimates the effect of a set of explanatory variables on each of the dependent variables while allowing the stochastic error term to be interrelated (Ma *et al*., 2006; Gillespie and Mishra, 2011). Contrary, univariate Tobit models ignore such correlation of disturbance term as well as the relationship between the intensity of adoptions of diverse pest control strategies. This might lead to bias and inefficient estimates. Ali *et al.* (2012) formulated multivariate regression as follows;

$Y_{ij}^* = X_{ij}\beta_i + \varepsilon_{ij}$, where j= 1,..,M and i = 1,…,n …………………………………………(8)

$Y_{ij} = Y_{ij}^*\ if\ Y_{ij}^* > 0, 0\ if\ otherwise$……………………………………………………...(9)

Where j=1,..., M represents available alternative pest control strategies.

Y_{ij}^* = A latent variable which captures the unobserved preferences.

X_{ij} = a set of independent variables (risk perception, socioeconomic and institutional characteristics).

ε_{ij}= stochastic error term

Y_{ij}= observable variable denoting the ratio of the number of strategies adopted from available alternatives.

Equation 9 will be in estimation due to the latent nature of the variable. Variables used in the model and their expected signs are described in Table 3. They were derived from review of previous studies (Zyoud *et al*., 2010; Hashemi and Damalas, 2011; Kassie *et al*., 2013; Rahman, 2013; Khan and Damalas, 2015; Mengestie *et al*., 2015; Murendo *et al*., 2015; Riwthong *et al*., 2016; Sharif *et al*., 2017).

Table 3: Description of variables in the Multivariate Tobit Model

Variables	Description	Expected sign
Dependent		
Intensity of adoption	Ratio of the number of practices adopted from each group of alternative pest management methods (ranging from 0 to 1)	
Independent		
AgeHH	Age of the household head in years	+
GendHH	Gender of the household head where 1=male, 0=otherwise	+/-
EducHH	Number of years of schooling of the household head	+
Household size	Number of people living in the household for the last six months.	+/-
Off-farminc.	Participation in the off-farm activity where 1= yes, 0=No.	+/-
Farm size	Total farm size in acres	+/-
RiskpercHuman	Risk perception towards pesticide use on human health where 1= strongly disagree, 2=disagree, 3= uncertain, 4 = agree, 5= strongly agree.	+
Grupmembership	Number of groups that the farmer belongs to.	+
Extencont.	Number of contacts with extension service provider.	+
Creditacc.	Access to credit 1= yes,0= otherwise	+/-
Traingpest	Number of training on pest management	+
CustomerOrient.	Attitude towards customer`s demand during tomato production and maketing where 1=strongly disagree, 2= disagree, 3=uncertain, 4=agree, 5= strongly agree.	+/-
Inforsource	Dummies of main primary information source for pesticides use and agriculture in general (fellow farmers, pesticide retailer, pesticide company and media).	+/-

CHAPTER FOUR
RESULTS AND DISCUSSION

4.0 Introduction

This part provides the findings and discussion of the study. First, descriptive statistics of small-scale tomato farmers` household characteristics and precautionary behaviour in pesticide use were presented in tables. Findings from preliminary diagnostics and Trivariate ordered probit model for determinants of the level of pesticide usage were presented in tables. The third objective was addressed where non-chemical pest control methods identified from the field were grouped using principal component analysis. Consequently, Multivariate Tobit model was used in estimating the determinants of the intensity of uptake of alternative pest management methods**.**

4.1 Descriptive statistics of the small scale tomato farmers

4.1.1 Characteristics of farm households

Table 4 present a brief description of interviewed households. The results show that small-scale tomato production is mostly male-dominated and with elderly people. The farm household heads had acquired a basic education (at least primary education) which is important in making farm decision relating to crop protection.

Table 4: A summary of household characteristics

Variables	Mean	Std. Err.
Age of Household head	40.375	0.5934
Gender of household head (male=1)	0.7813	0.0211
Education of household head	10.8333	0.1446
Household size	4.3854	0.0934
Participation in off-farm activities	0.4219	0.0252
Farm size (acres)	1.7945	0.0710
Group membership	1.2630	0.0574
Extension contacts	1.0833	0.0486
Access to credit	0.4115	0.0251
Training	0.8984	0.0474

The farmers had an average of five members per household and seven years of farming experience. The majority of them cultivate land less than a hectare in area and belonged to at least one farmer group. In addition, respondents had participated in had a minimum of one training program and had at least one contact with the extension service provider. The majority of respondents acquired information from other farmers.

4.2 Descriptive statistics of small-scale tomato farmers` precautionary behaviour in pesticide use

4.2.1 Preparation practices of chemical pesticide

The behaviour of small-scale tomato farmers during pesticide preparation was evaluated and the results presented in Table 4. Findings indicated that the majority (88.28%) of the farmers failed to read and follow the instructions on the pesticide product label which could have contributed to the misuse of pesticide. This could be attributed to the technicality of the language of instruction, small font size, and inability to read and understand the instructions perhaps due to low education levels (Mengistie *et al*., 2015). In Pakistan, a significant proportion (73%) of farmers allegedly failed to read information on the pesticide product label (Damalas and Khan, 2016).

Table 5: Pesticide preparation practices

	Per cent	
Practices	**Yes**	**No**
Read and follow pesticide product label instructions	11.72	88.28
Mix two or more pesticide products during preparation	11.20	88.80
Prepare pesticide at home compound	11.98	88.02
Prepare pesticide at the farm	88.28	11.72

In addition**,** more farmers were mixing pesticide at the farm (88.28%) as compared to those who were mixing pesticide at home (11.98%). However, a small proportion of farmers were mixing more than one pesticide product (11.20%) in one spray making a "chemical pesticide cocktail". Farmers claimed that mixing different pesticides made it more effective. The findings concur with Jensen *et al*. (2011) observation in Cambodia where the majority of farmers were mixing various pesticides to make it more effective.

4.2.2 Types of personal protective equipment used by small-scale tomato farmers

Varieties of protective gears worn by small-scale tomato farmers were identified and the results presented in Table 6**.** Protective gears with the highest percentage of users were boots (97.14%), followed by long-sleeved shirt/jackets (85.42%), coverall/pants (62.76%) and respirators (30.99%).

Table 6: Protective gears used by small-scale tomato farmers

	Per cent	
Type of protective gear	**Yes**	**No**
Mask	0.52	99.48
Respirator	30.99	69.01
Goggles	0.00	100.00
Hat	26.30	73.70
Gloves	18.49	81.51
Long sleeved shirt/Jacket	85.42	14.58
Coverall/Pants	62.76	37.24
Boots	97.14	2.86

On the other hand, mask (0.52%), gloves (18.49%) and hat (26.30%) were the least used protective clothing. None of the farmers used goggles during pesticide application which was attributed to the high cost of purchase, unavailability when needed and being uncomfortable. Correspondingly, preceding studies in developing countries (Damalas and Koutroubas, 2017; Bhandari *et al*., 2018) have reported limited use of gloves, hats, and masks by farmers during pesticide application. In Northern Oman, Al Zadjali *et al*. (2015) observed that farm owners and workers belonging to native farmer organization reported high usage of personal protective gears such as gloves and mask as compared to their counterparts. Some of the reasons attributed to failure/low usage of protective clothing as highlighted by farmers are presented in Table 7.

Table 7: Reasons for not wearing personal protective gears during pesticide preparation and application

Reasons	**Per cent**
Too expensive to purchase	36.96
Not necessary for each case	20.57
Uncomfortable	20.05
Time-consuming to wear	8.85
Unavailable when needed	13.54

Unaffordability due to high purchasing cost (36.96%), not necessary (20.57%) and being uncomfortable to wear particularly during high temperatures (20.05%) were the leading reasons for not using protective clothing such as mask and goggles. The findings corroborate with results from previous studies (Damalas *et al*., 2006; Yang *et al*., 2014; Bhandari *et al*., 2018) on pesticide use in developing countries.

4.2.3 Small scale tomato farmers` spraying practices

The spraying practices identified from the field are presented in Table 8**.** A closer look at the practice column indicates that the majority of farmers observed personal hygiene during and after pesticide application. For instance, more than 90% of the farmers avoided drinking, eating and smoking during spraying and washed their hands after spraying. In Northern Greece, Damalas and Koutroubas (2017) found out that the majority of farmers (both trained and untrained) were washing hands and took a shower after spraying pesticide.

Table 8: Precautionary behaviour during and after spraying chemical pesticide

	Per cent	
Practices	**Yes**	**No**
Avoid drinking while spraying	90.89	9.11
Avoid eating while spraying	92.71	7.29
Avoid smoking while spraying	90.36	9.64
Tuck in trousers/pants in boots	75.52	24.48
Observe direction of the wind while spraying	70.83	29.17
Spray early in the morning	90.89	9.11
Spray late in the evening	30.47	69.53
Wash hands after spraying	97.92	2.08
Take a shower and change clothes after spraying	93.75	6.25

Furthermore, most farmers sprayed early in the morning and observed wind direction to prevent pesticide drifts during spraying hence minimizing the risk of pesticide poisoning. A significant proportion (75.52%) of farmers were tucking in their trousers/pants in boots hence increasing the risk of pesticide-related illnesses. This could have been attributed to lack of knowledge of possible routes of exposure and pesticide-related illnesses.

4.2.4 Storage practices of chemical pesticide

Small-scale tomato farmers` storage practices are presented in Table 9**.** Findings from Table 9 reveal that the majority of farmers (66.41%) stored chemical pesticide in a locked and safe place. Probably, most farmers are aware of the hazardous nature of chemical pesticides.

Table 9: Pesticide storage practices

	Per cent	
Place of storage	**Yes**	**No**
Kitchen	2.08	97.92
Bedroom	11.98	88.02
Hang outside the house	9.64	90.36
In a locked and safe place(pesticide store)	66.41	33.59
Store with other foodstuff	10.16	89.84
Bury in the farm	2.34	97.66

Other storage places which were reported by farmers included bedroom (11.98%), kitchen (2.08%) and buried in the farm (2.34%). However, some farmers (10.16%) exhibited unsafe practices such as storing chemical pesticide together with other foodstuff. The results are consistent with findings from previous studies (Jensen *et al*., 2011; Macharia *et al*., 2013; Al Zadjali *et al*., 2015) in developing countries where farmers were inappropriately storing synthetic pesticides in places such as bedroom and kitchen to mention but a few.

4.2.5 Disposal of empty pesticide containers/rinsates

Methods of discarding empty pesticide containers and/or rinsates are presented in Table 10. Some of the ways in which farmers disposed of empty containers included burning (58.58%), burying (31.25%) and throwing in a pit latrine (16.93%) or bush (13.28%).

Table 10: Methods of disposing of empty pesticide containers and/or rinsates

	Per cent	
Disposal methods/practices	**Yes**	**No**
Burying	31.25	68.75
Burning	58.85	41.15
Throwing in the bush	13.28	86.72
Sell to recyclers	0.26	99.74
Reuse after washing	2.08	97.92
Throw in a pit latrine	16.93	83.07
Wash knapsack sprayer at the farm	81.51	18.49
Wash knapsack sprayer in the river/stream	14.84	85.16

However, a small of farmers were discarding rinsates and empty containers in unsafe ways. For instance, some farmers reported that they were reusing empty containers (2.08%) while others washed knapsack sprayer in the river/stream (14.84%). This could have contributed to water pollution as well as increased risk of ill-health experiences. Lack of knowledge of the dangers of inappropriate disposal could be attributed to unsafe practices. Similarly, Macharia *et al*. (2013) and Yang *et al*. (2014) reported unsafe disposal practices among farmers in Kenya and China respectively. For instance, a sizeable proportion (17%) of vegetable farmers in Kenya were disposing of rinsates in streams and /or ponds while cleaning spraying equipment.

4.3 Factors influencing the level of pesticide usage among small-scale tomato farmers

4.3.1 Descriptive statistics of the chemical pesticides actively in use by small-scale farmers

Utilization of synthetic pesticide for crop protection has become a common feature in modern agriculture in most developing countries. In this study, for instance, all farmers were using chemical crop protection products as their main pest control method in open field production system. Overdependence on synthetic pesticide could be attributed to factors such as ease of accessibility, availability, perceived efficacy and as a necessity for higher yields (Hashemi and Damalas, 2010; Jensen *et al*., 2011; Jallow *et al*., 2017; Khan and Damalas, 2015; Screinemachers *et al*., 2017). Probably, high incidences of insect pests and diseases, as well as pest resistance, could be forcing farmers to heavily rely on chemical control methods. Insecticides, fungicides, and herbicides were reported as the most commonly used types of pesticides in the study area. These findings are consistent with Waichman *et al*. 2007 and Bon *et al*. 2014 observations in Brazil and Sub-Saharan Africa respectively. The types and trade names of pesticides which were extensively utilized by farmers are presented in Table 11.

Table 11: Descriptive statistics of chemical pesticide widely used by small-scale farmers

Types and trade names of chemical pesticides	The aggregate amount of pesticide applied	Mean	Standard deviation	Overall application rate (Kg/Ha[a])	Manufacturer`s recommended application rate
Insecticides					
Tata Alpha	378.453	0.980	1.972	4.268[b]	0.2-0.25
Engeo	126.72	2.816	1.963	7.899 [b]	0.15
Coragen	38.299	0.580	0.773	1.970 [b]	0.125-0.15
Cypertox	77.828	0.628	0.781	2.1876[b]	0.7-0.75
Fungicides					
Mistress	155.235	2.426	3.286	9.239	2.0
Milraz	602.85	4.307	7.648	13.582	2.0
Ridomil	445.897	3.279	4.563	11.859	3-3.5
Victory	1016.46	3.411	4.544	13.470	2.5
Herbicides					
Round up	56.78	0.887	1.044	2.510 [b]	1.5
Weedal	18.198	0.728	1.013	3.127 [b]	2.0

Note: [a] estimated by dividing aggregate amount of pesticide applied by total treated area for each pesticide.

[b]expressed in Litres per hectare.

In terms of aggregate quantity of pesticide applied, Victory (1016.46) was the first followed by Milraz (602.85), Ridomil (445.90), Tata Alpha (378.45) and Engeo (126.72). Taking a closer look at the kilogram per hectare column in Table 10 indicate that majority of the farmers were overusing pesticides. For instance, farmers were applying 4.27 L/Ha of Tata Alpha instead of the recommended rate of 0.25 L/Ha. Similarly, with respect to fungicides, most farmers were overusing them. For example, on average farmers were applying 13.582 Kg/Ha of Milraz which is almost seven times higher than the recommended rate (2 Kg/Ha). Previous studies (Zhang *et al*., 2015; Jallow *et al*., 2017; Wang *et al*., 2018) have reported cases of pesticide overuse among small-scale farmers in developing countries including Kenya (Lagat *et al*., 2007; Gitonga *et al*., 2010). A list of pesticide names, active ingredients and their corresponding toxicity classification is presented in Table 12.

Table 12: Classification of pesticide used based on WHO toxicity class

Pesticide trade names	Active ingredient	WHO hazard class[c]
Insecticides		
Tata Alpha	Alpha-cypermethrin	II
Engeo	Thiamethoxam + Lambda-cyhalothrin	II
Coragen	Chlorantraniliprole	U
Cypertox	Lambda-cyhalothrin	II
Fungicides		
Mistress	Cymoxanil +Mancozeb	II+U
Milraz	Propineb + Cymoxanil	U+II
Ridomil	Metalaxyl +Mancozeb	II+U
Victory	Metalaxyl + Mancozeb	II+U
Herbicides		
Roundup	Glyphosate	III
Weedal	Glyphosate	III

[C] II= moderately hazardous, III=slightly hazardous, U= unlikely to present acute hazard in normal use.

Source: WHO, 2009

Monthly frequencies of insecticide and fungicide applications ranged from four to five times, which could have contributed to increased levels of pesticide usage. Ownership of knapsack sprayer by the majority of farmers (83.33%) could have contributed to the high frequency of application due to ease of access. Ownership of spraying (motorized and hand) equipment was associated with increased expenditure on agrochemicals in Ghana (Danso-Abbeam and Baiyegunhi, 2017). Similarly, monthly frequencies of herbicide ranged from one to two times in a growing season. Some farmers were misusing some pesticides by applying them to non-registered crops (Gok, 2018) probably due to lack of knowledge about pesticide use. Previous studies (Ngowi *et al*., 2007; Bon *et al*., 2014) have reported high frequencies of pesticide application and misuse in African agriculture. However, none of the farmers was using pesticides categorized under class Ia and class Ib which are extremely and highly hazardous respectively. Majority of the farmers were using pesticides which belonged to class II, class III and class U (WHO, 2009). Excessive use of hazardous crop protectants could have contributed to high incidences (84.64%) of self-reported health ailments experienced by farmers in the study area.

4.3.2 Preliminary diagnostics of the proposed explanatory variables used in the regression models

Before conducting further analysis, data were subjected to various tests to determine whether there was a problem of multicollinearity and heteroskedasticity. With regard to the statistical problem of multicollinearity, variance inflation test was used for continuous explanatory variables while discrete explanatory variables were subjected to pairwise correlation test. Results from Table 13 indicate that the VIF values (ranging from 1.08 to 1.7) were less than the common threshold VIF value of 10 (Ketema *et al*., 2016), hence multicollinearity was not a problem.

Table 13: Variance inflation factor test results for continuous explanatory variables

Variable	VIF	1/VIF
Age of household head	1.7	0.588398
Years of schooling of household head	1.2	0.832467
Household size	1.23	0.813257
Farming experience	1.43	0.700127
Farm size	1.12	0.889028
Pesticide use perception on crop productivity	1.14	0.876929
Risk perception w.r.t environment	1.27	0.788111
Risk perception w.r.t human health	1.24	0.808842
Customer orientation	1.18	0.849906
Number of Groups	1.08	0.929324
Number of trainings	1.39	0.717771
Number of extension contacts	1.39	0.720961
Distance to the market	1.13	0.887939
Mean VIF	1.27	

Note: w.r.t = with respect to.

With respect to pairwise correlation test results (Table 14), none of the proposed discrete independent variables had exceeded the threshold correlation coefficient of 0.75 as per the rule of thumb or a more restrictive correlation coefficient of $|r| > 0.7$ (Dormann *et al*., 2012) , hence there was no problem of multicollinearity. Consequently, all the proposed explanatory variables were used for further analysis.

Table 14: Pairwise correlation test results for categorical explanatory variables

Variables	Gender of the household head	Participation in off-farm activities	Access to credit	Main source of labour
Gender of the household head	1			
Participation in off-farm activities	0.0056	1		
Access to credit	-0.0568	-0.2213	1	
Main source of labour	-0.0987	0.0061	0.0446	1

To assess the econometric problem of heteroskedasticity, the White test was used and results are presented in Table 15. The white test was preferred over the Breusch–Pagan (BP) test because it considers the magnitude and the direction of change for the non-linear form of heteroskedasticity (William, 2015). Results from the white test for heteroskedasticity (Table 15) indicated that the variance of the error term was not constant ($p<0.01$). To resolve the econometric problem of heteroskedasticity, robust standard errors were reported in the analysis of the econometric models.

Table 15: Results from the white test of heteroskedasticity

Source	***chi²***	Degree of freedom	P-value
Heteroskedasticity	251.25	215	0.0455
Skewness	78.82	20	0.0000
Kurtosis	49.45	1	0.0000
Total	379.52	236	0.0000

4.3.3 Confirmatory Factor Analysis

Variables such as pesticide use risk perception with respect to human health and environment, customer orientation as well as farmers` perceived pesticide use effects on crop productivity were first subjected to confirmatory factor analysis. This is because several items relating to human health risk perception, environmental risk perception, productivity perception (with four items each) and customer orientation (with two items) were developed and measured using a five-point Likert scale ranging from 1(strongly disagree) to 5(strongly agree). The scores of unobservable constructs were generated by averaging the items of the measurements. The items were developed by researchers while others were obtained from previous studies (Hashemi and

Damalas 2010; Abdollahzadeh et al., 2015; Ozkaya et al., 2015). Confirmatory factor analysis was carried out to ensure discriminant validity, internal consistency, and convergence of the concepts. The results are presented in Appendix B, Table B.1. All factor loadings on the constructs ranged from 0.52 to 0.91 with the majority being above 0.600 indicating that the items loaded relatively well. To test the suitability of data for factor analysis, the Kaiser-Meyer-Olkin (KMO) test was carried out. The KMO values ranged from 0.500 to 0.671 indicating that the sample was relatively adequate and suitable for factor analysis. Cronbach`s alpha coefficients were evaluated to check the reliability of the unobservable concepts (Yang and Wu, 2016).

4.3.4 Determinants of the level of pesticide usage among small-scale tomato farmers

In order to determine the level of pesticide usage (in terms of underdose=1, recommended dose=2 and overdose=3), the amount of pesticide (in expressed in Kg/Ha or L/Ha) applied by farmers was calculated. The farmer`s reported application rate was compared with the manufacturer`s recommended application rate as per the information provided on the product label. Farmers who were applying amount less than the recommended rate were underusing pesticide (underdose) while those applying more than the recommended dose were overusing pesticides (overdose). Farmers who followed the recommended application rates were classified under the recommended dose category (recommended dose). Subsequently, three equations were simultaneously estimated to examine the determinants of the level of pesticide usage for each type of pesticide. To capture the possible cross-equation associations in the level of pesticide usage decisions, a Trivariate Ordered Probit model was employed in the current study.

Table 16: Descriptive statistics of the level of pesticide usage

Types of pesticide	Categories	Per cent
Insecticide	Underdose	2.08
	Recommended Dose	0.26
	Overdose	97.66
Fungicide	Underdose	7.81
	Recommended Dose	0.26
	Overdose	91.93
Herbicide	Underdose	83.33
	Recommended Dose	0.00
	Overdose	16.67

Visual inspection of Table 16 indicates that majority of the small-scale tomato farmers were using more than the recommended doses of insecticide (97.66%) and fungicide (91.93%) respectively. Farmers could be encountering higher incidence of insect pests and fungal diseases in the area which could be forcing them to apply higher levels of pesticide for crop protection. Previous study in Kuwait (Jallow *et al.*, 2017) revealed pesticide overuse by vegetable farmers due to the prevalence of pests in agricultural production. The major tomato insect pests and diseases reported by the majority of farmers include *Tuta absoluta*, whiteflies, thrips, aphids, cutworms, early blight and late blight. Similarly, prior studies (Desneux *et al.*, 2010; Sigei *et al*., 2014; Mueke, 2015) have reported incidences of insect pests and diseases as a major challenge during tomato production. Contrary, the majority of the farmers (83.33%) were applying less than the recommended dose of herbicide. Farmers with large household size and small farm size could be substituting chemical weeding with manual weeding due to the availability of cheap family labour which is more economical.

Table 17: Estimated correlation coefficients of the Trivariate Ordered Probit equations

Variables	**Fungicide**	**R.S.E**	**Herbicide**	**R.S.E**
Insecticide	0.7428***	0.1455	-0.2217	0.2326
Fungicide			-0.3192**	0.1399

Note:***,**,imply significant at 1% and 5% levels. R.S.E= Robust standard errors

There was a significant relationship between some of the level of pesticide usage decisions across the different types of pesticides (Table 17). For instance, the level of insecticide and fungicide usage decisions are positively correlated (complements) while herbicide and fungicides are negatively correlated (substitutes) probably due to unobserved common factors. This is plausible especially in commercial farms where farmers jointly use fungicide and insecticides to enhance crop protection against insect pests and diseases and improve yields, leading to increased farm income. Furthermore, the negative correlation between fungicide and herbicide is reasonable because they both compete for the same scarce resource (limited financial resources), hence a resource-poor farmer may opt to buy fungicide and use family labour for manual weeding (instead of applying herbicide) especially in small farms. Therefore, Trivariate ordered probit model was more appropriate since it takes into account the interdependence between the levels of pesticide usage decisions across the three types of pesticides. Ignoring such correlation would lead to inaccurate estimates.

Table 18 presents the results from the estimation of Trivariate ordered probit model. It consists of two parts, where the first part displays the regressors while the second part consists of the model diagnostics. Results from the second part of Table 18 indicates that the level of pesticide usage (response variable) is naturally ordered. Most of the cutoffs (threshold parameters) are statistically significant at 5% hence, the use of an ordered regression was more appropriate. Further confirmation from the Waldi Chi^2 test for the overall significance of the model (734.05 with 60° of freedom, $p<0.01$) indicates that the model fitted the data well and all the relevant variables were included in the model.

Farmer`s engagement in off-farm activities, group membership, access to credit, distance to market, the source of labour, number of extension contacts and Pesticide Company as a source of information were statistically significant in explaining the level of insecticide usage. With regard to the level of usage of fungicide, significant predictors included gender, main source of labour, farm size, number of training programs, number of extension contacts and information source dummy variable (pesticide company). In addition, the gender of the household head, farming experience, household size, risk perception with respect to the environment, pesticide use perception on crop productivity, access to credit and number of extension contacts were significant in explaining the level of herbicide usage.

Table 18: Coefficient estimates for the Trivariate Ordered Probit model

	Insecticide		Fungicide		Herbicide	
Variables	**Coef.**	**R.S.E**	**Coef.**	**R.S.E**	**Coef.**	**R.S.E**
Socioeconomic						
Gender of household head	0.4174	0.3166	0.4603**	0.1995	0.4960**	0.2264
Age of household head	0.0170	0.0166	0.0011	0.0111	-0.0096	0.0096
Years of schooling of household head	0.0428	0.0500	0.0517	0.0331	-0.0074	0.0295
Farming experience	-0.0104	0.0271	0.0147	0.0241	0.0426**	0.0176
Household size	-0.0268	0.0812	0.0322	0.0589	-0.1688***	0.0543
Participation in off-farm activities	-0.5743*	0.3194	-0.1290	0.2261	0.0609	0.1943
Farm size	-0.0364	0.0625	-0.1779***	0.0663	0.0063	0.0677
Farmer perception						
Risk perception w.r.t. human health	-0.2047	0.1481	-0.1642	0.1174	-0.0892	0.0980
Risk Perception w.r.t. environment	-0.0308	0.1469	0.0510	0.1210	-0.2332**	0.1019
Pesticide use perception on crop productivity	-0.0094	0.1253	-0.0871	0.0984	0.2277***	0.0875
Institutional						
Group membership	-0.2676**	0.1075	-0.0373	0.0873	0.0257	0.0761
Access to credit	-0.3705*	0.2094	0.0247	0.2209	0.5004***	0.1736
Number of trainings	0.0541	0.1944	-0.3292***	0.1154	-0.0928	0.1032
Distance to the market	0.0295**	0.0126	-0.0048	0.0075	0.0027	0.0056
Main source of labour	0.6262*	0.3231	-0.4145**	0.1941	0.1996	0.1817
Customer orientation	0.0956	0.0964	0.1211	0.1062	0.1643*	0.0939
Number of extension contacts	0.2535*	0.1470	0.3225***	0.1214	0.2514***	0.0940
Source of information[1]						
Pesticide retailer	-0.1490	0.3326	-0.1642	0.2234	-0.0641	0.1851
Pesticide company	4.5320***	0.3591	-1.2834**	0.5633	-0.1204	0.4333
Media	0.0860	0.5839	-0.3492	0.3581	0.2802	0.3618
Model diagnostics						
Number of observations	384					
Waldi $Chi^2(60)$ =	734.05					
Prob. > Chi^2 =	0.0000					
Log pseudo likelihood =	-271.6968					
/Cut_1_1	-0.1584	1.0369				
/Cut_1_2	-0.1022	1.0680				
/Cut_2_1	-1.6567**	0.7218				
/Cut_2_2	-1.6363**	0.7250				
/Cut_3_1	1.4350**	0.6414				

Note: ***,**,* imply significant at 1%, 5% and 10% levels respectively. R.S.E= robust standard errors, Coeff. = coefficient.
[1] the reference source of information is fellow farmers. Cut_ij = threshold parameters for each response variable (level of pesticide usage)

From Table 18, the gender of the household head had a positive effect on the likelihood of using a higher level of fungicide and herbicide at 5% significant level. Male-headed households relative to their female counterparts could have more access to crucial resources such as credit (possibly due to ownership of required collateral such as land) vital for bulk purchase of fungicide and herbicide which increases the likelihood of higher level of usage. On the other hand, on average, female farmers tend to be more risk-averse than male farmers, thus they may have a strong preference for safe pesticide use behaviour to safeguard their personal and family members` wellbeing, and to maintain food safety. This could lead to the reduced probability of using higher levels of fungicides and herbicides. In Nigeria, Rahman and Chima (2018) observed that male farmers were utilizing significantly more pesticides than female farmers. Similarly, Schreinemachers *et al*. (2017) observed that lower pesticide use was recorded where women were responsible for pest management activities as compared to their male counterparts. In China, Wang *et al*. (2018) revealed that female farmers had a higher propensity of pesticide overuse as compared to male farmers since agricultural production in the region is controlled.by male farmers with more past experience.

Farming experience had a positive effect on the probability of using a higher level of herbicide at 5% significant level. Farmers with rich experience have a higher likelihood of using a higher level of herbicide relative to farmers with less experience. Farmers with more experience (with accumulated social and physical capital) could be substituting manual weeding with herbicide application (to minimize production cost and due to energy loss), leading to increased likelihood of higher herbicide usage. Similarly, Jin *et al.* (2017) observed that farmers with more farming experience had a higher chance of overusing pesticide as compared to their counterparts. In contrast, Wang *et al*. (2018) indicated that farmers with rich experience have more skills (gained through practice) to control pesticide application (manage pest and diseases) without excessive use of the pesticide. Waichaman *et al*. 2007 observed an increase in herbicide usage among Brazilian vegetable farmers because it was economical than employing extra labour.

Household size had a negative influence on the likelihood of using a higher level of herbicide at 1% significant level. Increase in household size could increase the number of family members available for implementing farm activities such as manual weeding (substituting chemical weeding) on time, leading to a lower likelihood of increased level of herbicide usage. Alternatively, large household size could increase household expenditure which constraints financial resources available for bulk purchase of herbicide, hence decreasing the probability of increased level of herbicide usage. Correspondingly, Migheli (2017) argued that an increase in family size increases the availability of family labour vital for implementing farm activities which reduces the quantity of pesticide applied. Danso-Abbeam *et al*. (2014) indicated that large household size was negatively associated with investment in agrochemical inputs in cocoa production. Akinola and Owombo (2012) postulated that large households are faced with high consumption pressure which may limit adoption of agricultural technology including chemical input use.

Participation in off-farm activities had a negative influence on the likelihood of increased level of insecticide usage at 10% significant level. Off-farm activities could expose farmers to new ideas and information which could enhance farmers` use of alternative pest control methods. The information could also include the dangers associated with pesticide overuse, leading to the decreased likelihood of insecticide overuse. Similarly, Chang *et al*. (2012) observed that engagement of farm operators in non-farm activities reduced chemical usage. In Northern China, Brauns *et al*. (2018) observed that farmers who engaged in non-agricultural activities used more herbicides.

Farm size had a negative influence on the likelihood of farmers using a higher level of fungicide at 1% significant level. In this study, farm size was used as an indicator of wealth. Small landholdings could drive farmers whose livelihoods solely rely on agriculture to use a higher level of fungicide for crop protection, to increase yields and maximizing farm returns from limited available agricultural land. Alternatively, farmers with large landholdings could have access to accurate and relevant information on application rates, dangers of pesticide misuse and non-chemical pest control methods acquired through training and extension visits. This increases their knowledge of safe pesticide use leading to the decreased likelihood of higher level of fungicide usage as farm size increases. Farmers with large farms could also be willing to try out other alternative methods of pest control due to their large scale of operation (have more space and can absorb the risk of failure), unlike their counterparts. These results correspond to Rahman and Chima (2018) findings in Nigeria where farmers with small farms were applying substantially higher rates of pesticides than farmers with large farms. In contrast, Danso-Abbeam and Baiyegunhi (2017) revealed that farmers with large farms had a higher likelihood of increasing their investment in agrochemical inputs such as fertilizers, fungicide, and insecticide as compared to their counterparts.

Farmer`s pesticide use risk perception with respect to the environment had a negative influence on the likelihood of using a higher level of herbicide at 5% significant level. Farmers could develop an attitude toward a crop protection product based on their previous experience while using the product or information acquired about the crop protection product from reliable sources. A case in point is where the inappropriate application of herbicide in controlling weeds could have unintended adverse effects such as air pollution, soil contamination, water pollution and destruction of natural enemies which could increase farmers` risk perception. If farmers are aware of such ill environmental effects, they will be more cautious while applying herbicides, leading to increased likelihood of lower level of herbicide usage. Similarly, Schreinemachers *et al*. (2017) indicated that more knowledge of valuable (natural enemies) and damaging arthropods was related to decreasing pesticide usage. In contrast, Wang *et al*. (2018) observed that farmers who viewed pesticide use as harmful to the environment had a high probability of overusing pesticide because of fear of yield loss associated with pests leading to loss of income.

Farmer`s perception of pesticide use on crop productivity had a positive influence on the likelihood of using a higher level of herbicide at 1% significant level. Farmers could develop an attitude toward herbicide product after experiencing its benefits or disadvantages by using it, or through the acquisition of information about the product. Consequently, farmers with a higher perception of herbicide use benefits such as increased yields and better control of weeds are more likely to overuse herbicide probably due to lack of knowledge about the hazards of herbicide overuse. This is plausible since the overriding concern among farmers is crop loss attributed to pests (including weeds) leading to economic loss, which motivates them to use more herbicide to prevent loss. Correspondingly, Zhang *et al*. (2015) argued that farmers who anticipated higher harvests with more pesticide use had a higher probability of overusing pesticides. Jallow *et al*. (2017) observed that farmer`s perception of pesticide use as a prerequisite for attaining higher yields played a vital role in pesticide overuse in Kuwait.

Membership to a farmer group had a negative influence on the likelihood of a higher level of insecticide usage at 5% significant level. Being a member of a higher number of farmer organizations could provide easy and quick access to relevant information on pesticide use, purchase of essential agricultural inputs, access to the stable market, alternative crop protection methods, monitoring of production activities by the members, access to extension services and training at a lower cost. Subsequently, leading to a decreased likelihood of using a higher level of insecticide by group members. Additionally, group-setting provides linkages with other farmers which facilitates the exchange of new ideas, information and experiences, which shape farmers` behaviours, attitude, and practices leading to a lower likelihood of increased level of insecticide usage. In Colombia, Feola and Binder (2010) observed that membership to a farmer group decreased the likelihood of intensive use of the pesticide. Abebaw and Haile (2013), indicated that membership to a cooperative increased the likelihood of using pesticides.

Access to credit had a negative influence on the likelihood of using higher levels of insecticide at 10% significant level and positively influenced the probability of increased levels of herbicide usage at 1% significant level respectively. Access to credit increases liquidity position of farmers hence they can afford to purchase large quantities of herbicides leading to an increased likelihood of higher level of herbicide usage. On the other hand, inadequate investment in agricultural activities such as the purchase of sufficient quantities of insecticides could lead to a lower likelihood of higher level of insecticide usage. These observations corroborate with Rahman (2003) findings where an increase in farmer`s liquidity position due to access to credit increased pesticide usage rate in Bangladesh. In contrast, Danso-Abbeam and Baiyegunhi (2018) observed that access to credit was positively associated with the likelihood of adoption of insecticide among cocoa farmers.

Participation in training had a negative influence on the likelihood of using higher levels of fungicide at 1% significant level. To apply the recommended rate, farmers need access to information on target pest, application frequencies and pesticide doses all which can be acquired through training programs on pesticide use. Thus, farmers who have attended more training programs could have relevant information on fungicide dosage and toxicity level which averts overuse behaviour. Additionally, participation in training programs on pesticide use creates awareness of the adverse effects of pesticide overuse and could expose farmers to other non-chemical crop protection methods, leading to a lower likelihood of using a higher level of fungicide. In Pakistan, Khan *et.al*. (2015) observed that farmers who took part in training programs were less likely to overuse pesticide. Similarly, Mwatawala and Yeyeye (2017) observed that trained farmers were more likely to apply the recommended dose unlike untrained farmers in Tanzania.

Distance to the market had a positive effect on the likelihood of a higher level of insecticide usage at 5% significant level. In this study, distance to market was used as a proxy for access to market and other relevant information. In order to have an adequate supply of insecticide, farmers in remote areas could purchase pesticide in bulk to minimize transaction costs and to increase the stock, leading to an increased probability of unregulated use of higher level of insecticide. The positive influence could also be attributed to the difficulty of farmers in remote areas in accessing extension services and training programs on alternative insect control measures. Rahman (2003) reported that the close proximity of markets to farm households increased accessibility and availability of pesticides in Bangladesh.

Source of labour had a positive effect on the chance of a higher level of insecticide usage and negatively influenced the probability of using a higher level of fungicide at 10% and 5% significant level respectively. Labour constraints have been one of the major production challenge facing small-scale farmers. Consequently, farmers rely on cheap hired unskilled labour to lower production cost who might lack adequate knowledge on proper insecticide use, leading to increased chances of a higher level of insecticide usage. Farmers could find it easy to implement alternative pest control methods using unskilled labour leading lower likelihood of higher level of fungicide usage since it is relatively manageable. Another possible explanation could be farmers utilizing family labour might be more cautious while using fungicides to minimize negative human health effects since more family members are exposed to hazardous products, leading to lower chances of increased levels of fungicide usage. Migheli (2017) indicated that a decrease in pesticide use was negatively associated with increased use of family labour in Mekong Delta.

Customer orientation had a positive effect on the probability of a higher level of herbicide usage at 10% significant level. Farmers who are customer- oriented tend to produce good which is tailored towards meeting the market demand (for instance spotless and fresh produce). In order to meet the growing consumer demand under the current production environment characterized by high pest infestation, farmers are being forced to heavily rely on herbicide to suppress weeds and increase productivity. In return, farmers may gain higher access to lucrative markets and increase their income which might drive them to use higher levels of herbicide. Alternatively, farmers` misconception about herbicide efficacy and its insignificant effect on the ultimate consumer health since it is applied at the earlier stages of crop production (during land preparation) hence minimizing its effect on the final produce food safety could be driving them to use more herbicide. Damalas and Khan (2017) argued that small-scale farmers heavily rely on the pesticide to increase agricultural productivity and for crop protection with the aim of satisfying the increasing consumer demand for agricultural products and increasing income.

Number of extension contacts had a positive influence on the likelihood of higher levels of insecticide, fungicide and herbicide usage at 10% and 1% correspondingly. Government and non-government extension service providers serve as a major source of agricultural information in the most developing country including Kenya. Access to accurate and reliable information on pesticide application frequency, methods of application, amount, and pest threshold in order to initiate action and alternative methods could lead to a decreased likelihood of pesticide overuse. However, failure to provide such crucial details to the farmer may lead to an increased probability of higher pesticide usage. This could be the case in this study where extension service providers may have failed to provide such information leading to increased probability of higher level of insecticide, fungicide and herbicide usage. Alternatively, extension service provided to small scale farmers could have been geared towards enhancing agricultural intensification hence increased pesticide usage. Similarly, Bon *et al*. (2014) indicated that the majority of government extension programs in Africa encourages the use of pesticides in spite of its risks which could lead to an increased level of pesticide usage. Contrary, Denkyirah *et al. (*2016) argued that farmers acquire information on insect pest threshold through accessing extension services which reduce their frequency of pesticide application, leading to lower pesticide usage.

Reliance on pesticide company relative to fellow farmers for agricultural information had a positive effect on the probability of higher level of insecticide usage, and negatively influenced the probability of higher levels of fungicide usage at 1% and 5% significant level respectively. For a farmer to apply agricultural information, it should be truthful, accurate, reliable and from a trusted source. Pesticide company agents (whose salary are often tied to profits of pesticide sales) could be driven by profitable opportunities hence, in pursuit of their personal interests they aggressively promote the use of insecticides rather than prudent use of insecticide. Alternatively, pesticide company agents could be lacking knowledge on insecticide use hence providing inaccurate information to farmers leading to higher likelihood of increased level of insecticide usage. Farmers could also observe their fellow farmers as they implement the pest management activities on their farms which boosts their skills and confidence in them. Acquisition of accurate and reliable information on safe pesticide use from trained pesticide company personnel through organized seminars or farm visits could lead to a decreased likelihood of fungicide overuse. Schreinemachers *et al*. (2017) observed that farmers who relied on their friends and neighbours relative to other sources for information used a substantially lower percentage of pesticides. High incidences of pesticide misuse among farmers were attributed to the acquisition of unreliable information from untrained personnel (Shetty *et al*., 2010).

4.3 Factors influencing the intensity of uptake of alternative pest management methods

4.3.1 Identifying and grouping alternative (non-chemical) pest management methods

High incidences of pest is a major production constraint among small-scale tomato farmers. To address this problem, farmers employ numerous methods for crop protection against pests and to prevent crop loss hence increasing agricultural output. In this study, the majority of the farmers were using cultural methods as an alternative technique for dealing with the pest problem. However, none of the farmers was utilizing biological controls and biopesticides. Failure to use some of the alternatives to chemical pesticides was attributed to unavailability (41.93%), lack of awareness of other methods (28.13%), being ineffective (19.01%) and costly to use (10.94%). Ten non-chemical crop protection methods actively used by farmers were identified at the field during the study. Alternative crop protection techniques are presented in Table 19.

Table 19: List of alternative pest management methods actively in use by farmers

Serial number	Alternative methods
1.	Weeding
2.	Crop rotation
3.	Use of improved crop varieties
4.	Intercropping
5.	Mulching
6.	Pruning
7.	Crop residue destruction
8.	Irrigation
9.	Efficient use of fertilizer
10.	Use of traps

To facilitate further econometric analysis, identified practices were classified into four groups (components) using principal component analysis (Table 20). The approach involves categorizing related practices into components to facilitate subsequent analysis by fitting the groups into the model and drawing a conclusion. Unlike conventional techniques of grouping practices, the use of principal component approach is favourable in drawing a conclusion about a cluster in cases where few practices may represent the entire group. The approach is useful in reducing the dimensionality of data without losing much information. To arrive at the four principal components, orthogonal varimax rotation method (Goswami *et al.*, 2012) was used so that lesser number of highly interrelated practices would be classified under each cluster for easy interpretation and generalization about the group. Consequently, the Kaiser criterion was taken into consideration where components with Eigenvalues greater than one were retained (Kaiser, 1958). In this case, only variables with high factor loadings (greater or equal to 0.03) were considered for interpretation from the varimax rotation (Kamau, 2018).

The clusters and their corresponding factor loadings (coefficients of linear combinations) are presented in Table 20. With regard to the percentage of explained variance, the retained components explained 60.61% variability in the dataset. This presents a good fit indicating that the results from principal component analysis explained the data. Visually inspecting each column in Table 20 facilitates in understanding the contribution of each component in explaining the variability in the dataset. The first component explained 22.29% of the variance while the second, third and fourth components explained 14.16%, 12.49% and 11.68% correspondingly.

Table 20: Principal components of alternative methods of pest management

Practices	Comp1	Comp2	Comp3	Comp4	Communality
Crop residue destruction	**0.785**	0.065	-0.069	0.068	0.64
Irrigation	**0.901**	0.062	0.025	0.011	0.82
Efficient use of fertilizer	**0.701**	-0.366	0.049	0.015	0.64
Pruning	0.057	**0.812**	0.029	-0.032	0.67
Use of traps	0.004	**0.827**	-0.014	0.021	0.69
Intercropping	-0.023	-0.082	**0.835**	-0.017	0.74
Mulching	0.008	0.102	**0.668**	0.096	0.60
Weeding	0.146	-0.027	**0.632**	0.150	0.61
Crop rotation	-0.003	0.019	-0.003	**0.910**	0.83
Improved crop varieties	-0.055	0.013	0.064	**0.837**	0.74
Eigenvalues	2.006	1.274	1.124	1.051	
Eigenvalues % contribution	22.286	14.159	12.491	11.677	
Cumulative percentage	22.286	36.445	48.936	60.613	

Note: Comp = component

Taking a closer look at each column in Table 20 helps to describe each cluster based on the strongly related practices. The first group (component 1) comprise of crop residue destruction, irrigation and efficient use of fertilizer all with positive factor loadings. Pruning and use of traps both with positive loadings belong to the second cluster (component 2). The third component constitutes of intercropping, mulching and weeding all with positive loadings. Finally, crop rotation and use of improved crop varieties belong to the fourth cluster both with positive coefficients of linear combination. The communality column represents the aggregate variance of each variable retained in the four components. In this case, all items in the principal components meet the minimum criteria (communality of above 0.6) as they accounted for more than sixty per cent of the variance in the components (MacCallum *et al*., 2001).

Table 21 presents descriptive statistics of the composition of each group (alternative pest management methods) and their respective percentage of farmers using them.

Table 21: Descriptive statistics of non-chemical pest management methods

Categories of alternative methods	**Percentage of users**	**Constituents**
Crop management practices (CMP)	98.70%	Crop residue destruction Irrigation Efficient use of fertilizer
Preventive measures(PM)	97.14%	Crop rotation Use of improved crop varieties
Control measures (CM)	95.32%	Weeding Intercropping Mulching
Mechanical methods(MM)	66.23%	Pruning Use of traps

The most used cluster of alternative pest management methods was crop management practices with 98.7% of farmers utilizing it. This group constitutes of crop residue destruction, irrigation and efficient use of fertilizer. Maintaining field sanitation through crop residue destruction reduces the build-up of pests and spreading of insect and diseases to other crops. Avoidance of water stress through irrigation facilitate in suppressing pest population which thrives well due to inadequate provision of water. Provision of adequate nutrients through fertilizer application enhances crop growth alters soil pH, hence reducing crop susceptibility to pest (Filho *et al*., 1999; Mills and Daane, 2005; McGovern, 2015).

The second cluster (Table 21) with the highest number of users (97.14%) was preventive measures. It includes crop rotation (Banjo *et al*., 2010) and the use of improved crop varieties (Karungi *et al*., 2011). Use of improved crop varieties (insect and disease resistant varieties) enhance crop resistance against pest attack while crop rotation minimizes pest population by altering their source of food or host (Veisi, 2012; Abang *et al*., *2*014). The third group controlled measures which entailed weeding, intercropping and mulching (Banjo *et al.*, 2010; Karungi *et al.*, 2011; Bangarwa and Norsworthy, 2014) whose percentage of the user was 95.32%. Weeding eradicates weeds and exposes soil-borne pests to natural enemies by bringing them on the ground. Intercropping reduces the attractiveness of the main crop to potential pests and may also act as a cover crop, hence preventing the growth of weeds. Similarly, the use of mulch helps in controlling the growth of weeds and improves soil fertility (Knox *et al*., 2012) and regulates soil moisture by reducing water evaporation. Finally, the least used component (Table 20) was mechanical methods (66.23%) which comprised of pruning and use of traps which belong to mechanical method. For instance, removal and destruction of infected parts of the plant by pruning subdue pest reproduction and dispersion. For example, use of traps to capture and eradicate insects (for instance sticky traps) or trap crops to attract pest away from the desired crop contributes towards a reduction of the pest population by altering its habitat (Khan and Damalas, 2015a; Jebapreetha *et al*., 2017).

4.3.2 Determinants of the intensity of uptake of alternative pest management methods

In order to determine the extent of usage of each group of non-chemical pest management methods by farmers, the number of methods used by a farmer in each group was expressed as a ratio of the total possible number of practices in each group (ranging from 0 to 1). The ratio was used as a proxy for the intensity of uptake of alternative (non-chemical) methods. Subsequently, Multivariate Tobit model was employed in estimating the determinants of the intensity of uptake of alternative pest management methods. Table 22 presents the estimated correlation coefficients of any pair of error terms in the Multivariate Tobit equations. Majority of the correlations coefficients are strongly significant. The maximum correlation in absolute term is 39% which is relatively low. This indicates that the Multivariate Tobit model specification is vital, and disregarding such correlations would have led to inconsistent parameter estimates. Results from Table 22 indicates that there is significant complementarity (positive correlation) and substitutability (negative correlations) between the intensity of adoption decisions. Further confirmation from likelihood ratio test (Chi^2 (6) = 72.3927, $p<0.01$) of joint significance of correlation coefficients of the error terms rejects the null hypothesis of the independence of adoption decision, showing that it is more efficient to use multivariate Tobit than the univariate Tobit models. Moreover, Waldi *Chi-square* test results ($\chi^2(60) = 171.63$, $p=0.0000$) indicates that the model fitted data well and all the relevant variables were incorporated in the model.

Table 22: Estimated Correlation coefficients of the Multivariate Tobit equations

Variables	Crop management practices	Mechanical methods	Control measures	Preventive measures
Crop management practices	1			
Mechanical methods	-0.3935***	1		
Control measures	0.0289	0.1315**	1	
Preventive measures	0.0174	-0.0605	-0.1061**	1
Likelihood ratio test of rho_{ij} = 0, $\chi^2(6)$ =72.3927; Prob > chi^2 = 0.0000				

Note: ***,**,* imply significant at 1%, 5%, and 10% levels respectively; rho_{ij} = correlation between error terms of any pair of Multivariate Tobit equations.

Results from the estimation of the Multivariate Tobit model are presented in Table 23. Out of the 15 explanatory variables included in the model, 9 variables were statistically significant in explaining the intensity of adoption of non-chemical pest management methods.

Table 23: Estimates of the Multivariate Tobit Model for determinants of intensity of adoption of alternative pest management methods

	Crop management practices		Mechanical methods		Control measures		Preventive measures	
Variables	**Coeff.**	**R.S. E**	**Coeff.**	**R.S.E**	**Coeff.**	**R.S.E**	**Coeff.**	**R.S. E**
Socioeconomic characteristics								
Age of household head	0.0023	0.0015	0.0032	0.0033	0.0037***	0.0014	-0.0011	0.0016
Gender of household head	0.0146	0.0370	0.0657	0.0818	0.0016	0.0382	0.0362	0.0369
Years of schooling of HH	0.0045	0.0055	0.0278**	0.0118	0.009	0.0056	0.0133**	0.0067
Household size	0.0129	0.0092	0.0180	0.0185	0.0065	0.0092	-0.0006	0.0092
Participation in off -farm activities	-0.0562*	0.0308	0.0385	0.0715	0.0112	0.0349	-0.0026	0.0302
Farm size	0.0017	0.0119	-0.009	0.0291	-0.0310**	0.0125	0.0067	0.0091
Farmer perception								
Risk perception w.r.t. human health	0.0040	0.0124	0.0504*	0.0259	0.0094	0.0134	0.0184	0.0145
Institutional characteristics								
Group membership	-0.0002	0.0133	-0.0042	0.0298	-0.0129	0.0127	0.0309**	0.0137
Number of extension contacts	0.0106	0.0176	0.0635	0.0407	-0.0133	0.019	-0.0023	0.0172
Access to credit	-0.0151	0.0324	0.0515	0.0679	0.0124	0.0329	-0.0233	0.0314
Number of training	-0.0028	0.0194	0.0438	0.044	0.0392*	0.0207	-0.0101	0.0183
Customer orientation	-0.0232	0.0149	0.0359	0.0292	-0.0162	0.0163	0.0379**	0.018
Informal Information sources[1]								
Pesticide retailer	-0.0560*	0.0323	0.0189	0.0734	0.0467	0.0327	0.0152	0.0318
Pesticide Company	0.0434	0.0699	-0.0462	0.2073	-0.0368	0.0663	0.0208	0.0593
Media	0.0364	0.0817	0.0961	0.1767	-0.0529	0.0614	0.0924	0.0651
Constant	0.5334***	0.0892	-0.3475*	0.2082	0.3620***	0.0950	0.6187***	0.1125
Number of observations	384							
Waldi $Chi^2(60)$	171.63***							
Log Pseudo likelihood	-468.01							

Note: ***, **,* represents significant at 1%, 5% and 10% levels respectively; [1] the base category source of information is fellow farmers. HH=household head. R.S.E = robust standard errors. Coeff. = Coefficient, w.r.t= with respect to. .

From Table 23, the age of the household head had a positive influence on the intensity of uptake of control measures at 1% significant level. Control practices such as weeding, intercropping and mulching are relatively labour-intensive and capital-intensive methods. To carry out these activities, a farmer may need capital to hire additional labour, purchase materials for mulching or seeds for intercropping. Thus, older farmers who may have accumulated social and physical resources over time may adopt higher numbers of control practices than young farmers who may lack such resources. Another possible explanation could be young farmers(unlike older farmers who solely rely on agriculture for income) may lack the adequate time needed to implement activities such as weeding which require long working hours since they are engaged elsewhere (non-farm activities). This increases their preference for chemical methods which are considered less time consuming and more effective than alternative methods, hence the lower number of control practices adopted. Similarly, In Greece, Damalas and Hashemi (2010) observed that young farmers displayed higher intensities of adoption of pest management practices related to Integrated Pest Management (IPM) than old farmers.

Education of the household head had a positive influence on the intensity of uptake of mechanical and preventive methods at 5% significant level. Preventive methods such as the use of improved crop varieties and mechanical methods (for instance, use of traps and pruning) requires knowledge about the pest, the environment, and management techniques as well as special skills which can be acquired through formal education. Education increases information access, processing capability and ability to apply the acquired information. As a result, better-educated farmers are able to implement such methods with ease which increases the number of practices adopted as compared to their counterparts. The findings are consistent with Khan and Damalas (2015) results on factors influencing cotton farmer`s adoption of an alternative to chemical pest control in Pakistan.

Farmers engagement in off-farm activities negatively influenced the intensity of uptake of crop management practices at 10% significant level. Crop management practices probably have a high demand for labour and management time spent on the farm. Therefore, farmers engaging in non-farm activities divert labour and time away from crop management activities which lower the number of crop management practices adopted. This observation is in line with Brauns *et al*. (2017) findings where participation in off-farm activities was positively associated with increased use of pesticides (decreased use of traditional hand weeding method) by farm households in China. Another possible explanation for the negative relationship could be due to a lower allocation of non-farm income to crop management activities as compared to non-agricultural activities which lead to a lower number of crop management practices being adopted. For instance, allocation of a higher proportion of off-farm income to household expenditure (due to large household size) reduces the available funds for investment in agricultural activities leading to a lower number of crop management practices adopted.

Farm size had a negative effect on the intensity of uptake of control measures at 5% significant level. Control measures such as weeding and mulching require higher investment in labour, and .as farm size increases it may become less feasible for the resource-poor farmers to meet the higher weeding labour and mulching materials requirement of the land under cultivation probably due to increased production cost and competition of labour with other farm activities. As a result, a lower number of control practices will be adopted by farmers as farm size increases. On the other hand, small-scale farmers in Kenyan rural areas mostly rely on family labour to lower opportunity cost which increases the number of control practices adopted due to cheap family labour. In contrast, Zulfiqar and Thapa (2017) observed that increase in farm size resulted in higher number of land preparation and sowing practices being adopted by cotton farmers as a component of an innovative cleaner production alternative.

Farmer`s pesticide use risk perception with respect to human health had a positive influence on the intensity of uptake of mechanical methods at 10% significant level. Farmers` negative attitude towards synthetic pesticide use due to previous adverse human health experience might motivate them to seek alternative methods of crop protection which do not endanger their health and the environment. For instance, previous ill-health experience as a result of chemical pesticide use may increase farmers` concern over health status hence increasing preference for an alternative to chemical methods. Mechanical methods such as the use of traps and pruning are eco-friendly and thus may not pose a threat to human health unlike the use of chemical pesticides. This increases the number of mechanical methods adopted by farmers who have heightened risk perception. Previous study (Khan and Damalas, 2015) has associated heightened risk perception with the adoption of alternative pest control methods. In contrast, Tu *et al*. (2018) observed that farmers with higher risk perception were less likely to adopt eco-friendly rice production in the Vietnamese Mekong Delta due to fear of failure (uncertainty) of the new eco-friendly practices to achieve the desired outcome

Membership to a group positively influenced the intensity of uptake of preventive measures at 5% significant level. To adopt higher numbers of preventive measures such as the use of improved crop varieties and crop rotation, a farmer may require credit, relevant information, training and other essential services. These services are easily accessible through cooperative membership due to economies of scale which enhance success in a number of preventive practices adopted. Furthermore, group membership creates linkages which facilitate the exchange of ideas, experiences and new innovations which can increase the number of preventive practices adopted. These findings are consistent with Tu *et al*. (2018) findings where membership in the agricultural club had a positive influence on the adoption of eco-friendly rice production in Vietnam such as Integrated Pest Management methods.

Participation in training programs had a positive effect on the intensity of uptake of control measures at 10% significant level. To adopt a higher number of control techniques such as mulching, weeding and intercropping requires knowledge on the pest, its habitat and ways of suppressing it. This information can be accessed by participating in training. Demonstration of new methods through training programs enhances farmer`s skills and confidence in the new methods which may increase the number of control practices adopted. Correspondingly, Khan (2009) observed that participation in training was positively correlated with the likelihood of adoption of alternative pest management practices in Pakistan. Similarly, Williamson *et al*. (2003) reported that farmers who had undergone training (relative to untrained farmers) preferred alternative crop protection methods over synthetic pesticides as they had acquired information on adverse human and environmental effects of pesticide use through training.

Customer orientation had a positive influence on the intensity of uptake of preventive measures at 5% significant level. Customer orientation involves understanding customer`s needs and creating value for the customers by offering high quality and safe food to others. To satisfy these needs (for instance large fruit size, blemish free, chemical free goods) a farmer may seek alternative methods of crop protection which are less detrimental to consumer health. Utilizing improved crop (such as high yielding and pest resistant) varieties and practising crop rotation may contribute towards meeting the customers' demands by minimizing chemical pesticide application due to health and food safety concerns. In return, farmers will gain access to lucrative markets offering premium prices for their products. Consequently, increased revenue due to high market demand for their products will motivate farmers to adopt a higher number of preventive measures. Prior studies (Cameron, 2007; Buurma and Velden, 2016) have highlighted consumer demand as one of the major drivers of adoption of IPM.

Finally, pesticide retailer as a source of information had a negative effect on the intensity of uptake of crop management practices at 10% significant level. Efficient use of fertilizer, optimal provision of water through irrigation and maintaining sanitation through crop residue destruction may require special knowledge on crop production which the pesticide retailer maybe be lacking probably due to low levels of education or lack of training. This lowers the number of crop management practices adopted by a farmer who relies on pesticide retailer for information. Furthermore, pesticide retailers who are driven by profit motive are more likely to promote synthetic pesticide use and provide information on how to use the product relative to alternative methods which decrease the adoption of crop management practices. On the contrary, farmer to farmer exchange of information and ideas facilitates higher uptake of a number of crop management practices probably due to vast knowledge on local production conditions acquired through farming experience as well as trust since they are known to each other. Additionally, the farmers providing information instil confidence in other farmers as they demonstrate new practices acquired through training, thus leading to higher adoption of crop management practices. Similarly, Wagner *et al*. (2016) observed that farmers who relied on pesticide dealers for information on pest management were more likely to use synthetic pesticides than other alternative methods.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The following conclusions were based on the three objectives;

1. Safety behaviours in pesticide use were limited particularly in the use of personal protective equipment such as mask, gloves, and goggles. Factors such as the high cost of purchase and discomfort were associated with lack of/limited use of protective gears.
2. Majority of the farmers were overusing insecticide, fungicide while underusing herbicide during pest control. The findings further showed that the likelihood of higher level of pesticide usage was positively influenced by gender, farming experience, distance to the market, number of contacts with the extension provider and customer orientation to mention but a few. On the other hand, participation in training programs, membership to a group, farm size, and participation in off-farm activities, household size and risk perception negatively influenced the level of pesticide usage. This observation offers a wide range of interventions to promote safe pesticide use.
3. Majority of the farmers employed cultural control methods while none of the farmers utilized biopesticide and biological control methods as alternatives to the chemical pesticide. The results also indicated that age, education, participation in training programs, group membership, risk perception and customer orientation positively influenced the extent of uptake of alternative pest control methods. However, participation in off-farm activities, farm size and information source (pesticide retailer) had a negative effect on the extent of uptake of alternative pest control methods.

5.2 Recommendation

From the aforementioned discussions and conclusions, the following was recommended;

1. To the pesticide companies and the government, sensitization of the dangers of pesticide misuse on human health and environment should be carried out through farmer groups, pesticide dealers and partnership with other relevant stakeholders to facilitate change in behaviour, attitude, and practices and promote safety behaviours in pesticide use. For instance, the use of experience groups with a mentor could be influential in sharing experiences among farmers. Moreover, farmers should be encouraged to join farmer groups and other social networks to facilitate the exchange of new ideas, information, increase their bargaining power, access vital farm inputs,

protective gears, access lucrative markets, credit, and other relevant services at a lower cost.

2. To the MoALF and other private extension service providers, there is a need for upgrading the skills of their personnel to enhance their effectiveness and implementation of a farmer to farmer extension provision services with a strong focus on promoting safe pesticide use and use of alternative crop protection methods to avert pesticide misuse behaviour at the farm fields. Furthermore, provision of participatory training programs on safe pesticide use and alternative crop protection methods (for instance through farm demonstrations and farmer field schools) which are gender sensitive and age inclusive to facilitate mass to access to accurate and reliable information to all relevant stakeholders in the tomato value chain(from chemical input suppliers to producers and traders).
3. To public policymakers and other development partners, there is a need for promotion and implementation of new efficient integrated pest management approaches and other alternative methods which are tailored towards the needs of the farmers. For instance, to enhance effective adoption of alternative methods, there is a need for dissemination of relevant information through relevant government and non-governmental information dissemination channels to in order to reduce synthetic pesticide use to a bare minimum. Integrated pest management method is an all-inclusive technique which cost-effective, eco-friendly, guarantees yields and contributes towards sustainable agriculture. Strict regulation and improved monitoring of pesticide use at the grass root level through the relevant government machinery(Kenya Bureau of Standards) and peer monitoring in farmer groups to enhance access to standard chemical crop protection products.

5.3 Areas of further research

Though this study only covered small-scale farmers growing tomatoes in open-fields, it could also be vital for future research to compare the level of pesticide usage and extent of uptake of alternative methods under greenhouse and open-field production system.

The study did not look at consumers` perception of chemical pesticide use in tomato production, yet one of the current issues relate to food safety and health concern. Consequently, forthcoming research can venture into this area not only in Nakuru County but also in other counties.

The study did not evaluate consumers` willingness to pay for horticultural products grown in an eco-friendly way. Therefore, further research should be done on this area to inform policymakers on vital interventions to enhance food safety, improve human health, promote the use of alternatives to pesticide, environmental conservation and contribute towards sustainable agriculture.

Finally, the study did not assess the determinants of pesticide-related disease incidences experienced by small scale farmers which could provide numerous interventions to minimize pesticide poisoning and to improve human health.

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APPENDICES

APPENDIX A: FARM/HOUSEHOLD QUESTIONNAIRE

The purpose of this study is solely academic and particularly to contribute to the understanding of determinants of pesticide usage and uptake of alternative pest control methods among small-scale tomato farmers in Nakuru County, Kenya. I, kindly request your **voluntary** participation in answering the questions, any information provided will be strictly **confidential.** Tick where appropriate.

SECTION A: GENERAL INFORMATION

A1. Date of interview ____

A2. Name of enumerator____

A3. Sub county ________________

A4. Ward___________________

A5. Location___________________

A6 Household Head Mobile Phone No.___________________

Section B: SOCIO-ECONOMIC AND INSTITUTIONAL CHARACTERISTICS

B1.1 Gender of the household head		**B1.2** Age of the household head	**B1.3** Education of the household head
1. Male	0. Female	In years	Number of schooling years

B1.4 How many **members** have been living in the household for **at least** the last six months?

B1.5 What is your **main** occupation?

0. Farming [ ] 1. Business person [ ]2. Casual Labourer [ ] 3. Salaried Employee [ ]

4. Other, specify……………………..

B1.6 Do you have any other source(s) **of income apart from** farming**? (If No, Skip to B1.8)**

1.Yes [ ] 0.No [ ]

Off-farm Income Estimation for the Last One Year

B1.7.1 If Yes, where else do you get income from**?**	**B1.7.**2 Number of months	**B1.7.3** Average income	**B1.7.4** Total

Codes for Off-farm activities, 1=Rental payments, 2=Self-employed, 3=Salaried, 4=Remittances, 5=Pension, 6=other specify………..

B1.8 What is the **total farm size** in a**cres**? **…………**

B1.9 Which tomato variety do you **mostly** grow?**………………..**

B2.0 Where do you grow tomatoes?

0. Under a Greenhouse 1. Open –field/Outdoors 2. Both

B2.1 How long have you been growing tomatoes (years)?.............

B2.2 How many **production seasons** did you have in the last one year?.........

B2.3 What was the size of land **under tomato production** (acres)? ……

B2.4 How far is the **Nearest Input Market** from the homestead (walking minutes)?... …..

B2.5.0 Do you belong to a **group/ organization** in your community? (If **No, Skip to B2.6**)

1. Yes [ ] 0. No [ ]

B2.5.1 If **Yes**, How many **Active groups** do you belong to? **……**

B2.5.2 If **Yes**, what is the **Purpose** of the group (s)?

0. Production and marketing 1.Savings and credit 2. Religious group 3. Welfare 4. If others, Specify………………….

B2.6 Where do you get **information on** tomato pest management and agriculture in general from? (**Select at most 4 suitable sources)**

1. Other farmers 2. Agricultural Extension Officer 3. Pesticide Retailer 4. Agrochemical company 5.Media 6. Other specify ………………

<u>Information on Social Network Member Whom You Share Information on Agriculture in the Area</u>

B2.7.0 Name **at most two people** In the area whom you share information on tomato pest management and agriculture**. (SocNetMemb)**		**B2.7.1** Years of schooling of the person whom you share agricultural information in the area. **(networked)**	**B2.7.2** Distance to the nearest social network member**. (DistSocNet)** **In Walking minutes**	**B2.7.3 How often do you meet** with the social network member whom you share information with in the area? **(SocNetCont)**
1				
2				

Code for the frequency of contact with the social network member where 0=Daily, 1= At least once a week, 2= At least once a month, 3= annually.

B2.8.0 Have you ever received **extension services** on tomato production in the last one year? **(If NO, Skip to B2.9.0)**

1. Yes 0. No

B2.8.1 If **Yes**, How **many times** were you visited by extension provider per year? ….

B2.8.2 Who **offered the extension services** or technical advice on tomato production**? Choose one which is most suitable.**

0. Government extension officer's 1.Agrochemical company 2. Fellow farmers 3. Other source (s), specify……………

B2.9.0 Have you ever received **Credit** in the last one year? **(If NO, Skip to B3.0.0**)

1. Yes [ ] 0. No [ ]

B2.9.1 How much credit did you borrow? …………….

B3.0.0 Have you ever attended any **training** on pest management in tomato production in the last one year? **(If NO, Skip to B3.2.0)**

1. Yes 0. No

B3.1.1 How many **times per year** did you receive the training on tomato production in the last one year?

B3.2.0 Where **do you sell your** tomatoes?

1. Local retailers 2. Wholesale traders 3. Cooperative 4. Supermarkets 5. Processing Companies 6. Other, specify…………

B3.2.1 Which is the **main tomato marke**t outlet?

1. Local retailers [ ] 2. Wholesale traders [ ] 3. Cooperatives [ ] 4. Supermarkets [ ] 5. Processing companies [ ] 6.Others (specify)…………………………..

SECTION C: TOMATO PESTICIDE USE AND HANDLING PRACTICES

C3.3. Did you use **chemical pesticide** (s) in tomato production during the last production season**? (IF No, SKIP to D5.1.5)**

1. Yes [ ] 0. No [ ]

C3.3.1 If Yes in C3.3, What influenced your **decision on the type of pesticide to** apply during tomato production?

0. On the first appearance of pests [ ] 1. On calendar basis [ ] 2. Own farming experience [ ] 3. On recommendation by another farmer [ ] 4. On recommendation by pesticide dealer [ ] 5. On first symptom of crop damage [ ] 6. On recommendation by extension agent [ ] 7. Other, specify …………………….

C3.3.2 What influenced your **decision on the time of application** of pesticide during tomato production?

0. On the first appearance of pests [ ] 1. On calendar basis [ ] 2. Own farming experience[ ] 3. On recommendation by another farmer[ ] 4. On recommendation by pesticide dealer [ ] 5. On first symptom of crop damage [ ] 6. On recommendation by extension agent[ ].

7. Other, specify …………………….

C3.3.3 What was used to apply pesticide in the last tomato production season?

1. Knapsack sprayer [ ] 2. Other, specify……………..

C3.3.4 If knapsack sprayer**, Where** did you get it from?

0. I own it [ ] 1. Borrowing from a neighbor[ ] 2. Other, specify…………………….

C3.3.5 What was the **main source of labour which was used to** apply the chemical pesticide in the last production season?

1. Family labour [ ] 2. Hired labour [ ] 3. Other, specify………………………

Information on Quantity of Pesticide Used in Tomato Production during the Last Production Season

C3.3.6 Did you apply pesticide during…….			**C3.3.7** Which type of pesticide did you use?	**C3.3.8** What was the pesticide name?	**C3.3.9** Source of Pesticide	**C4.0** Purchased Quantity(In Kg/Litre)	**C4.1** Quantity of Undiluted pesticide Used in Kg/Ltr.	**C4.1.1** How many times did you apply pesticide Per Month.	**C4.1.2** What was the treated area in Acres /square meters ?	**C4.1.3** What was the problem addressed?
		1=yes 0=no								
1	Seedbed preparation									
2	Before sowing in the seedbed									
3	Seedlings in the seedbed									
4	Just before transplanting									
5	During land preparation									
6	During transplanting									
7	After transplanting									
8	Flowering and fruit development									
9	Just before harvesting									
10	Post-harvest									

Codes for the type of pesticide used where 0=Insecticide, 1=Herbicide, 2=Fungicide, 3= Nematicide, 4=Bactericide, 5=other specify…

Codes for the source of pesticide used where 1= Pesticide retailer, 2=Other farmer, 3= Agrochemical companies, 4= Other specify………

Codes for problem addressed where 0= Insects, 1= Weeds, 2= Fungus, 3= Nematodes, 4= Bacteria, 5= Others specify……

<u>Information on Tomato Pesticide Handling Practices in the Last Production Season</u>

C4.1.4 Did you…… during tomato production?			**C4.1.5** Did you Wear…….during pesticide application?		**C4.1.6** Did you …….. during pesticide application?		**C4.1.7** Where did you store Pesticides?		**C4.1.8**Did you dispose empty pesticide containers by…….. ?	
		1=yes 0=no		1=yes 0=no		1=yes 0=no		1=yes 0=no		1=yes 0=no
1	Read and follow label instructions		Glove		Observe wind direction while spraying		Kitchen		Burying	
2	Use one pesticide		Mask		Spray early in the morning		Bedroom		Burning	
3	Prepare pesticide at Home Compound		Hat		Spray late in the evening		In a locked and safe place		Throw in the bush	
4	Prepare pesticide at At the farm		Respirators		Avoid drinking		Store with other food stuff		Selling to recyclers	
5	Others specify		Coverall/pants		Avoid eating		Hang outside the house		Reuse after washing	
6			Boots		Avoid smoking		Other specify		Wash pesticide application equipment at the river	
7			Long sleeved shirt /jackets		Wash hands afterward				Wash pesticide application equipment at the farm.	

8			Tuck in trousers in the boots		Take a shower and Change cloths				Other specify	
9			Other specify		Other specify					

C4.1.9 If No in C4.1.5, give reason for **not wearing some of the** protective clothing .**Choose one** which is most appropriate .

0. Too expensive to purchase[ ]   1. Not necessary for each case[ ]   2. Uncomfortable [ ]

3. Time-consuming to wear[ ]   4. Unavailable when needed [ ]   5. Other, specify…………

C5.0 Have you ever experienced **at least one ill health symptom** within 24 hours after applying pesticide in the last one year**?(If No, Skip to C5.1.2)**

1. Yes   0.No

C5.1.1 Which **symptoms** did you experience after spraying pesticide? **Choose at most three.**

1. Headache[ ]   2. Dizziness[ ]   3. Nausea[ ]   4. Difficulty in breathing[ ]   5. Vomiting[ ]   6. Skin irritation[ ]

7. Eye irritation[ ]   8. Backache[ ]   9. Stomachache[ ]   10. Other, specify……………..…….

C5.1.2 How long do you take before harvesting tomatoes after pesticide application (days)?.....

C5.1.3 Which factor influenced your decision on harvesting time after pesticide application**? Choose the most appropriate one).**

1. Market demand[ ]   2. Own experience[ ]   3. On recommendation by other farmers[ ]

4. On recommendation by pesticide dealers [ ]   5. On recommendation by Extension Officer [ ]   6. Other, specify……………

C5.1.4 What did you **do immediately after harvesting** tomatoes **before** selling them? **Choose the most appropriate one.**

0. None [ ] 1. Wash [ ] 2. Air[ ]   3.Wipe[ ]   4. Other, specify………..

SECTION D: ALTERNATIVE (NON-CHEMICAL) PEST CONTROL METHODS

D5.1.5 Did you use **alternative tomato pest control methods** in the last production season? **(If No, Skip to D5.1.9)**

1. Yes [ ]   0. No [ ]

Information on Alternative (Non-Chemical) Pest Control Methods used during Tomato Production

Alternative_pest_control.sav

	D5.1.6 Did you practice/use ….during tomato production?		**D5.1.7** Did you use…..during tomato production?		**D5.1.8** Did you use …….during tomato production?	
		1=yes 0=no		1=yes 0=no		1=yes 0=no
1	Weeding		Predators		Bio-insecticides	
2	Crop rotation		Pathogens		Plant incorporated protectants(PIP)	
3	Insect and disease resistant variety		Parasites		Bio-nematicides	
4	Intercropping		Others specify		Bio-herbicides	
5	Mulching				Others specify	
6	Pruning					
7	Uprooting and destruction of crop residue					
8	Irrigation					
9	Fertilizer application					
10	Pheromone traps					
11	Others specify					

D5.1.9 Give reasons for not using some of the **non-chemical (alternative) pest** control methods. **Choose one which is the most suitable**.

0. Being ineffective [ ]   1. Unavailability of other methods [ ]   2. Costly to use [ ]

3. Unaware of alternative methods [ ]   4. Others, Specify………

SECTION E: RISK PERCEPTION ON PESTICIDE USE IN TOMATO PRODUCTION

E6.0 Risk perception of pesticide use in relation to human health		**Tick where appropriate**				
		1=strongly disagree	**2=**dis**a**gree	**3=**uncertain	**4=**agree	**5=**strongly agree
1	Pesticide use is harmful to farm family health**.**					
2	Pesticide use is harmful to the user`s health.					
3	Pesticide use is harmful to other farmers` health**.**					
4	Inappropriate Pesticide use causes chronic illness**.**					
5	Improper Pesticide use causes acute illnesses.					

E6.1.1 Risk perception on pesticide use in relation to environment.		**Tick where appropriate**				
		1=strongly disagree	**2=**disagree	**3=**uncertain	**4=**agree	**5=**strongly agree
1.	Improper pesticide use affects food safety.					
2.	Pesticide use affects air quality.					
3.	Pesticide use affects water quality.					
4.	Improper Pesticide use affects biodiversity.					
5.	Inappropriate Pesticide use leads to soil contamination .					

E6.1.2 Perception of pesticide use on crop productivity in tomato production		**Tick where appropriate**				
		1=strongly disagree	**2**=disagree	**3**=uncertain	**4**=agree	**5**=strongly agree
1	Utilizing more pesticides leads to high yields.					
2.	Using more pesticides leads to high product quality.					
3.	Utilizing more pesticides leads to better control over pests and diseases					
4.	Pesticides are not a necessity for high product quality.					
5.	Utilizing less pesticides leads to low yields.					

SECTION F: CUSTOMER ORIENTATION AND SOCIAL INFLUENCE IN TOMATO PRODUCTION AND MARKETING

F6.6 Customer orientation in tomato production and marketing**.**		**Tick where appropriate**				
		1=strongly disagree	**2**=disagree	**3**=uncertain	**4**=agree	**5**=strongly agree
1	It is important to have a strong focus on understanding customer`s needs during tomato production and marketing.					
2	It is essential to have a strong focus on creating customer value during tomato production.					
3	It is vital to have a strong emphasis on customer commitment during tomato production.					

F6.7 Social influence in tomato production and marketing.		**Tick where appropriate**				
		1=strongly disagree	**2**=disagree	**3**=uncertain	**4**=agree	**5**=strongly agree
1	My relatives think I should use pesticides appropriately.					
2	My friends think I should use non-chemical pest control methods.					
3	My family members think I should properly use pesticide.					
4	Those in my social circle think I should use non-chemical pest control methods.					
5	People who influence my behaviour think I should use pesticide properly					

THANK YOU FOR YOUR COOPERATION AND PARTICIPATION. END!

Appendix B: Confirmatory Factor Analysis

Table A.1: Factor analysis for describing risk perception and customer orientation constructs

Constructs	**Items**	**Factor Loadings**	***CR***	***AVE***	**KMO**
Human health risk perception	Pesticide use is harmful to farm family health.	0.684			
	Pesticide use is harmful to the user`s health.	0.626			
	Pesticide use is harmful to other farmer`s health.	0.632			
	Improper pesticide use causes acute illness.	0.657	0.536	0.423	0.671
Environmental risk perception	Pesticide use affects air quality.	0.515			
	Pesticide use affects water quality	0.679			
	Improper pesticide use affects biodiversity.	0.735			
	Inappropriate pesticide use leads to soil contamination.	0.762	0.609	0.462	0.668
Productivity perception	Utilizing more pesticides leads to high yields.	0.913			
	Using more pesticides leads to high product quality.	0.657			
	Utilizing pesticides leads to better control over pests.	0.607			
	Utilizing pesticides leads to low yields.	0.885	0.775	0.604	0.650
Customer orientation	It is important to have a strong focus on understanding customer`s needs during tomato production	0.801			
	It is vital to have a strong emphasis on customer commitment during tomato production.	0.801	0.373	0.641	0.500

Note: CR= Composite Reliability, AVE = Average Variance Extracted, KMO = Kaiser-Meyer-Olkin.

Appendix C: Summary of STATA output

Table C.1: Results from Trivariate ordered probit model estimation

Mixed-process regression			
	Number of obs	=	384
	Wald chi2(60)	=	734.05
Log pseudolikelihood = -271.69675	Prob > chi2	=	0.0000

	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
InsecticideOrder						
GendHH	.4174133	.3165974	1.32	0.187	-.2031063	1.037933
AgeHH	.0170284	.0166157	1.02	0.305	-.0155378	.0495947
EducHH	.0428058	.0500181	0.86	0.392	-.0552279	.1408394
HHsize	-.026836	.0811809	-0.33	0.741	-.1859478	.1322757
TomfarmExp	-.0103536	.0271231	-0.38	0.703	-.063514	.0428067
Farmsz	-.0363806	.0624713	-0.58	0.560	-.1588221	.0860609
Grupnumber	-.267573	.1074788	-2.49	0.013	-.4782276	-.0569184
Creditrecieve	-.3705287	.2093821	-1.77	0.077	-.7809101	.0398526
OffarmInc	-.5742627	.319439	-1.80	0.072	-1.200352	.0518261
Extencontacts	.2535215	.1469869	1.72	0.085	-.0345676	.5416106
Traingcont	.0540938	.194433	0.28	0.781	-.3269879	.4351755
DistInputMkt	.0294788	.0125541	2.35	0.019	.0048733	.0540843
Labourpestapply	.6261633	.3230711	1.94	0.053	-.0070443	1.259371
RiskPerHuman	-.2047015	.1480754	-1.38	0.167	-.494924	.085521
RiskPercEnviron	-.0307629	.1469361	-0.21	0.834	-.3187523	.2572264
ProductivityPerc	-.0093641	.1253091	-0.07	0.940	-.2549655	.2362372
Inforsource1_dummy3	-.1489692	.3325766	-0.45	0.654	-.8008073	.5028689
Inforsource1_dummy4	4.532026	.3591114	12.62	0.000	3.82818	5.235871
Inforsource1_dummy5	.0860446	.5839266	0.15	0.883	-1.058431	1.23052
TomCustOrient	.0955662	.0963526	0.99	0.321	-.0932815	.2844139
FungicideOrder						
GendHH	.46033	.1994551	2.31	0.021	.0694052	.8512548
AgeHH	.0010576	.0111195	0.10	0.924	-.0207362	.0228513
EducHH	.0517122	.0330669	1.56	0.118	-.0130977	.116522
HHsize	.0322478	.0589392	0.55	0.584	-.0832709	.1477666
TomfarmExp	.0147318	.0241167	0.61	0.541	-.0325362	.0619997
Farmsz	-.1778568	.0663085	-2.68	0.007	-.3078192	-.0478945
Grupnumber	-.037294	.0873158	-0.43	0.669	-.2084297	.1338418
Creditrecieve	.0246866	.2208582	0.11	0.911	-.4081874	.4575607
OffarmInc	-.1289973	.2261419	-0.57	0.568	-.5722274	.3142328
Extencontacts	.3224725	.1213562	2.66	0.008	.0846187	.5603263
Traingcont	-.3291863	.1154469	-2.85	0.004	-.5554581	-.1029145
DistInputMkt	-.0047784	.0074967	-0.64	0.524	-.0194716	.0099149
Labourpestapply	-.4144566	.1941461	-2.13	0.033	-.794976	-.0339372
RiskPerHuman	-.1641862	.1173834	-1.40	0.162	-.3942534	.065881
RiskPercEnviron	.0509777	.1210406	0.42	0.674	-.1862576	.288213
ProductivityPerc	-.087136	.0983951	-0.89	0.376	-.2799869	.105715
Inforsource1_dummy3	-.1642003	.2234287	-0.73	0.462	-.6021124	.2737118
Inforsource1_dummy4	-1.283443	.5633397	-2.28	0.023	-2.387569	-.1793178
Inforsource1_dummy5	-.3491796	.3581067	-0.98	0.330	-1.051056	.3526966
TomCustOrient	.1211263	.1062028	1.14	0.254	-.0870274	.32928
HerbicideOrder						
GendHH	.49595	.226372	2.19	0.028	.052269	.939631
AgeHH	-.0095759	.0095891	-1.00	0.318	-.0283703	.0092185
EducHH	-.0073554	.0294753	-0.25	0.803	-.0651258	.0504151
HHsize	-.1688179	.0543066	-3.11	0.002	-.2752569	-.0623789
TomfarmExp	.0425694	.017565	2.42	0.015	.0081426	.0769962
Farmsz	.006348	.0676736	0.09	0.925	-.1262899	.1389858
Grupnumber	.0256706	.0760638	0.34	0.736	-.1234117	.1747528
Creditrecieve	.5003825	.1736164	2.88	0.004	.1601007	.8406644
OffarmInc	.0608665	.1943273	0.31	0.754	-.320008	.441741
Extencontacts	.2514179	.0939647	2.68	0.007	.0672504	.4355853
Traingcont	-.092834	.1032383	-0.90	0.369	-.2951774	.1095095
DistInputMkt	.0026639	.005592	0.48	0.634	-.0082962	.0136241
Labourpestapply	.1996121	.1816707	1.10	0.272	-.1564559	.5556801
RiskPerHuman	-.0891631	.0980413	-0.91	0.363	-.2813204	.1029943
RiskPercEnviron	-.2332277	.101923	-2.29	0.022	-.432993	-.0334624
ProductivityPerc	.2277441	.0874953	2.60	0.009	.0562564	.3992317
Inforsource1_dummy3	-.0641368	.1851168	-0.35	0.729	-.426959	.2986854
Inforsource1_dummy4	-.1204295	.4333003	-0.28	0.781	-.9696826	.7288235
Inforsource1_dummy5	.2802094	.3618411	0.77	0.439	-.4289861	.9894048
TomCustOrient	.1642908	.0939392	1.75	0.080	-.0198267	.3484083
/cut_1_1	-.1584223	1.036933	-0.15	0.879	-2.190774	1.87393
/cut_1_2	-.1022439	1.067995	-0.10	0.924	-2.195476	1.990988
/cut_2_1	-1.656679	.7217715	-2.30	0.022	-3.071325	-.2420325
/cut_2_2	-1.636283	.7250331	-2.26	0.024	-3.057322	-.2152443
/cut_3_1	1.434983	.6414042	2.24	0.025	.1778538	2.692112
/atanhrho_12	.9567535	.3245745	2.95	0.003	.3205991	1.592908
/atanhrho_13	-.2254861	.2445966	-0.92	0.357	-.7048866	.2539143
/atanhrho_23	-.3307177	.1557931	-2.12	0.034	-.6360667	-.0253688
rho_12	.7428253	.1454778			.3100485	.920594
rho_13	-.2217407	.23257			-.6074603	.2485946
rho_23	-.3191656	.139923			-.5622154	-.0253634

Table C.2: Results from Multivariate Tobit model estimation

Log pseudolikelihood = -468.01429 Wald chi2(60) = 171.63; Prob > chi2 = 0.0000

	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
rtolerance						
GendHH	.0146237	.0369722	0.40	0.692	-.0578406	.0870879
HHsize	.0129467	.0091689	1.41	0.158	-.005024	.0309174
EducHH	.0044745	.0055047	0.81	0.416	-.0063145	.0152635
AgeHH	.0023135	.001543	1.50	0.134	-.0007107	.0053376
Grupnumber	-.0002401	.013329	-0.02	0.986	-.0263644	.0258842
OffarmInc	-.0562208	.0307839	-1.83	0.068	-.1165561	.0041144
Farmsz	.0016781	.0119251	0.14	0.888	-.0216946	.0250508
Extencontacts	.0106304	.0175845	0.60	0.545	-.0238346	.0450954
Creditrecieve	-.0150986	.032438	-0.47	0.642	-.0786759	.0484787
Traingcont	-.0028167	.0193983	-0.15	0.885	-.0408366	.0352033
RiskPerHuman	.0040375	.0124391	0.32	0.745	-.0203427	.0284177
Inforsource1_dummy3	-.0559779	.0323232	-1.73	0.083	-.1193302	.0073744
Inforsource1_dummy4	.0433898	.0699231	0.62	0.535	-.093657	.1804365
Inforsource1_dummy5	.0364196	.0817254	0.45	0.656	-.1237593	.1965985
TomCustOrient	-.0232273	.014851	-1.56	0.118	-.0523347	.0058802
_cons	.5334256	.0892229	5.98	0.000	.358552	.7082992
rhabitat						
GendHH	.0657293	.0818099	0.80	0.422	-.0946153	.2260738
HHsize	.0179644	.0184753	0.97	0.331	-.0182465	.0541753
EducHH	.0277704	.0117529	2.36	0.018	.0047351	.0508057
AgeHH	.003249	.0032855	0.99	0.323	-.0031906	.0096885
Grupnumber	-.004214	.0297598	-0.14	0.887	-.0625422	.0541141
OffarmInc	.038535	.0715453	0.54	0.590	-.1016913	.1787612
Farmsz	-.0089623	.0290502	-0.31	0.758	-.0658997	.047975
Extencontacts	.0635276	.0406677	1.56	0.118	-.0161796	.1432347
Creditrecieve	.0514759	.0678814	0.76	0.448	-.0815693	.184521
Traingcont	.0438453	.0439884	1.00	0.319	-.0423704	.130061
RiskPerHuman	.0504163	.0259231	1.94	0.052	-.0003921	.1012246
Inforsource1_dummy3	.018876	.0734363	0.26	0.797	-.1250565	.1628085
Inforsource1_dummy4	-.0461999	.20733	-0.22	0.824	-.4525593	.3601595
Inforsource1_dummy5	.0960972	.1767433	0.54	0.587	-.2503132	.4425077
TomCustOrient	.0358953	.0292136	1.23	0.219	-.0213623	.0931528
_cons	-.3475098	.2081992	-1.67	0.095	-.7555727	.0605531
rcontrol2						
GendHH	.001606	.0381815	0.04	0.966	-.0732285	.0764404
HHsize	.006543	.0091929	0.71	0.477	-.0114748	.0245607
EducHH	.0090082	.0055676	1.62	0.106	-.0019041	.0199205
AgeHH	.0037249	.0013502	2.76	0.006	.0010787	.0063712
Grupnumber	-.0128606	.0127464	-1.01	0.313	-.037843	.0121218
OffarmInc	.0111586	.0349195	0.32	0.749	-.0572824	.0795997
Farmsz	-.0310301	.0125411	-2.47	0.013	-.0556102	-.00645
Extencontacts	-.0133103	.0190188	-0.70	0.484	-.0505864	.0239659
Creditrecieve	.0124457	.0329148	0.38	0.705	-.0520662	.0769576
Traingcont	.0391701	.0206817	1.89	0.058	-.0013653	.0797055
RiskPerHuman	.0094405	.0133555	0.71	0.480	-.0167358	.0356168
Inforsource1_dummy3	.0467017	.0327289	1.43	0.154	-.0174457	.1108492
Inforsource1_dummy4	-.0367754	.0662723	-0.55	0.579	-.1666667	.0931159
Inforsource1_dummy5	-.0528715	.061434	-0.86	0.389	-.1732799	.0675369
TomCustOrient	-.0162396	.0162696	-1.00	0.318	-.0481273	.0156482
_cons	.361998	.0950353	3.81	0.000	.1757323	.5482637
rpreventive						
GendHH	.0361722	.0368916	0.98	0.327	-.036134	.1084784
HHsize	-.000599	.0091633	-0.07	0.948	-.0185586	.0173607
EducHH	.0132658	.0066751	1.99	0.047	.0001829	.0263487
AgeHH	-.001054	.0016481	-0.64	0.522	-.0042843	.0021762
Grupnumber	.0308509	.0136829	2.25	0.024	.0040328	.057669
OffarmInc	-.0025633	.0302244	-0.08	0.932	-.0618021	.0566755
Farmsz	.006735	.0091207	0.74	0.460	-.0111413	.0246114
Extencontacts	-.0023481	.0172234	-0.14	0.892	-.0361054	.0314092
Creditrecieve	-.0233199	.031383	-0.74	0.457	-.0848295	.0381898
Traingcont	-.0100682	.0183141	-0.55	0.582	-.0459632	.0258268
RiskPerHuman	.0184052	.0145496	1.27	0.206	-.0101114	.0469219
Inforsource1_dummy3	.0152419	.0317945	0.48	0.632	-.0470741	.077558
Inforsource1_dummy4	.0208061	.0592725	0.35	0.726	-.0953658	.136978
Inforsource1_dummy5	.0924234	.0650572	1.42	0.155	-.0350863	.2199332
TomCustOrient	.0378799	.0179705	2.11	0.035	.0026583	.0731014
_cons	.6186807	.1125433	5.50	0.000	.3980998	.8392616
/lnsigma1	-1.314351	.0308137	-42.65	0.000	-1.374745	-1.253958
/lnsigma2	-.6322256	.0455963	-13.87	0.000	-.7215926	-.5428585
/lnsigma3	-1.282235	.0390983	-32.80	0.000	-1.358867	-1.205604
/lnsigma4	-1.302018	.0416948	-31.23	0.000	-1.383738	-1.220298
/atrho12	-.4158802	.059913	-6.94	0.000	-.5333076	-.2984528
/atrho13	.028868	.0507122	0.57	0.569	-.0705261	.1282621
/atrho14	.0173647	.0540708	0.32	0.748	-.0886121	.1233416
/atrho23	.1322458	.0543324	2.43	0.015	.0257562	.2387353
/atrho24	-.0605316	.0562465	-1.08	0.282	-.1707727	.0497096
/atrho34	-.1064839	.049081	-2.17	0.030	-.2026809	-.0102868
sigma1	.2686486	.008278	32.45	0.000	.2529041	.2853732
sigma2	.5314078	.0242302	21.93	0.000	.4859777	.5810848
sigma3	.2774164	.0108465	25.58	0.000	.2569518	.2995109
sigma4	.2719824	.0113403	23.98	0.000	.2506398	.2951423
rho12	-.3934541	.0506381	-7.77	0.000	-.4879054	-.2898961
rho13	.02886	.05067	0.57	0.569	-.0704094	.1275634
rho14	.017363	.0540545	0.32	0.748	-.0883809	.1227199
rho23	.1314802	.0533931	2.46	0.014	.0257505	.2343008
rho24	-.0604577	.0560409	-1.08	0.281	-.1691317	.0496687
rho34	-.1060832	.0485287	-2.19	0.029	-.1999504	-.0102865

Likelihood ratio test of rho12 = rho13 = rho14 = rho23 = rho24 = rho34 = 0:
chi2(6) = 72.3927 Prob > chi2 = 0.0000

Appendix D: A scanned copy of research permit

THIS IS TO CERTIFY THAT:
MISS. CATHERINE WAMBUI KINUTHIA
of EGERTON UNIVERSITY, 0-101
Nairobi,has been permitted to conduct
research in *Nakuru County*

on the topic: *DETERMINANTS OF PESTICIDE USE AND UPTAKE OF ALTERNATIVE PEST CONTROL METHODS AMONG SMALL SCALE TOMATO FARMERS IN NAKURU COUNTY, KENYA*

for the period ending:
3rd November,2018

Permit No : NACOSTI/P/17/23473/19815
Date Of Issue : 3rd November,2017
Fee Recieved :Ksh 1000

....
Applicant's Signature

....
Director General
National Commission for Science, Technology & Innovation

CONDITIONS

1. **The License is valid for the proposed research, research site specified period.**
2. **Both the Licence and any rights thereunder are non-transferable.**
3. **Upon request of the Commission, the Licensee shall submit a progress report.**
4. **The Licensee shall report to the County Director of Education and County Governor in the area of research before commencement of the research.**
5. **Excavation, filming and collection of specimens are subject to further permissions from relevant Government agencies.**
6. **This Licence does not give authority to transfer research materials.**
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8. **The Commission reserves the right to modify the conditions of this Licence including its cancellation without prior notice.**

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RESEARCH CLEARANCE PERMIT

Serial No.A 16362

CONDITIONS: see back page

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NAIROBI-KENYA

Ref: No. **NACOSTI/P/17/23473/19815**

Date: **3rd November, 2017**

Catherine Wambui Kinuthia
Egerton University
P.O. Box 536-20115
EGERTON.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Determinants of pesticide use and uptake of alternative pest control methods among small scale tomato farmers in Nakuru County, Kenya"*** I am pleased to inform you that you have been authorized to undertake research in **Nakuru County** for the period ending **3rd November, 2018.**

You are advised to report to **the County Commissioner and the County Director of Education, Nakuru County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

GODFREY P. KALERWA MSc., MBA, MKIM
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Nakuru County.

The County Director of Education
Nakuru County.

Appendix E: Conferences Where Research Findings Were Presented

Kinuthia, C.W., Ayuya, O.A. and Nyaanga, J.G. (2018). *Determinants of Uptake of alternative Pest control Methods: Case of small-scale tomato farmers in Kenya.* A paper presented at The 2nd National Agri-Nutrition Conference, 11-13 September 2018, Kenya School of Government in Nairobi.

Kinuthia, C.W., Ayuya, O.A. and Nyaanga, J.G. *Factors Influencing Level of Pesticide Usage among Small-Scale Tomato Farmers in Kenya.* A paper presented at Tropentag Conference on Global Food Security and Food Safety: Role of Universities. September 17-19, 2018, University of Ghent, Belgium.